

## The prediction of nasolabial dimensions: A stereophotogrammetric study

Ali R. Al-Khatib<sup>a</sup>, Zainul A. Rajion<sup>b</sup>

From the <sup>a</sup> College of Dentistry, University of Mosul, <sup>b</sup>School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kelantan, Malaysia.

Correspondence: Ali R. Al-Khatib. College of Dentistry, University of Mosul, Mosul, Iraq. Email: ali69123@yahoo.com.

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### ABSTRACT

**Objective:** To find the most accurate measurements for the nasolabial dimensions prediction utilizing the three dimensional technology.

**Design:** Cross-sectional study.

**Setting:** School of Dental Sciences, Universiti Sains Malaysia, Kelantan, Malaysia.

**Participants:** This study was conducted on 101 volunteers (16-30 years). The participants had harmonious balanced face, competent lips and no craniofacial abnormalities. Data were captured using stereophotogrammetry system which consists of Sony digital cameras, synchronize switch and a calibration control frame.

**Main outcome measures:** Eighteen facial, seven nasal and 11 labial dimensions were measured and analyzed. The stepwise multiple regression analysis was applied and the level of significance was established at  $p < 0.05$ .

**Results:** The measurements of the combination of nasolabial dimensions were developed. The prediction rates were 90% and 96% and for the upper lip height, nose height respectively. However, the low prediction rate was recorded for the lower vermilion and lateral lip heights 17% each.

**Conclusions:** New measurements for nasolabial dimensions prediction with application of three dimensional imaging technology were offered. This study could provide reliable and objective reference material for plastic surgeons for the planning of the cosmetic nasal surgery. Moreover, these information could be beneficial in the post-surgical prosthesis construction.

**Keywords:** Soft tissues, morphology, stereophotogrammetry.

### توقع أبعاد الأنف والشفاه: دراسة ثلاثية الأبعاد

#### الخلاصة

**الأهداف:** هدفت الدراسة إلى تطوير متغيرات جديدة لدراسة أبعاد الأنف والشفاه باستخدام تقنية الصورة ثلاثية الأبعاد.

**تصميم الدراسة:** دراسة مقطعية.

**مكان الدراسة:** كلية طب الأسنان في جامعة العلوم الماليزية.

**المشاركون:** شارك في هذه الدراسة 101 متطوع تتراوح أعمارهم بين 16-30 سنة. وقد إتصف المشاركون بوجه خالي من التشوهات الخلقية في منطقتي الجمجمة والفكين. تم التقاط المعلومات باستخدام جهاز التصوير الثلاثي الأبعاد.

**المتغيرات:** تم قياس 36 متغير في مناطق مختلفة من الوجه وخاصة المناطق الأنفية ومناطق الشفتين تم استخدام الإنحدار المتعدد لتحليل النتائج علماً بأن القيمة الاحتمالية المعنوية كانت  $P > 0.05$ .

**النتائج:** تراوح المعدل للقياسات بين 90% و96% بالتعاقب للطول الأنفي وإرتفاع الشفة العليا. أما بالنسبة لحافة الشفة السفلي و لإرتفاع الشفة الجانبي فقد بلغ 17%.

**الاستنتاجات:** تم الحصول على متغيرات جديدة للتنبؤ بأبعاد الأنف والشفاه باستخدام تقنية الأبعاد الثلاثية. هذه المتغيرات يمكن أن تستخدم لغرض الإعداد لعمليات الجراحة التجميلية في مناطق الأنف والشفاه بالإضافة إلى إعداد التراكيب التعويضية لتلك المناطق في الوجه.

A normal appearance of the face is based on a balance among different morphological structures that vary according to ethnicity, sex and across generations<sup>(1,2)</sup>. The size and shape of the nasal area and lips have an important influence on the appearance of the human face<sup>(3,4)</sup>. Obvious nasolabial deformities can occur as a consequence of developmental anomalies or after trauma or surgery. Surgical reconstruction is usually accomplished by reconstructing the deformed part<sup>(5)</sup>. Although the surgical intervention looks straightforward, slipping of the lip line, distortion, unfavourable scar position, asymmetry, disturbed facial expressions have been described in the literature<sup>(6)</sup>. These are commonly encountered due to lack of valid references for preoperative assessment<sup>(5)</sup>.

