ORIGINAL ARTICLE

Characterizing the lateral slope of the aging female eyebrow

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BACKGROUND: Ideal eyebrow aesthetics give a framework for brow rejuvenation and surgical procedures do not always provide satisfying results. Previous studies have shown elevation of the medial brow with aging; however, they failed to characterize overall shape changes.

OBJECTIVE: To characterize changes in eyebrow slope with increasing age to better direct brow rejuvenation.

METHODS: From standardized anteroposterior facial photographs of 100 women 20 to 80 years of age, eyebrow height was measured at the medial limbus and arch apex from a mid-pupillary horizontal. The slope of the eyebrow was calculated. Using group analysis, mean height and slope were compared using the Mann-Whitney U test. Regression analysis was used to determine the relationship between slope and age.

RESULTS: Mean slope significantly decreased from 20 to 29 years of age to 40 to 49 years of age (0.22 versus 0.12; P=0.03), and then increased between 40 and 49 years of age and \geq 60 years of age (0.12 versus 0.21; P=0.05). Medial height did not change significantly, and arch apex significantly decreased between 20 and 29 years of age and 40 and 49 years of age. Regression analysis showed a quadratic relationship between age and slope, with the decrease in slope until the fifth decade of life being directly related to increasing age. After this, age was not a significant contributor to slope changes.

CONCLUSIONS: With increasing age, the slope of the eyebrow decreases until the fifth decade dependent on age. After the fifth decade, age no longer plays a significant role. Therefore, choice of brow lift technique should be carefully selected.

Key Words: Aging eyebrow; Brow lift; Eyebrow shape; Eyebrow slope

I deal eyebrow aesthetics were first described in 1974 by Westmore (1) as a lateral arch with the apex terminating above the lateral limbus of the iris, and with medial and lateral ends of the eyebrow at the same height. Since this description, the ideal shape has been refined, and studies have shown that surgeons and patients both prefer an eyebrow shape with a lateral upward slope in which the arch apex is positioned just lateral to the lateral limbus (2-4). These aesthetics provide a framework for brow rejuvenation.

The focus of brow rejuvenation procedures is on position, shape and symmetry of the eyebrows. Potential pitfalls and criticisms of surgical brow lift techniques include an 'unnatural' shape and appearance, excessive elevation of the medial eyebrow, a medial or flat apex shape and overelevation of the entire eyebrow without lowering the medial segment, yielding a surprised appearance (5-7). Because of these criticisms, surgeons performing brow rejuvenation procedures focus on reshaping the eyebrows more than repositioning. However, to accomplish this, we must fully understand the aging process at the eyebrow.

Recently, Matros et al (8) studied eyebrow position in two groups of Caucasian women: 20 to 30 and 50 to 60 years of age. They found that the eyebrow overall was positioned higher in the older group and that the medial eyebrow was elevated more than the lateral eyebrow.

La caractérisation de la courbe latérale des sourcils de la femme avec l'âge

HISTORIQUE : Une esthétique idéale du sourcil fournit un cadre pour rajeunir le front, mais les interventions chirurgicales ne donnent pas toujours des résultats satisfaisants. Des études antérieures ont démontré une élévation de la partie médiale du front avec le vieillissement, mais n'ont pas caractérisé les changements de forme globaux.

OBJECTIF : Caractériser les changements de la courbe des sourcils avec l'âge, afin de mieux orienter le rajeunissement du front.

MÉTHODOLOGIE : À partir de photographies faciales antéropostérieures normalisées de 100 femmes de 20 à 80 ans, les chercheurs ont mesuré la hauteur des sourcils par rapport au limbe médial et à l'apex de l'arche à partir du milieu de la pupille horizontale. Ils ont calculé la courbe des sourcils. Au moyen de l'analyse de groupe, ils ont comparé la hauteur et la courbe moyennes en se servant du test de Mann-Whitney. Ils ont utilisé l'analyse de régression pour déterminer le lien entre la courbe et l'âge.

RÉSULTATS : La courbe moyenne diminuait considérablement entre 20 à 29 ans et 40 à 49 ans (0,22 par rapport à 0,12; P=0,03), puis augmentait entre 40 et 49 ans et 60 ans et plus (0,12 par rapport à 0,21;P=0,05). La hauteur médiane ne changeait pas de manière significative, tandis que l'apex de l'arche diminuait de manière significative entre 20 à 29 ans et 40 à 49 ans. L'analyse de régression a révélé un lien quadratique entre l'âge et la courbe, la diminution de la courbe jusqu'à la cinquième décennie étant directement proportionnelle à l'avancement en âge. Par la suite, l'âge n'était plus un élément significatif des changements de courbe.

