

# Computerized Photogrammetry Used to Calculate the Brow Position Index

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## Abstract

**Background** The orbital region is of vital importance to facial expression. Brow ptosis, besides having an impact on facial harmony, is a sign of aging. Various surgical techniques have been developed to increase the efficacy of brow-lift surgery. However, no consensus method exists for an objective measurement of the eyebrow position due to the curvature of the face. Therefore, this study aimed to establish a method for measuring the eyebrow position using computerized photogrammetry.

**Methods** For this study, 20 orbital regions of 10 volunteers were measured by direct anthropometry using a digital caliper and by indirect anthropometry (computerized photogrammetry) using standardized digital photographs. Lines, points, and distances were defined based on the position of the anthropometric landmarks endocanthion and exocanthion and then used to calculate the brow position index (BPI). Statistical analysis was performed using Student's *t* test with a significance level of 5 %.

**Results** The BPI values obtained by computerized photogrammetric measurements did not differ significantly from those obtained by direct anthropometric measurements ( $p > 0.05$ ). The mean BPI was  $84.89 \pm 10.30$  for the computerized photogrammetric measurements and  $85.27 \pm 10.67$  for the direct anthropometric measurements.

**Conclusion** The BPI defined in this study and obtained by computerized photogrammetry is a reproducible and efficient method for measuring the eyebrow position.

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**Keywords** Anthropometry · Computer-assisted image processing · Eyebrows · Photogrammetry · Plastic surgery

## Introduction

The orbital region is of vital importance to facial expression [8]. The orbicularis oculi, corrugator and depressor supercilii, procerus, and frontal muscles, acting alone or in combination, are responsible for facial physiognomy [6]. These also play an important role in interpersonal communication, clinical evaluation of a patient, and facial harmony. In this context, brow ptosis may convey undesirable signs of sadness and, especially, facial aging.

Various surgical techniques have been developed and applied in plastic surgery to increase the efficacy of brow-lift surgery with regard to positioning of the eyebrow's most lateral point in the inferosuperior direction [1–3, 5, 6, 8, 11–14, 16–18]. However, methods for evaluating brow-lift are either subjective or difficult to reproduce. The difficulty arises because these methods do not use fixed reference points that can be identified both pre- and postoperatively to allow reliable and reproducible measurements.

Many anthropometric facial landmarks have been described in the literature [7], but none of them allow a sequential measurement considering the postoperative

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displacement of the eyebrow. Therefore, a method that permits an objective measurement of the eyebrow position would be extremely valuable for this type of surgical procedure, whether in basic research or in clinical and surgical applications.

Computerized photogrammetry is a widely used and validated tool for measuring various facial regions [9] that provides relative measurements, such as proportions and angles, which can be used to minimize small positioning differences despite a preestablished photographic standardization [4, 10, 15]. However, computerized photogrammetry still is not a validated method for measuring eyebrow position due to the curvature of the face, especially in the orbital and periorbital regions.

This study aimed to establish a method for measuring the eyebrow position using computerized photogrammetry.

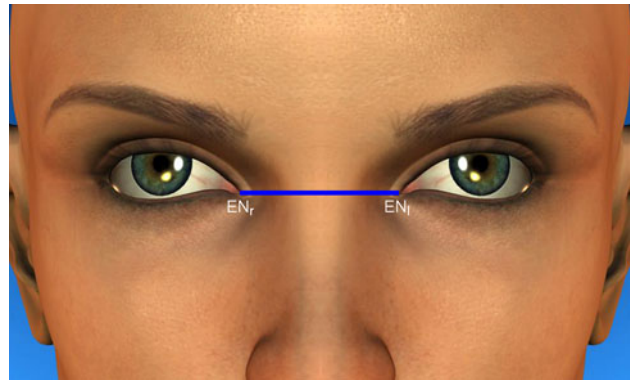
## Participants and Methods

The study was approved by the Research Ethics Committee of the Universidade Federal de São Paulo (UNIFESP), Brazil, and performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its subsequent revisions. Written informed consent was obtained from all the participants before their inclusion in the study, and anonymity was ensured.