Currently, measuring and analyzing photographs and radiographs have largely determined the present understanding of facial aesthetics and proportion<sup>(7)</sup>. However, these methods have focused on the soft-tissue profile as presented on two dimensional images. These methods may not provide sufficient information for surgeons to allow an accurate prediction of the postoperative appearance<sup>(8)</sup>. Advance technology have applied the three-dimensional (3D) approaches to study and evaluate facial soft tissues, however, few studies has focused on the nasolabial region<sup>(9,10)</sup>.

Thus, the aim of the present study was to develop new predictors for the nasolabial dimensions prediction utilizing the 3D technology.

## MATERIALS AND METHODS

The sample of the present study consisted of 101 subjects (50 males and 51 females) aged between 16-30 years. They were selected according to the following inclusion criteria: harmonious balanced face, competent lips and no history of previous facial surgery, maxillofacial trauma or congenital anomalies in the face areas. The study was approved by the Human Ethics Research Committee at the Universiti Sains Malaysia [No.156.4 (5) 2008].

The system relayed upon sophisticated stereo triangulation algorithms to identify and match the 3D position of the landmarks<sup>(11-13)</sup>. It has been constructed by the collaboration between Universiti Sains Malaysia and Universiti teknologi Malaysia. It consists of two Sony digital cameras (model DSC-V1, resolution 2592x1994) mounted together

on a specially prepared holder (**Figure 1**). The cameras are triggered simultaneously by remote control synchronize switch. The calibration frame is adjusted to be in front of the cameras and hold by two vertical arms. Well distributed circular retro-reflective markers are placed around the control frame. They are distributed to be clearly visible on both right and left images. The calibration frame and camera holder are fit into a solid base with a movable trolley for easy movement.

The camera calibration was conducted to determine the physical camera parameters. To perform the calibration, camera was fixed at 700mm away from previously calibrated control frame with well-known highly accurate x, y and z coordinates<sup>(12-13)</sup>. After the first capture, the target board was rotated 90° to allow for additional 3 images to be taken. In addition, the camera was rotated around its z axis by 90° to capture another four convergent photographs. Bundle adjustment using Australis software version 6.06, (Photometrix Pty. Ltd., Victoria, Australia) was used to determine the camera parameters (**Figure 2**).



**Figure 1.** The complete imaging station from frontal view showing the camera base and remote control switch.

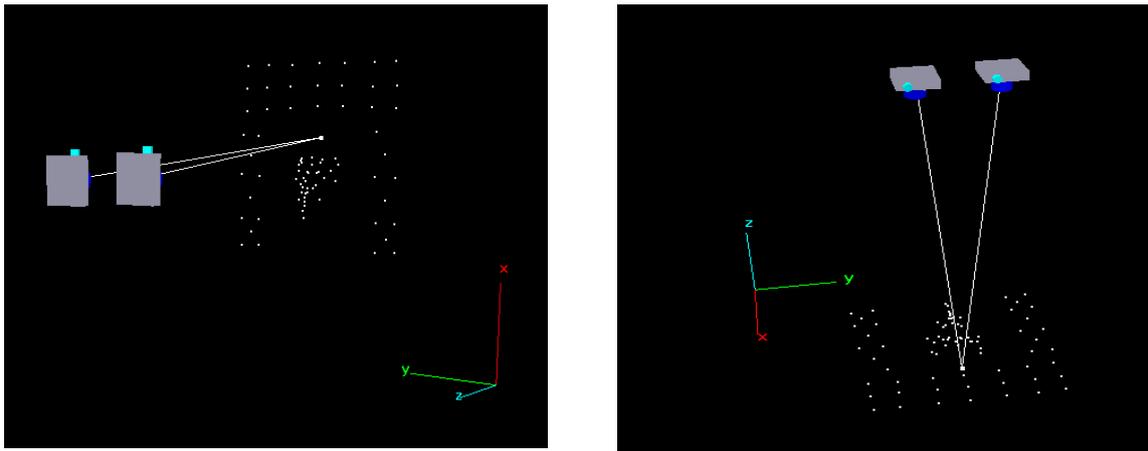


Figure 2. Image created by Australis software where the two imaginary lines intersected and the coordinates on the intersection point could be calculated.