CONCLUSIONS : Avec l'âge, la courbe du sourcil diminue jusqu'à la cinquième décennie. L'âge ne joue plus un rôle important par la suite. Il faut donc choisir attentivement la technique de redrapage du front.

This study helps to explain why brow lifting techniques that preferentially elevate the medial or mid portion of the eyebrow lead to an unnatural appearance. A similar study by Patil et al (9) also showed these results in a female Indian population, illustrating that this pattern transcends ethnicity.

These two studies compared different points on the eyebrow between subjects, in isolation of one another and, in doing so, they do not fully capture the shape of one subject's eyebrow before comparison. To do this, we must know how one point relates to another within each eyebrow. To capture this, we can calculate the lateral slope of the eyebrow. In the present study, we set out to characterize the shape changes occurring in the aging female eyebrow, specifically the changes in slope with increasing age, by performing photographic measurements of the eyebrows of 100 women 20 to 80 years of age. We hypothesized a decrease in eyebrow slope with increasing age.

METHODS

Research ethics board approval was obtained through Western University Health Sciences Research Ethics Board (London, Ontario, HSREB# 18550E). Standardized anteroposterior facial digital photographs were obtained, after verbal consent, from a random cohort of

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Figure 1) Example of standardized AP facial photograph: photograph taken at a distance of 5 ft (1.52 m), head held with lateral limbus in line with root of the helix and ruler in coronal plane of the brow



Figure 2) Measurements of the eyebrow taken from anteeroposterior facial photographs. Mid-pupillary axis marked as horizontal reference. A Height at medial limbus; B Height of arch apex; L Length between A and B

100 Caucasian women 20 to 80 years of age at rest. Exclusion criteria were previous periorbital or forehead surgery, use of botulinum toxin (within the past six months), or any trauma or neurological condition affecting the forehead or brow. Standardized anteroposterior facial photographs were taken of the subjects using one camera at 5 ft (1.52 m) (standardized focal length 60 mm). The subject's head was positioned such that the lateral canthus was in line with the root of the helix. The subjects also held a metric ruler in the coronal plane of the brow to standardize measurements among subjects (Figure 1).

Using Adobe Photoshop Elements 10 (Adobe Inc, USA), the primary author took measurements from the photographs. For each photograph, the mid-pupillary axis was marked as a horizontal reference line. Lines representing the eyebrow height at the medial limbus (A) and the highest point of the eyebrow representing the arch apex point (B) were drawn. A line drawn between these two lines, parallel to the horizontal reference, was used to represent length. Lines A, B and length were then all measured against the metric ruler in the photograph by rotating and moving the corresponding lines on screen. Measurements were taken once. From these measurements, eyebrow height (H=B-A) for each subject was calculated. This height was then used to calculate the eyebrow slope (Slope = H/L) (Figure 2).

Using SSPS version 20 (IBM Corporation, USA), a group analysis was conducted according to decade of age, comparing mean heights and slope of each group to one another using the Mann-Whitney U test for

TABLE 1			
Eyebrow height measurements	according to	age	group

	Age	Subjects,	Medial	Arch apex	Height
Group	range	n	limbus (A)	(B)	(B – A)
1	20–29	20	1.96±0.42	2.30±0.40 [†]	0.34±0.19 [‡]
2	30–39	21	1.99±0.35	2.26±0.30	0.27±0.14
3	40–49	21	1.90±0.30	2.08±0.24 [†]	0.18±0.13 [‡]
4	50–59	25	1.90±0.32	2.12±0.25	0.22±0.17
5	≥60	13	1.78±0.38	2.10±0.38	0.32±0.18 [‡]
Total		100			

*Measurements presented as mean \pm SD in cm; [†]Significant (P≤0.05) paired comparisons according to Mann Whitney U test. Group 1 and 3, P=0.046; [‡]Significant (P≤0.05) paired comparisons according to Mann-Whitney U test. Group 1 and 3, P=0.008; group 1 and 5, P=0.024

TABLE 2

Eyebrow	slope	according	to	age	group
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Group	Age range, years	Subjects, n	Slope*
1	20–29	20	0.22±0.13 [†]
2	30–39	21	0.18±0.09
3	40–49	21	0.12±0.10 [†]
4	50-59	25	0.15±0.12
5	≥60	13	0.21±0.11 [†]
Total		100	

*Measurements presented as mean \pm SD; [†]Significant (P≤0.05) paired comparisons according to Mann-Whitney U test. Group 1 and 3 (P=0.03); group 3 and 5 (P=0.05)

a nonparametric distribution; $P \le 0.05$ was considered to be statistically significant. Simple linear and curve estimation regression analysis was conducted to further analyze the relationship between slope and age. Post hoc analysis was also conducted using regression analysis examining subjects 45 years of age younger and older than 45 years of age.

