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Nasal Profile Assessment Using Geometric Morphometrics in a Sample of Chilean Population. Clinical and Forensic Implications

Evaluación del Perfil Nasal Mediante Morfometría Geométrica en una Muestra de Población Chilena. Implicancias Clínicas y Forenses

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SUMMARY: The search of morphological patterns of nasal profile using traditional morphometrics has been the goal of several studies aiming to orient therapeutical planning and forensic techniques such as facial reconstruction. The present study aims to find and describe such patterns with geometric morphometric tools in a sample of Chilean population with geometric morphometric tools. We used the lateral X-rays of 156 individuals (men and women) and 14 landmarks in bone and soft tissues. Procrustes analysis was performed followed by principal component analysis to assess general shape variation, regression of shape components against centroid size to study to allometric effect and discriminant analysis by sex with cross-validation test. Our results show the lack of shape patterns, and that the size, followed by sex, explains within a limited scope the shape changes which suggests the presence of uncontrolled variables and a high effect of inter-individual variation. In general terms bigger profiles, more frequent in men, show a lower Pronasal point, a more prominent nasal dorsum with a thicker layer of soft tissue, and a vertically expanded upper lip. We suggest the reassessment of the importance of individual aesthetic evaluation for clinical purposes, and recommend caution in concluding results based on forensic reconstruction techniques.

KEY WORDS: Nasal profile; Geometric morphometrics; Sexual dimorphism.

INTRODUCTION

Evaluation of the nasal form is an extensively used anatomical tool. It is used for planning and postsurgical evaluation in orthopedics as well as plastic and reconstructive surgery (Mahler *et al*., 1983; Pancherz & Anehus-Pancherz, 1994; Grayson & Cutting, 2001). In forensic anthropology this constitutes a fundamental base in the reconstruction in two and three dimensions of medical-legal identification, with the correct position of the nose, eyes, mouth and ears as the golden rule (De Greef *et al.*, 2009). In the case of a study with clinical objectives, generally aesthetic criteria based on beauty cannons are acceptable, which makes difficult an objective evaluation of the nasal form. Furthermore, regarding basic considerations related to sexual dimorphism it has been described the importance of recognizing the differences of the nasal form in different populations as aesthetic appreciations are influenced by cultural standards (Leong & White, 2006). This population diversity is at the same time essential in forensic analysis wherein one of the most complex and key aspects of reconstruction, is the location of the tip of the nose or pronasal point (Prn). This provides an idea of the form and nasal extension (Gerasimov, 1971; Wilkinson, 2004). In reference to sexual dimorphism of nasal profile, noses of men tend to be straight with a lower Pronasal, while women have a more concave nasal dorsum with pronasal located in an upper position (Springer *et al.*, 2008). Even though these characteristics aid in pre-surgical decisions to obtain harmonious and satisfactory results for the patient, in forensic reconstruction the success depends on the real positioning of the soft tissues. Nevertheless, pronasal is a point difficult to locate, with a variety of techniques that use hard tissue as base (Gerasimov; Krogman & Iscan, 1986; George, 1987; Prokopec & Ubelaker, 2002). The traditionally used techniques presented low precision levels when analyzed in the Chilean population (Lopez *et al*., 2010) and are based on the use of linear morphometrics, which uses one-dimensional values such as distances and proportions, presenting limitations that could explain the differences found between

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the different traditional location methods (Adams *et al.*, 2004; Toro *et al.*, 2010). Among new antropometric methods, one of the most advanced is geometric morphometrics, which is the study of the shape variation and how this covariates with other variables (Bookstein, 1991; O'Higgins & Jones, 1998; Slice, 2007). Geometric morphometrics shows several advantages, such as the mathematical and statistical study of form components, shape and size, separately or together with high detail. It also allows the graphical reconstruction and visualization of the shape under study and its changes, which is highly useful in morphological sciences (Slice; Toro *et al.*).