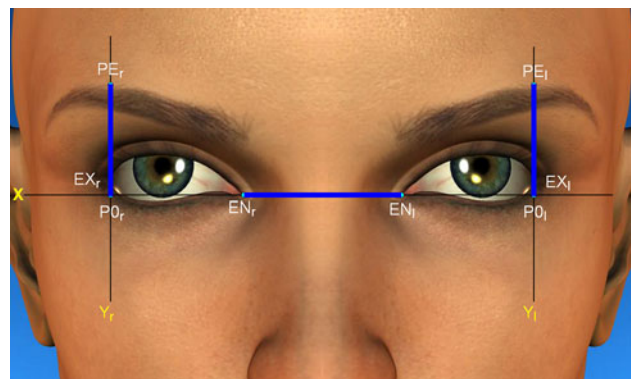
Direct anthropometric measurements and digital photographs for later indirect anthropometric measurements were taken from 10 female volunteers, all Caucasians, ages 18–48 years. The distance between the right ( $EN_r$ ) and left ( $EN_l$ ) medial palpebral commissures (endocanthion) was measured (Fig. 1). The line segment  $EN_r$ – $EN_l$  was extended in both directions (line X) beyond the lateral orbital rim. The exocanthion (EX) of the right ( $EX_r$ ) and left ( $EX_l$ ) eyes were marked. From each EX landmark, a line Y was traced perpendicular to line X, extending in both directions and beyond the superior ridge of the eyebrow (lines  $Y_r$  and  $Y_l$ ). The intersection point of lines X and Y was called point zero ( $P0_r$  and  $P0_l$ ), and the intersection point of line Y and the superior ridge of the eyebrow was called point of the eyebrow ( $PE_r$  and  $PE_l$ ). These intersections define the P0–PE distance (Fig. 2). The brow position index (BPI) was defined bilaterally ( $BPI_r$  and  $BPI_l$ ) as the ratio between the measured P0–PE and  $EN_r$ – $EN_l$  distances multiplied by 100.

### Direct Anthropometric Measurements: Caliper

Direct anthropometric measurements were made with a digital caliper (precision, 0.01 mm; OTMT Machines, NY, USA) (Fig. 3a, b). The  $EN_r$ – $EN_l$ ,  $P0_r$ – $PE_r$ , and  $P0_l$ – $PE_l$  distances were measured by the first researcher (R1), who



**Fig. 1** Diagram showing the  $EN_r$ – $EN_l$  distance between the *left* and *right* endocanthion (EN). *r* right, *l* left

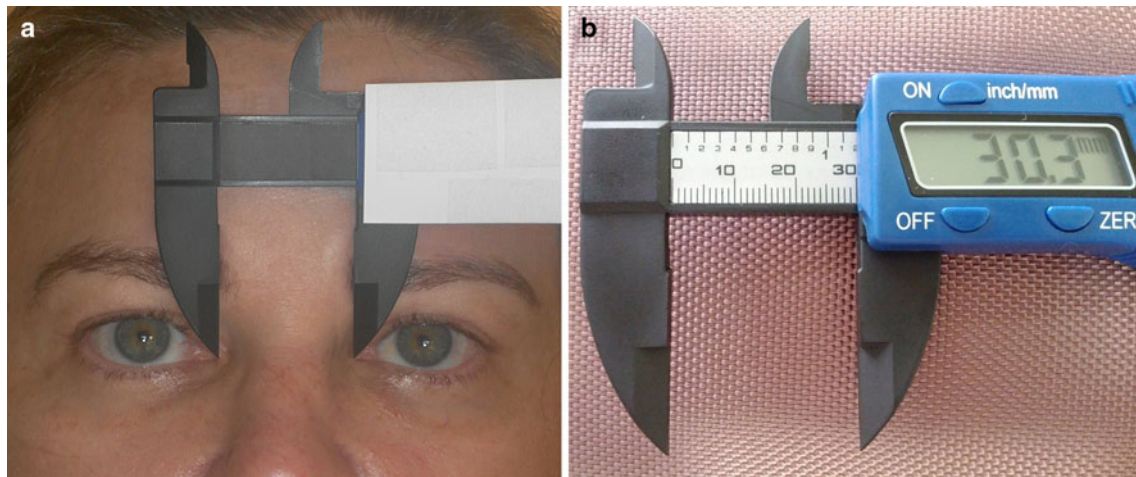


**Fig. 2** Diagram showing lines X and Y, point zero (P0), point of the eyebrow (PE), and the P0–PE distance on the *left* and *right* sides of the face

was blinded to measurement results due to the complete concealment of the caliper display. The data were recorded by a second researcher (R2), and the results were kept confidential. The distances were measured in triplicate, and the average value of each distance was calculated.

### Indirect Anthropometric Measurements: Computerized Photogrammetry

A photograph of each volunteer was taken in JPEG format using a 3-megapixel digital camera (Fuji, model S7000) with a focal length of 7.8–46.8 mm and an automatic flash. The photographs were taken showing the orbital region, according to Hochman et al. [9]. To keep R1 blinded to the measurement results, the part of the monitor that displays the measurements was covered with an opaque film. Distances were measured in triplicate with the UTHSCSA ImageTool, version 3.0 software for Windows following the same procedure described for direct anthropometry. The software tools were used without image magnification (zoom).