The control frame of the stereophotogrammetric system was calibrated by a similar approach. Another set of images were captured for the calibration frame by the previously calibrated camera <sup>(12)</sup>. The coordinates of each retro-reflective marker on each image was digitized. Using Australis software, bundle adjustment option was applied and the 3D coordinates of the control frame were displayed on coordinate dialogue box.

The volunteer was seated in natural head position and the landmark sites were placed directly on each subject's face with water soluble pen. The landmarks and distances selected were defined according to previous studies <sup>(14)</sup> as shown in **Table 1** and **Figure 3**. After the facial landmarks were labelled, the image capture steps were begun under standardized illumination. The participant was seated on an adjustable stool and the distance from the participant to the camera stereo pair was fixed at 700 mm <sup>(12, 13)</sup>. The head was adjusted to be positioned in the middle of the calibration frame. Each participant's head was elevated approximately 5 degrees above the Frankfort horizontal plane to avoid shadow coverage of the sub nasal and sub mental areas (**Figure 4**). The face was relaxed and the teeth were placed in centric occlusion. Once the participant's head was in the correct orientation, frontal views were obtained. Following this, the participant was rotated to the right side and then the left side by about 45 degrees to the wall. In these positions, the right and left oblique lateral views were captured <sup>(12, 13)</sup>.

The researcher analyzed the right and left images of each view on the computer screen using

Australis photogrammetric software. The position of the landmark was magnified on the computer screen then click over it. Lighting and contrast facilities were incorporated to increase visualization of landmarks during digitization. All of the land marks on the right and left images of each view were digitized simultaneously. After that, the right and left images were triangulated and intersected. The measurements and x, y, z coordinates were displayed in a separate data sheet.

The accuracy and precision of the measurements were estimated by repeating the procedures for 15 participants. Accuracy is defined as the closeness of measured values to the true value, whereas precision refers to the closeness of repeated measurements of the same quantity <sup>(15)</sup>. All anthropometric distances were measured directly on the face with considerable care so as not to distort the labelled points. The procedures were done by using digital callipers (Mitutoyo, Japan) to an accuracy of 0.1 mm. Each distance was measured twice and the mean value was utilized for the analysis. After obtaining direct measurements, 3D data were also collected. Image digitization and data collection from the images were performed to detect the accuracy of the measurements. After that, the same 15 participants were re-evaluated by the same examiner after 24 hours to assess the precision of the measurements. Based on previous studies <sup>(16, 17)</sup> any differences in duplicate stereophotogrammetric measurements less than 2 mm can be considered to indicate acceptable accuracy.