Considering the analytical advantages of geometric morphometrics, our aim is to evaluate the nasal profile of a group of Chilean inidviduals using this effective and recent tool to determine the presence of morphological patterns and anatomical elements generating a greater variability, analyzing their relevance in an aesthetic analysis and forensic reconstruction and identification.

MATERIAL AND METHOD

We used 156 digital cranium radiographs (74 men and 82 women) taken in strict lateral norm and with millimetric scale in patients between 18 and 40 years of age (age of nasal maturity, van der Heijden *et al.*, 2008). Radiographic images were selected from the Radiology database of the Universidad de Talca. Only radiographs of patients with normal occlusion and nasal morphology without signs of alterations were included.

Fourteen landmarks were selected according to previous works in the area (for review, Lopez *et al*.), according to the objectives of this work and following homology criteria of Bookstein. These are listed in Figure 1, and described in Table I. Location and digitization were performed with TPSdig software (Rohlf, 2010), to subsequently carry out with MorphoJ software (Klingenberg *et al*., 2011) the following analysis:

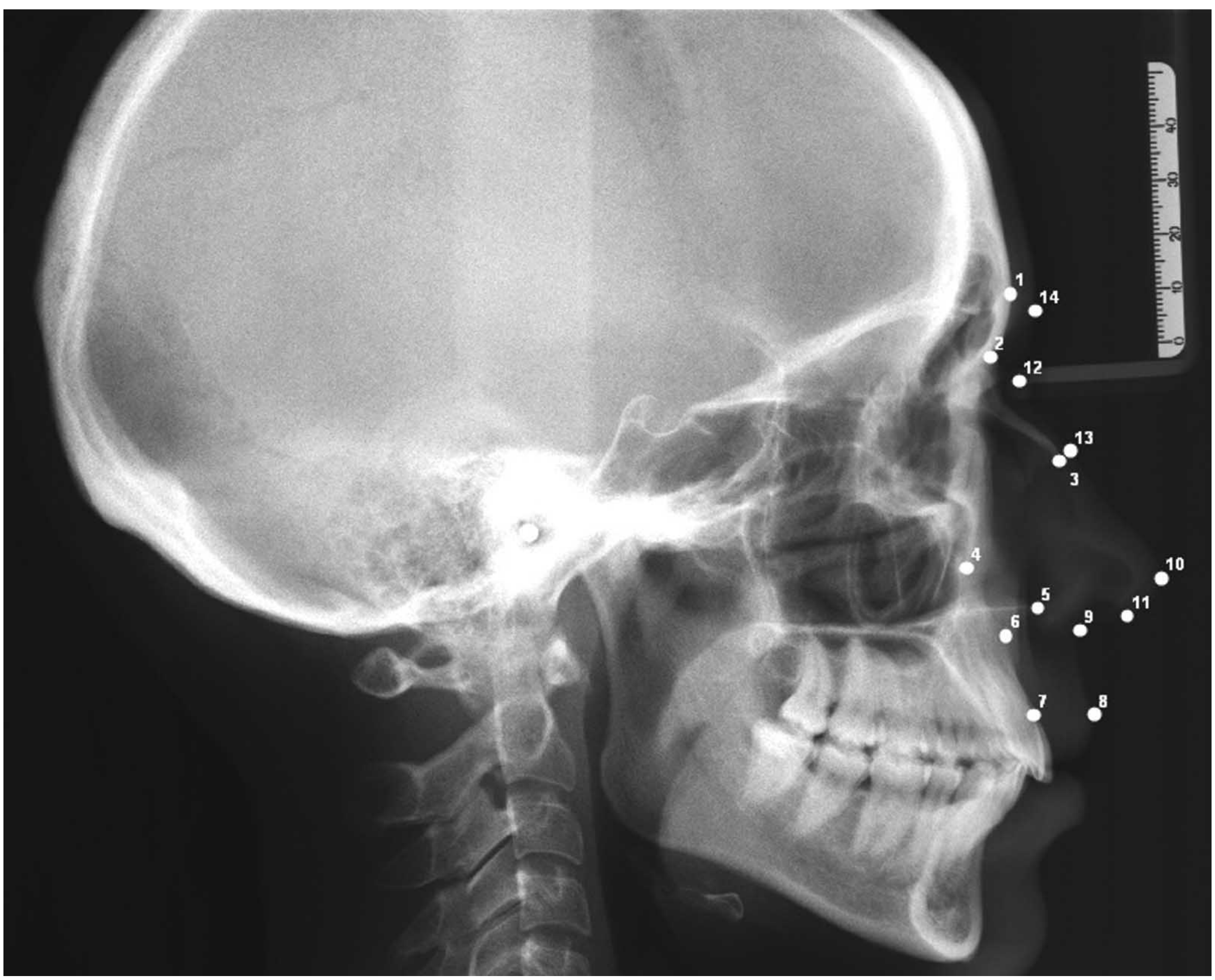


Fig. 1. Lateral radiograph indicating position of the landmarks selected for analysis. Description found in Table I.

Table I. List of landmarks selected according to Bookstein (1991) criteria.

1.	Glabella: Most prominent point in the midline of frontal bone.
2.	Nasion: Intersection of frontonasal and internasal sutures.
3.	Rhinion: Lowest and mid point of internasal suture.
4.	Alare: Most posterior point of the radiographic curve of the nasal notch.
5.	ANS: Anteror nasal spine.
6.	Point A: Most concave point of the curve between ANS and prosthion.
7.	Prosthion: Lowest and most anterior point of maxilla between incisors.
8.	Upper lip: Point noted on upper lip vermillion margin.