**Fig. 3** **a** Direct measurement of the EN<sub>r</sub>-EN<sub>l</sub> distance between the right and left endocanthion (EN) using a digital caliper (precision, 0.01 mm) without the millimeter ruler and with complete

concealment of the caliper display for a blinded reading. **b** Digital caliper used in the study showing the millimeter ruler and the digital display

**Statistical Analysis**

All direct and indirect anthropometric measurements were analyzed by parametric statistics to verify the accuracy of this method for calculating the BPI. Student’s *t* test was performed with a significance level of 5 % ( $p < 0.05$ ).

**Results**

The mean values of the BPI for the right and left sides of the face based on direct and indirect anthropometric measurements are shown in Table 1. No significant differences were found between mean BPI<sub>r</sub> and mean BPI<sub>l</sub> using either the direct and indirect anthropometric measurements. Also, no statistically significant differences were found between the two measurement methods in terms of BPI<sub>r</sub>, BPI<sub>l</sub>, or BPI<sub>r</sub> + BPI<sub>l</sub> values.

The results from the comparison of brow position indexes for the right and left sides of the face obtained from direct and indirect anthropometric measurements are shown in Table 2. The comparisons of the mean brow

**Table 2** Results of the inferential analysis between brow position index (BPI) values for the right and left sides of the face obtained from direct (digital caliper) and indirect (computerized photogrammetry) anthropometric measurements

Comparisons	Calculated <i>t</i> value	<i>p</i> value
Caliper (BPI <sub>r</sub> vs. BPI <sub>l</sub> )	0.77	0.4610
Computerized photo (BPI <sub>r</sub> vs. BPI <sub>l</sub> )	1.62	0.1400
BPI <sub>r</sub> (caliper vs. computerized photo)	1.51	0.1660
BPI <sub>l</sub> (caliper vs. computerized photo)	0.09	0.9280
BPI <sub>r</sub> + BPI <sub>l</sub> (caliper vs. computerized photo)	0.678	0.5060

Student’s *t* test was used for paired data with a significance level of 5 % ( $p < 0.05$ )

position index (BPI<sub>r</sub> and BPI<sub>l</sub>) between and within groups are shown in Figs. 4 and 5, respectively.

**Discussion**

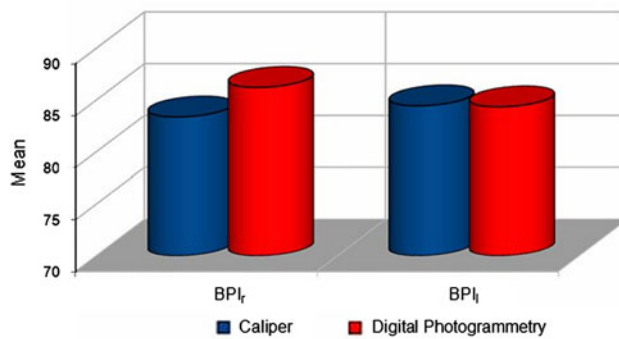
Eyebrows have a great aesthetic influence on facial physiognomy. As a result, there is a continuous search and development of surgical techniques in plastic surgery to allow better repositioning of the eyebrow for correction of distortions and unaesthetic variations in its position [2, 8, 13, 16]. Several techniques and strategies have been used for more than a century, and to date, no consensus has emerged identifying one as the most efficient, long-lasting, and successful in providing this type of correction.

Faced with this fact and the need to choose a technique suitable for the patients, plastic surgeons search comparative studies for information that may help them make

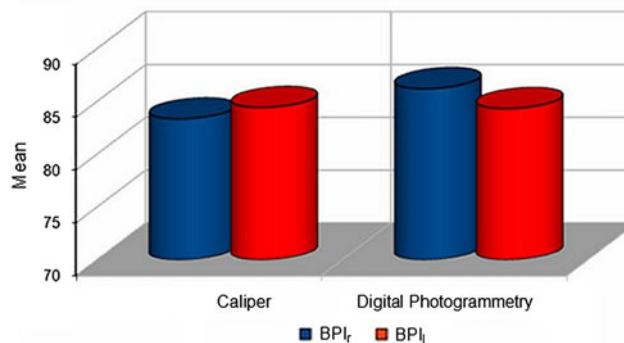
**Table 1** Mean right and left brow position indexes (BPI<sub>r</sub> and BPI<sub>l</sub>) for direct (caliper) and indirect (computerized photogrammetry) anthropometric measurements

Index	Caliper			Computerized photogrammetry		
	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD
BPI <sub>r</sub>	10	85.35	10.68	10	86.21	11.43
BPI <sub>l</sub>	10	84.43	10.47	10	84.33	10.39
BPI <sub>r</sub> + BPI <sub>l</sub>	20	84.89	10.30	20	85.27	10.67