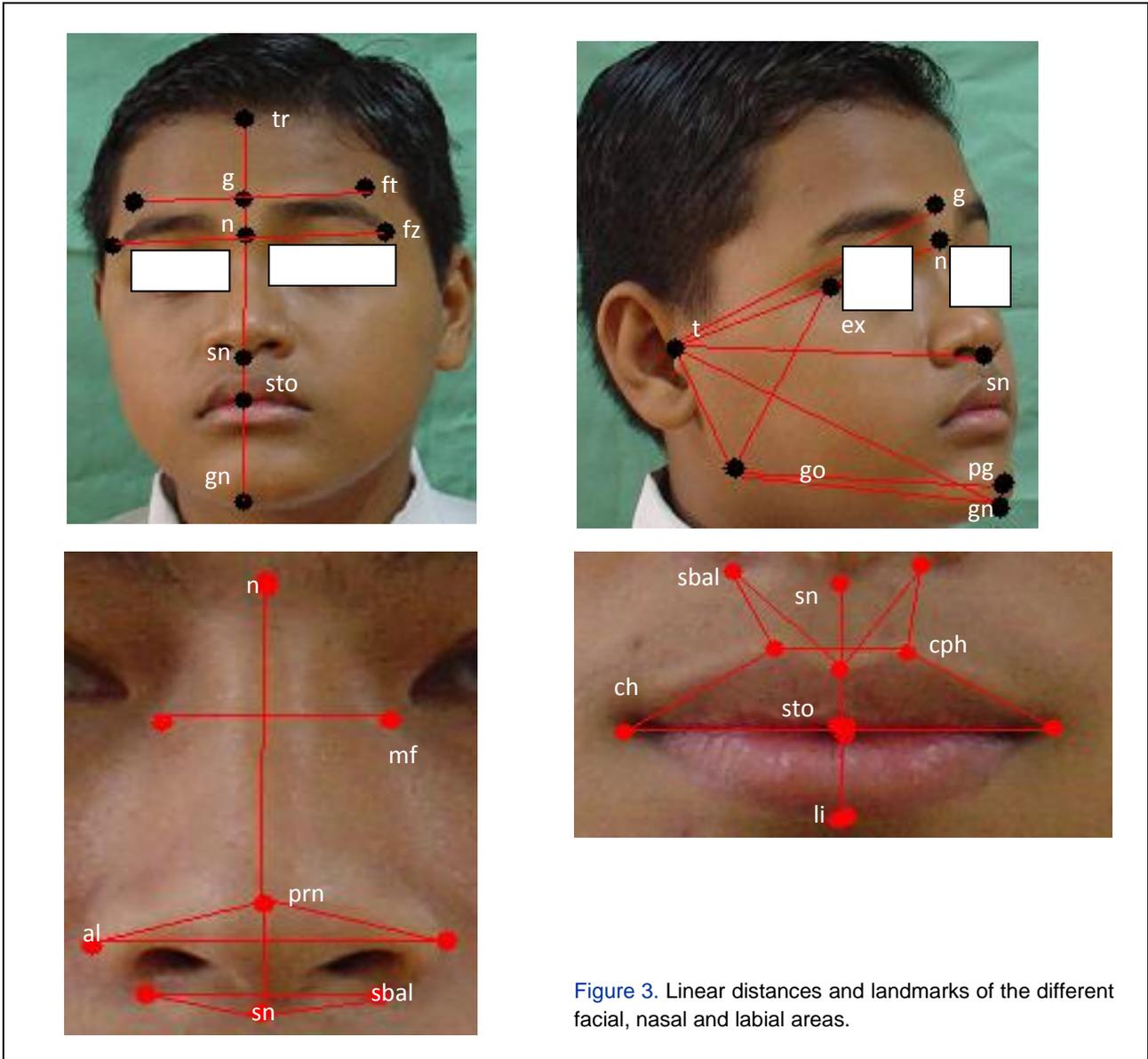


Figure 3. Linear distances and landmarks of the different facial, nasal and labial areas.

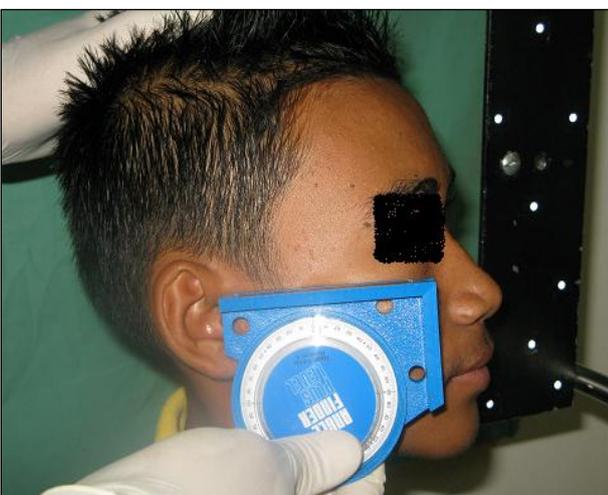


Figure 4. The participant's head adjusted and standardised using angle finder instrument.

**Statistical analysis**

Paired t-tests and intra class correlation coefficients were used to evaluate accuracy and precision respectively. A stepwise linear regression was performed to investigate the relationships between different measurements in each sex. The coefficient of determination ( $R^2$ ) which is the squared value of the correlation coefficient was calculated. This has been utilized to determine the relative importance of the significant predictors. Moreover,  $\beta$  - Beta – a coefficient that denotes the nature of the relationship between dependents and independents was presented. Data were analyzed using the SPSS 18.0.1 program and statistical significance was set at  $p < 0.05$ .