9.	Subnasal: Point in sagittal midplane where the base of the nose meets upper lip.
10.	Pronasal: Most anterior point of the nose.
11.	Columella: Point in the soft tissue profile perpendicular with the Subnasal-Pronasal line at its midpoint.
12.	Soft Nasion: Deepest point located in the concavity between forehead and soft tissue of the nose.
13.	Soft Rhinion: Point in soft tissue given by an angle of 90 degrees from Pronasal – Rhinion – Soft tissue point.
14.	Soft glabella: Most prominent point in the soft tissue of the forehead.

Procrustes fit: consists of translation, rotation and scaling of the 156 landmark configurations. As a result of this stage consensus configuration is obtained, the reference for quantification of shape changes; centroid size, shape-independent size measurement; Procrustes coordinates and Procrustes distances, descriptors of similarities and differences between individuals (Bookstein; O'Higgins & Jones; Slice).

Principal component analysis (PCA): Procrustes fit produces shape data that is mathematically not suitable to perform traditional statistical analyses, so projection methods are used to generate Euclidian morphometric spaces where analyses can be carried out (Adams, Rohlf & Slice; O'Higgins, 2000). PCA of projected data is here used to explore general shape variation.

Multivariate regression: to assess the effect of size in shape changes (allometry), Procrustes coordinates regression against centroid size as independent variable was performed, grouped by sex. To test the null hypothesis of independence of the variables, a non-parametric permutation test of 10.000 rounds was applied.

Discriminant analysis (DA): was used to assess morphological changes associated to sex. A 1,000 rounds permutation test for the null hypothesis of equal group means was performed (Klingenberg & Monteiro, 2005). The accuracy of DA results was assessed by leave-one-out cross validation test.