RESULTS

Facial photographs of 100 women at rest were analyzed. The subjects were divided into groups based on decade of age, with group 5 having the fewest number of subjects (n=13). Table 1 shows the mean medial limbus (A), arch apex (B) and height difference (B–A) measurements. The Mann-Whitney U test was used to complete paired comparisons between each of the groups and significant differences are noted in Table 1. For medial limbus height, there were no significant differences between any of the groups, demonstrating stable medial eyebrow height with increasing age. From group 1 to group 3, the arch apex height significantly decreased with increasing age (2.30 cm versus 2.08 cm; P=0.046); however, after group 3 there was no significant change with increasing age. For height difference (B–A), the height decreased from group 1 to group 3 (0.34 cm versus 0.18 cm; P=0.008) and then with increasing age after the fifth decade, increased once again in group 5 (0.18 cm versus 0.32 cm; P=0.024).

Table 2 summarizes the mean slope and SD calculated for each group. Again, paired comparisons between all groups were performed using the Mann-Whitney U test. As age increased from group 1 to group 3, the mean eyebrow slope significantly decreased (0.22 versus 0.12; P=0.03). Then, as age increased beyond group 3, slope increased significantly again at group 5 (0.12 versus 0.21; P=0.05). This pattern across the groups reflects what was apparent with height difference.

To determine the relationship between age and slope, simple linear regression analysis was performed with slope as the dependent variable. Using a linear model, there was an insignificant relationship, with age contributing only 0.4% of the change seen in slope (Figure 3). Regression analysis was also performed using curve estimation and found that a quadratic relationship, giving a parabolic curve, best predicted the data (Figure 4). This model demonstrated that 7% of the change apparent in slope was accounted for by age, and this was statistically significant (P=0.03) (Figure 4).



Figure 3) Scatterplot of slope versus age with linear regression model (slope as the dependent variable). Linear model: Y=-0.001x + 0.195, $R^2=0.004$, P=0.522



Figure 4) Scatterplot of slope versus age with quadratic regression model (slope as dependent variable). Quadratic model: $Y= 0.443 - 0.013x + 0.0001x^2$; $R^2=0.07$, P=0.031

Taking into account the results of the group analysis and the quadratic regression analysis, the data were subsequently analyzed by categorizing individuals into groups 45 years of age and younger, and older than 45 years of age because this appeared to be a transition point in the data. For age \leq 45 years, a linear model best described the relationship, with nearly 17% of slope being predicted by age (P=0.002) (Figure 5). With increasing age, the change in slope was negative, demonstrating a flattening of the eyebrow. For age >45 years, a linear model was the best fit; however, it was not a significant relationship, with age accounting for only 3% of the change that was apparent in slope (P=0.24) (Figure 6).

DISCUSSION

Eyebrow shape is important for many women, particularly the changes that occur with facial aging, and brow lifts are an important part of facial rejuvenation. However, brow lifts do not always provide satisfying results (2). This failure to rejuvenate the brow is likely due to an imbalance in goals, with more of the focus being on repositioning of the brow and not reshaping. Studies investigating eyebrow position with aging have actually shown an elevation in the brow with age, particularly at the medial and mid-portion (8-10). van den Bosch et al (8) studied eyebrow position in men and women and found that above the pupil, the mid eyebrow elevates with advancing age. As well, the



Figure 5) Scatterplot of slope versus age \leq 45 years with linear regression model (slope as dependent variable). Linear model: Y = -0.006x + 0.373, R²=0.166, P=0.002



Figure 6) Scatter plot of slope versus age >45 years with linear regression model (slope as dependent variable). Linear model: Y = 0.003x + 0.0291; $R^2=0.031$, P=0.239

studies by Matros et al (9) and Patil et al (10) also showed overall elevation of the brow in older groups and elevation of the medial brow more than the lateral. Taking these studies one step further, we aimed to characterize the changes occurring in the lateral slope of the eyebrow, which describes the overall shape, and is an important element in the aesthetics of facial aging.