## RESULTS

### Accuracy and precision

Most of the mean differences between the direct calliper and indirect measurements were not statistically significant ( $p > 0.05$ ) as shown in (Table 1). They ranged between 0.14 mm and 2.10 mm. The precision was generally high, with most of intra class correlation coefficients values being greater than 0.80 (Table 1).

### Stepwise regression analysis

In this study, the best combination of independent variables for the multiple regression was presented (Table 2). The forehead width (fz-fz) and lower face height (sn-gn) were the best two predictors. The best combination of independent variables was obtained by nose height (n-sn) (Table 2). The regression coefficients and the  $R^2$  values for every nasolabial dimension are shown in the same table. The highest estimated values with this method based on the study group were 96% and 90% for the nose height (n-sn), and upper lip height (sn-sto) respectively.

Table 1. Accuracy and precision of the nasal, oral and labial measurements.

Variable	Abbreviation	Difference (mm)	ICC
Facial			
Forehead width	ft-ft	0.41	0.83*
Supraorbital breadth	fz-fz	0.23	0.91*
Height of the forehead I	tr-g	1.90	0.86*
Supraorbital depth	g-t	0.89	0.87*
Upper third face depth	n-t	0.50	0.91*
Orbito-tragial depth	ex-t	0.60	0.80*
Maxillary depth	sn-t	0.66	0.92*
Mandibular region depth I	gn-t	1.20*	0.68*
Depth of lower jaw I	gn-go	2.10*	0.67*
Mandibular region depth II	pg-t	1.20	0.81*
Mandibular ramus height	go-t	2.12*	0.88*
Depth of lower jaw II	pg-go	1.10	0.98*
Orbitogonial depth	ex-go	0.71	0.84*
Physiognomical face height	tr-gn	2.20	0.92*
Morphological face height	n-gn	0.62	0.85*
Lower face height	sn-gn	0.71	0.95*
Mandible height	sto-gn	2.10*	0.85*
Upper face height	n-sto	1.95	0.81*
Nasal			
Nasal root width	mf-mf	0.74*	0.85*
Nose width	al-al	0.77*	0.95*
Width of ala insertion	sbal-sbal	0.14	0.82*
Ala length	al-prn	0.59	0.83*
Nasal tip protrusion	sn-prn	0.88*	0.98*
Nose height	n-sn	0.54	0.84*
Nasal bridge length	n-prn	0.65	0.92*
Labial			
Philtrum width	cph-cph	0.26	0.95*
Mouth width	ch-ch	0.22	0.92*
Labial fissure half-width	ch-sto	0.50	0.96*
Upper lip height	sn-sto	1.04*	0.82*
Philtrum length	sn-ls	0.57	0.85*
Upper vermilion height	ls-sto	1.11*	0.83*
Lower vermilion height	sto-li	1.04*	0.81*
Cutaneous lower lip height	li-sl	0.40	0.96*
Upper lip lateral height	sbal-cph	0.29	0.93*
Length from crest of the philtrum to the commissure	ch-cph	0.47	0.93*
Lateral lip height	sbal-ls	0.19	0.98*

\* Statistically significant difference  $p < 0.05$ .

Table 2. The best predictors of the nasolabial dimensions.

Dependent variable	Cons*	IV**	$\beta$	IV**	$\beta$	IV**	B	IV**	B	IV**	$\beta$	R <sup>2</sup>
mf-mf	4.49	n-gn	0.09	fz-fz	0.09							0.35
al-al	3.12	n-gn	0.17	fz-fz	0.13							0.63
sbal-sbal	13.80			fz-fz	0.08							0.17
al-prn	18.48	prn-gn	0.54	sn-gn	0.53							0.37
sn-prn	6.80	prn-gn	1.01	sn-gn	1.08							0.73
n-sn	3.97	n-sto	0.38	sn-gn	0.87	n-gn	0.61	Sto-gn	0.18	me-gn	0.12	0.96
n-prn	5.03	n-sto	0.60	sn-gn	0.86	sto-gn	0.51	n-gn	0.34	tr-g	0.06	0.86
cph-cph	7.73	sto-gn	0.11									0.21
ch-ch	16.11	tr-gn	0.11	fz-fz	0.13							0.50
ch-sto	15.74	n-sto	0.17									0.27
sn-sto	5.21	sn-gn	0.77	sto-gn	0.17	me-gn	0.15	n-sto	0.53	n-gn	0.52	0.90
sn-ls	4.65	sn-gn	0.64	sto-gn	0.46	prn-gn	0.15					0.65
ls-sto	0.27	sn-gn	0.15									0.46
sto-li	3.56	ft-ft	0.05									0.17
li-sl	8.14	sto-gn	0.37	me-gn	0.21							0.42
sbal-cph	9.09	sn-gn	0.12									0.17
ch-cph	16.63	sn-gn	0.17									0.29
sbal-ls	12.17	n-sto	0.09									0.17