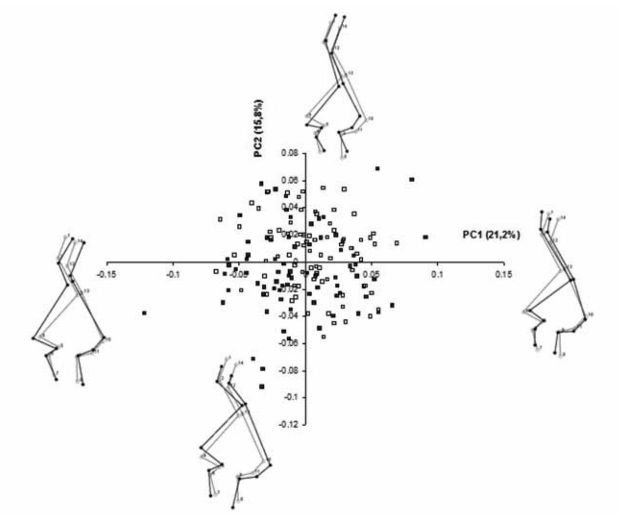
Measurement error: ten subjects (five men and five women) were digitised in three different days. Procrustes fit and analysis of variance (ANOVA) of shape components were performed to assess the effect of measurement error (Klingenberg *et al.*)

RESULTS

Procrustes ANOVA showed that the variance due to landmark digitisation is lower than the variance explained by the shape differences between individuals (individual sum of squares=0.139; error sum of squares=0.0164; $p<0.01$), which makes measurement error neglectible and discards it as a confounding factor.

The exploratory PCA of nose shape components shows that, in our sample there are no clear shape patterns, even when grouping the variables by sex (Fig. 2). The first three principal components (PCs) did not explain more than 48% of the variation observed, and there is not a clear distribution of individuals in the chart. Men and women data are rather superposed. Size appears to have an effect. The upper right square of the graph corresponds to nasal pyramids of lesser dimensions, and data in the upper left square, to those where the pronasal point is located in an ascending position with a straighter nasal dorsum. All of these changes occur with ENA as the fixed point.

The allometric effect of centroid size assessed with multivariate regression was significant ($p<0.01$, Fig. 3), showing thesame features as in PCA: smaller noses with a straighter dorsum, the apex in a higher position, and a relatively shorter upper lip. Profile size difference between



PCA plot showing PCs 1 and 2. Data does not organize in a clear way, revealing a lack of shape pattern explaining the observed variation (?= women; n=men). Shape changes associated to data organization can be observed at the end of each axis. The gray outline is the mean landmark configuration and the black outline corresponds to the associated shape change.

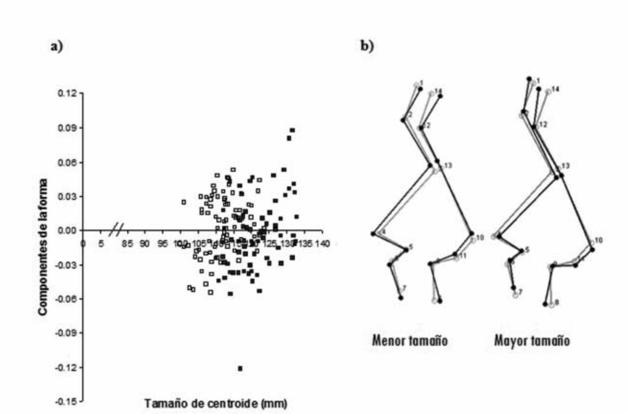


Fig. 3. a) Regression of shape components against centroid size, variables grouped by sex (?= women; n= men). b) Shape changes associated to different dimensions of the nasal pyramid. Gray outline corresponds to consensus or average shape and the black outline, to the allometric effect.nose. The grey outline is the mean landmark configuration and the black outline is the shape change associated to +40mm of change of centroid size.

sexes was significant (F=108.1; df=1,154; p<0.01), and DA of nose shape showed significant differences between women and men consensus (p<0.01). However, and in agreement with PCA results, cross-validation test showed that a not small proportion of men (17/74) presented a feminine nasal shape, and only 9/82 women show masculine nasal features. Women showed a straighter dorsum with a thinner layer of soft tissue, particularly at the level of the rhinion point, and a higher apex. Men nasion and nasal notch are located in a more posterior position, with a more acute inferior nasal curvature (Fig. 4)