SD standard deviation



**Fig. 4** Comparison of the mean *right* and *left* brow position indexes (BPI<sub>r</sub> and BPI<sub>l</sub>) between the groups



**Fig. 5** Comparison of the mean *right* and *left* brow position indexes (BPI<sub>r</sub> and BPI<sub>l</sub>) within the groups

informed treatment decisions. Berkowitz et al. [2] used the EX and Troilius [17] used measurements of the eyebrow and pupil positions as reference landmarks to compare pre- and postoperative measurements. These structures used in clinical surgical practice as reference landmarks may lead to a possible bias because they may not be present in the same position pre- and postoperatively. The pupil position is patient dependent despite a rigorous photographic standardization, and the EX is displaced upward during rhytidoplasties involving the orbital and eyebrow regions [1]. For this reason, our objective was to define an anthropometric facial landmark that could serve as a reference point for a reliable and reproducible measurement of the eyebrow position.

Bone structures are landmarks described in the literature as not displaced during rhytidoplasties. They are totally reliable concerning general displacement but provide poor reproducible measurements for direct and indirect anthropometry. Moreover, bone structures are deeply located and covered with soft tissue, which can be easily displaced during deep palpation in landmark identification [4, 9], making it difficult to perform direct anthropometric measurements of the orbital region. This difficulty is even more pronounced when indirect anthropometric measurements

(computerized photogrammetry) are performed due to the impossibility of identifying bone structures in an image. On the other hand, bone structures become identifiable on radiographs, but they can be correlated only with other bone structures because eyebrows do not show a precise and reliable contour defined by the superior-most brow hair follicles on radiographs.

In face of these difficulties and with the purpose to develop a viable method for measuring the position of the eyebrow in a reliable and reproducible manner using computerized photogrammetry, we decided to define a new index, the BPI. After making this decision, we were faced with another dilemma: Photogrammetry of the orbital regions still was not validated as a measuring method due to the curvature of the face in these regions [7, 15]. Therefore, the calculation of the BPI had to be proven reliable and reproducible by computerized photogrammetry.

The EN was chosen as a starting point for determination of the BPI because it is an anthropometric landmark that does not vary when patients undergo facial rejuvenation surgery [4] such as rhytidectomy, frontal lift, orbitoplasty, peri-orbitoplasty, or blepharoplasty. Point zero (P0) defines a reference point that does not change even when the EX is displaced upward during facial rejuvenation surgeries because EX is a reference only for the construction of line Y. Line X remains unchanged after these surgeries because it has the right and left EN as its reference landmarks.

Measurements obtained with computerized photogrammetry were compared with those obtained using direct anthropometry. Statistical analysis showed that despite the hypothesis that the curvature of the face could negatively affect photogrammetric measurements, no statistically significant differences were found in BPI values between measuring methods.

An important advantage of using computerized photogrammetry in clinical practice is the possibility of reducing or even eliminating errors arising from anthropometric measurements taken directly from the patient using rigid instruments such as calipers, dividers, rulers, or protractors placed in contact with compressible regions of the face, including the brow and periorbital region. Another advantage of this indirect anthropometric method is the reduced time of exposure and embarrassment patients may feel during measurements. It also allows the surgeon to take the measurements under proper conditions at a time other than during a patient visit.

Computerized photogrammetry of the frontal region of the face also can be an invaluable tool for the objective assessment of postoperative results, especially in facial rhytidectomy. Measurements made with this technique are precise to the nearest 0.01 mm, allowing more accurate comparisons between results of pre- and postoperative assessments.

Frontal rhytidectomy is a peculiar procedure because the facial region in focus has a particular and dynamic structure. The support of this region results from the interplay of forces produced by elevator muscles (frontalis-occipital complex muscle) and the depressors of the brow (orbicularis oculi, depressor supercillii, procerus, and corrugator muscles). These forces are in equilibrium preoperatively.

After frontal rhytidectomy (with or without the aid of endoscopy) with dissection of the muscles, the dynamic equilibrium is achieved after the healing process is complete. Thus, photogrammetry permits measurement of the position of the eyebrows and other structures at different postoperative stages. The same approach also can be used in clinical practice for cases such as injury or transection of the frontal branch of the facial nerve, whether accidental or surgical. Photogrammetry allows indirect monitoring of reinnervation and recovery through observation of the eyebrow position, which is a benefit that the patient can appreciate. It also is important to note that besides its clinical, surgical, scientific, and academic importance, standardized photographic documentation also can be used in situations involving legal issues or disputes.

## Conclusion

The BPI obtained by computerized photogrammetry is an efficient and reproducible method for measuring the eyebrow position.

**Conflict of interest** The authors declare that they have no conflict of interest.

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