\*Constant.

\*\*Independent variables.

## DISCUSSION

Preoperative assessment of nasolabial region is an essential part of preoperative planning. Objectively determined postoperative changes can be interesting as it could provide a guide for future cases<sup>(18)</sup>. In this study, 3D imaging system is used to measure and predict the nasolabial dimensions. These variables were chosen according to reports from previous studies,<sup>(13,19,20)</sup> and the sample included various age interval. According to Farkas<sup>(14)</sup>, incremental changes in the face may continue after 16 years but with lesser speed. For that reason and to avoid any interference, the age and sex have been adjusted during statistical analysis. Facial measurements calculated from 3D landmarks may display some differences to those obtained by direct measurement, but any discrepancies shown are generally small in magnitude and unlikely to bias results of analyses. The differences for some of the measurements could be attributable to alterations in the position of related structures during calliper measurement<sup>(13,21-22)</sup>. Furthermore, some distances are small, making it difficult to achieve high accuracy and precision<sup>(23)</sup>. It should be noted that 3D imaging systems are non-contact tools that eliminate the problems associated with surface pressure caused by calipers, reduce the measurement time and subject cooperation during sessions, and allow images to be archived<sup>(16, 23)</sup>.

The quality of a statistical method based on regression equations depends, among other aspects, on the selected variables. For example, differences relating to nasal variables could be due to variations in deciding on the location of the landmark, nasion, which is actually an osseous intersection<sup>(14)</sup>. Indeed, discrepancies may appear between studies in labial variables when measurements are taken with the lips in various positions, for example relaxed, closed, and displaying different degrees of contraction<sup>(24)</sup>.

The results of the present study illustrated that the highest R<sup>2</sup> values were calculated for the nose height (n-sn) and upper lip height (sn-sto) distances. Moreover, the R<sup>2</sup> values of some distances such as nasal tip protrusion (sn-prn), philtrum length (sn-ls) are moderate. The present study indicated that nasal tip protrusion, philtrum length are mostly affected by the lower face height distances. As well as, the supraorbital breadth (fz-fz) was the only horizontal distance that could be used in the prediction of the various nasolabial dimensions, although the R<sup>2</sup> was low.

During surgical consultation, instead of being guided by aesthetic ideal, surgeons and clinicians should show understanding for the appropriate proportions of individual nose for patient<sup>(25)</sup>. In the available literature, very few reports were found describing the inter-relations of nasolabial dimensions<sup>(26)</sup>. In a previous study<sup>(26)</sup>, significant associations were noted between nasal and labial

dimensions, particularly between horizontal nasal and labial dimensions. The correlation analysis also showed that a wide nasal base could be expected in individuals with long upper labial areas. The study showed that nose length and height were negatively affected by the length of the lips<sup>(26)</sup>. These findings indicate that individuals with short noses tend to have large labial dimensions that may produce some variation in the proportions of the lower face. However, they did not describe how facial dimensions could be used for the prediction of nasolabial one.

In the present study, we continue emphasizing, on the importance of the association between nasolabial measurements and the different face compartments to preserve the facial harmony as a whole. Hopefully, this article will provide the reader with an additional approach that helps to improve success in the treatment planning of a difficult problem. However, further studies are required to apply these relations in the clinical practice.

## CONCLUSION

This study has provided information for the predicting of several nasolabial dimensions. Hopefully, this article will provide the reader with an alternative approach with demonstrated success in the treatment of plastic surgical problems. Further studies with different populations and age intervals, are indicated.

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