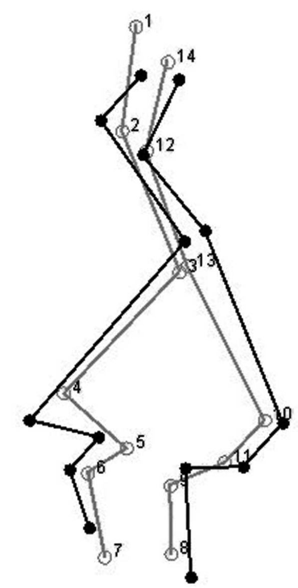


Fig. 4. Discriminant analysis of sexual dimorphism in the nasal pyramid. Gray outline corresponds to consensus shape in women and black outline to consensus shape in men.

DISCUSSION

The objective study of the nasal profile morphology is important in many areas of applied anatomy. The aim of this study is the shape analysis of nasal profile using geometric morphometric tools, given its many advantages, to describe morphological patterns in clinical use as in forensic anthropology, in a mixed adult sample of Chilean population.

Over the last years, studies using mostly linear morphometrics have been carried out to determine aesthetical and functional nasal patterns that orient therapies to correct deformities caused by development and trauma, and to predict development patterns for facial orthopaedics (Ramírez *et al.*, 2006). In forensic anthropology, facial reconstruction based on skeletal remains requires the development of sensible methods that consider modifications due to growth and development (Sforza *et al.*, 2010), which have not been totally found, as it can be seen for Chilean (López et al.) and European individuals (Macho, 1989).

In relation to the general variation of the nasal profile, PCA of shape components suggests that for a population as represented in our sample, to define clear morphological patterns would not be possible, explaining the first three PCs less than one half of the shape variation (Fig. 2). Another important factor in sexual dimorphism that could explain shape variation is the total size of profiles. In geometric morphometrics, size is represented by a shape-independent size estimator, the centroid size (CS). Although only noted marginally in the PCA result, the allometric effect can be observed clearly when shape components are regressed against CS. At the same time regression results indicated greater CS in men, according to that described in studies based on linear morphometrics (Troncoso *et al*., 2008; Porter & Olson, 2003; Milgrim *et al.*, 1996; Aung *et al*., 2000).

Therefore, can the relationship between the nasal profile shape and size or sex be defined? Our results suggest that variation of the profile shape is related more so with size and sex together as women present a lesser CS than men and vice versa. Starck & Epker (1996) recognized the importance of size in nasal sexual dimorphism through cephalometric analysis, nevertheless concluded that after compensating the differences in size, men and women have identical nasal profile, which did not occur in our study. DA confirmed the results with respect to the CS-sex-shape relationship noting that the differences between men and women are the same as those related to size. Morphologically the greatest differences between men and women are the localization of Pronasal point, orientation of nasal bones and thickness of soft tissue of nasal dorsum, concurring with Suazo *et al*. (2007) and Anderson *et al.* (2008). Women present a straighter profile with a more elevated tip, while men present a more convex profile and descendant Pronasal, differing with results obtained by Springer *et al.* (2009), and also have nasion and the nasal notch more posteriorly placed, with a more pronounced inferior nasal curvature (Fig.4).

Regarding soft tissue, women presented reduced thickness in nasal dorsum soft tissue, with relation to the rhinion point (Fig. 4). Upper female lip presents vertical contraction which concurs with results by Sforza *et al*. and Zankl *et al*. (2002), indicating that the philtrum is longer in men than in women at different growth stages demonstrated during the study of Italian and Central European populations respectively (Fig. 4). The discriminating analysis also indicated that the angle between points Alare-ANS-Pronasal is more acute in the female profile, and more obtuse in the average male profile. This difference is one of the most marked in the shape analysis and could have some aesthetic relevance in relation to sexual dimorphism at the time of evaluating the possibilities of nose reconstruction in forensics as in severe facial trauma, congenital defects as cleft palate or orthodontics corrections that involve nasal profile improvement, affording an opportunity for differentiation between men and women. Its potential use to complement Powel esthetic analysis or other nasal profile analysis technique, requires further study.