In our study, we aimed to characterize the changes occurring in the aging female eyebrow by measuring the lateral slope in a random cohort of women 20 to 80 years of age. Ideally, to perform the present study, one would follow a cohort of women as they aged and measure their eyebrows at progressive time points. However, this would take many years to obtain results and is, therefore, not practically feasible. Moreover, there are many factors that contribute to an individual's eyebrow shape such as ethnicity, facial shape and size, and cosmetic practices. To eliminate error caused by eyebrow cosmetic practices (threading, plucking, waxing, etc), we took our measurements from the superior edge of the eyebrow, which reflects the natural slope of the lateral arch. As well, we chose our medial measurement to be taken at the medial limbus and not canthus because there is a wide variation in the medial extent of the eyebrow depending on ethnicity, hair thickness, and cosmetic practices.

From our group and regression analyses, we found that slope changes occurring with aging yields a parabolic curve. With increasing age,



Figure 7) Anteroposterior facial photographs of three study subjects representing the pattern of eyebrow shape change with aging. A Thirty years of age; slope 0.23. B Forty years of age; slope 0.07. C Fifty-eight years of age; slope 0.12

the slope of the eyebrow decreased up until the fifth decade and, unexpectedly, increased with increasing age thereafter (Figure 7). The regression analysis showed that the decrease in slope observed before the fifth decade was linearly dependent on increasing age, and was secondary to descent of the arch apex while the medial height remained stable. This stability of medial height was not what we expected based on previously published studies. This may be because our medial measurement was taken at the limbus and not canthus, as in previously published studies. Despite this, these findings contribute to the improvement of surgical brow rejuvenation procedures that aim to elevate the brow. These findings emphasize the importance of keeping brow elevation focused laterally, in the area of the arch apex, and avoiding medial brow elevation to restore a lateral slope and more youthful shape.

Our results also demonstrate a subsequent increase in eyebrow slope after the fifth decade of life secondary to an increase in height; however, the arch apex remained stable and the medial brow height decreased nonsignificantly. The regression analysis demonstrated that this change was independent of increasing age and, therefore, there must be other, more significant factors contributing to eyebrow slope changes after the fifth decade. A plausible explanation is that differential muscle action acting on the brow is the main contributor. We have shown that the arch apex height decreased until the fifth decade and then remained stable. It could be that, near this age, the descent of the arch apex is such that it causes reactionary hyperactivity of the frontalis, leading to increased muscle tone at rest. This increased tone would raise the arch apex, or prevent it from descending further, while resting tone of the medial depressors (corrugator, depressor supercilii, orbicularis oculi and procerus) act to keep the medial eyebrow height stable (or descend slightly), resulting in increased eyebrow slope at rest once again.

This increase in eyebrow slope after the fifth decade is important in the evaluation of patients with respect to facial aging and potential brow rejuvenation. Paradoxical elevation of the eyebrow apex has been described previously and it has been suggested that this chronic activation of the frontalis muscle acts to overcome clinical or subclinical levator weakness to reduce visual field obstruction (11,12). This is supported by studies that have shown that after upper blepharoplasty, frontalis stimulus is alleviated leading to eyebrow descent (6). It is pertinent to evaluate the position and shape of the eyebrow, as well as the degree of upper lid laxity and transverse forehead rhytids when considering brow lifts because upper lid surgery may affect eyebrow position. Hypertonicity of the frontalis has also been described as a reaction to the antagonist action of the corrugator supercilii, orbicularis oculi and procerus muscles that all act to depress the medial brow (12).

A major factor influencing the aging brow is the changing relationship of the muscles of the periorbit. A better understanding of this changing relationship is most relevant to the use of botulinum toxin. Both the amount and needle placement can be altered based on how those muscle interactions alter with age. In patients younger than the fifth decade, paralysis of the central frontalis and lateral orbicularis can correct the lateral brow ptosis that we have shown in this cohort. In patients older than the fifth decade, however, a hyperactive frontalis is likely essential in maintaining lateral brow height. Botulinum toxin treatment in women of this older population should, therefore, be performed with caution. Medial brow position must also be altered with caution. We have demonstrated that medial brow height does not alter with age; thus, any attempt at treating glabellar wrinkles should strive not to elevate this.

CONCLUSIONS

In the present study, we found that eyebrow slope decreases due to arch apex descent and is dependent on increasing age up until the fifth decade. After the fifth decade, the slope increases independent of increasing age. Our findings, in addition to previous studies, illustrate the complexity of the aging process at the eyebrow, reiterating that it is not simply brow ptosis over time. More accurately, eyebrow shape changes are a result of varying degrees of skin ptosis and antagonist muscle action at rest. This illustrates the importance of evaluating each patient with respect to goals of forehead and brow rejuvenation procedures, and choosing a technique that will be best suited to their individual brow. Most importantly, it emphasizes that eyebrow changes with aging is a dynamic process related to differential muscle action at rest and that static correction may not always be the best form of rejuvenation.

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