The important morphological variability in our sample could be explained by several factors that are not controlled, for example, ethnic diversity that gave origin to the Chilean population (Cruz-Coke, 1976; Rocco *et al*., 2002) and which effect in Chilean cranial anatomy is of noted importance (del Sol, 2006). Furthermore, late development proposed for soft nose beyond skeletal maturity, can also be an additional factor (Macho; Zankle et al.; Sforza *et al*.). Moreover, the not minor proportion of men with profile characteristics that could be considered feminine according to observations in the cross validation test, may also explain the lack of difference between men and women in the search of a morphological pattern in PCA, as a priori would be expected according to studies already quoted based on linear morphometrics, and the analyses of other structures typically considered dimorphic such as the osseous pelvis (Gonzalez *et al.*, 2009; Pretorius *et al*., 2006) and the cranium in its various structures (Rosas & Bastir, 2002; Pretorius *et al*.; Green & Curnoe, 2009), which have been studied using geometric morphometrics. Using analysis based on linear morphometrics some authors have found relevant the role of sexual dimorphism in the form and dimensions of the nose to obtain an aesthetically acceptable result (Porter & Olson; Troncoso *et al.*) From a clinical esthetic point of view we consider it important to evaluate the form of nasal pyramid individually, not only pursuing the harmony of sex, often requested by the patient. In our study variability of the profile form of subjects whose morphology is commonly classified as “normal”, is more often individual, rather than associated to sex.

In conclusion, the diversity in the nasal profile of a sample of Chilean population is the result of variables wherein size and sex, though important would not be the most relevant factors. Thus the difficulty in building useful patterns in related areas such as clinic and forensic anthropology. In the first case, this does not necessarily constitute a problem since individual evaluation is a widely used method. In the second case however, finding sensitive methods that allow an accurate reconstruction appears to be a difficult task, as has been observed in previous studies based on traditional morphometrics.

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RESUMEN: La descripción de patrones morfológicos del perfil nasal en la población que orienten la toma de decisiones y evaluación terapéutica, y que aseguren el éxito de técnicas como la reconstrucción facial forense, ha sido el objetivo de numerosos estudios basados en el uso de morfometría tradicional. El objetivo de este trabajo es el estudio del perfil nasal en una muestra de población chilena utilizando herramientas de la morfometría geométrica. Se utilizaron las radiografías de una muestra mixta de 156 individuos adultos y 14 hitos en perfil duro y blando. Se realizó el análisis de Procusto, seguido de análisis de componentesprincipales para el estudio exploratorio de la forma, regresión de los componentes de la forma contra el tamaño de centroide para el estudio del efecto alométrico en la forma del perfil nasal, análisis discriminante para la variable sexo y prueba de validación cruzada. Los resultados muestran que de las variables controladas, el tamaño y luego el sexo serían las que más explican la variabilidad observada, sin embargo el peso general de estas variables es bajo, sugiriendo la presencia de otras variables no controladas, y un gran componente de variación entre los individuos. Morfológicamente, se observa que los perfiles de mayor tamaño, de mayor frecuencia en hombres, presentan un punto nasal más descendido y un dorso nasal más curvo, así como un labio más expandido verticalmente. Desde el punto de vista estético, se sugiere dar importancia a la evaluación individual con fines terapéuticos. En antropología forense, se sugiere la prudencia en las conclusiones basadas en técnicas de reconstrucción debido a la falta de patrones morfológicos que orienten la técnica de manera certera.

PALABRAS CLAVE: Perfil nasal; Morfometría geométrica; Dimorfismo sexual.

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