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Forensic facial reconstruction: Nasal projection in Brazilian adults

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ABSTRACT

The nose has a marked cognitive influence on facial image; however, it loses its shape during cadaveric decomposition. The known methods of estimating nasal projection using Facial Reconstruction are lacking in practicality and reproducibility. We attempted to relate the points Rhinion, Pronasale and Prosthion by studying the angle formed by straight lines that connect them. Two examiners measured this angle with the help of analysis and image-processing software, Image J, directly from cephalometric radiographs. The sample consisted of 300 males, aged between 24 and 77 years, and 300 females, aged 24 to 69 years. The proposed angle ranged from 80° to 100° in both sexes and all ages. It was considered possible to use a 90° angle from projections of the Rhinion and Prosthion points in order to determine the Pronasale position, as well as to estimate the nasal projection of Brazilian adults.

1. Introduction

Forensic Facial Reconstruction can be defined as an auxiliary technique to human identification. It can aid the investigations of unknown bodies, as images, produced from a reconstruction of an unidentified skull, can be broadcast by the media and recognized by a family member [1].

However, it is important to consider that many of individual variations found in humans have no relation to bone size and shape but are relevant to the concept of identity of a face. Variations such as birthmarks, scars and facial expressions may not be predicted by the analysis of the skull, so the exact representation of the face is greater than the scope of forensic techniques and scientific data alone.

Nevertheless, the scientific approximation of facial characteristics depends on the knowledge of population traits and averages over soft tissue thickness, overlying known craniometric points, also eyes and lips position, among others. Using these guidelines, one can successfully produce images that resemble the relationships of the cutaneous portions in the living person.

Mean values of these tissue data are often used when reproducing a face, which can add a certain level of imprecision [2,3]. For the same points, the thickness presents important variations, depending on the technique used for measurements, which are demonstrated in most studies [1,4–14]. Also, the level of errors within the studies is statistically acceptable, but they add a level of imprecision that interferes with the success of the field [2,15].

The nose has remarkable cognitive importance in facial recognition [16], as it often connects an individual to their morphology. However, the soft tissue components that define the nose's shape and projection have no known bone portion correspondence [16–18], and little of its appearance remains after tissue decomposition [19]. Therefore, nose reconstruction has been a target of constant questioning, as it lacks scientific validation in study and application of facial-reconstruction techniques [17].

With aging, many changes occur to facial tissues and must be taken into account during Facial Reconstruction, as they are likely to change the facial expression. Nasal projection increases with age, in a downward and forward direction [13,20–24]. This growth in the nasal region occurs even after the age of 20 years, considered the age when an individual's bone growth is complete. Most of this growth occurs until early adulthood, but the exact age varies according to individual features and may continue even after, although with less intensity [20,24,25].

Sex-related differences appear only after childhood, when facial growth accentuates the prominence of the nose in boys. Soares and Andrade [16], Enlow [21] and also Inada et al. [26] concluded that

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there are no differences in nasal projection between boys and girls in early childhood, when both tend to have short, round and snub noses. However, Albert et al. [27] found little information about head and face bone changes after adulthood.

The current guidelines for nasal projection prediction from skull elements are often inaccurate, especially because they require complex tracing and execution of the nasal form. In the last century, only a few studies have tried to determine nasal projection for specific use in Forensic Facial Reconstruction. The most noteworthy were presented by: Gerasimov [28]; Krogman and Íscan [29]; George [30]; Williamson [31]; Lebedinskaya et al. [32]; and Prokopec and Ubelaker [33]. A critical study carried out by Stephan et al. [34] testing the four most commonly used methodologies in Forensic Facial Reconstruction suggests that new parameters need to be considered in order to relate nasal projection to recognized skull points.

Our study proposes a methodology that uses elements of the skull to determine the nasal projection point (Pn). The craniometrical landmarks used should be easily identified in a dry skull to allow for direct 3D modeling and digital work. From the results of pilot studies, the investigated hypothesis is that the vertices of a 90° angle between projections from Rhinion and Prosthion points could provide good approximation of the Pronasal point.

2. Material and methods

From a Brazilian, adult population, the sample consisted of 600 lateral radiographs of the head (cephalometric radiographs) where 300 males and 300 females were selected from the archives of digital databases, available at four Institutes for Dental Radiology, located in Sao Paulo, Brazil. Authorization for the use of these archives was granted and stored. No subject was exposed to radiation and the ethics committee of the University of São Paulo approved the research by the number: FR 289336 protocol 131/2009

The inclusion criteria comprehended the availability of the lateral radiograph of individuals who were at least 24 years old who had not undergone orthognathic surgery and who had no craniofacial deformities, classified according to their biological gender and age. Radiographic images whose quality impaired the visualization of the three points considered in this study (Rhinion, Prosthion and Pronasale, in soft tissue) were excluded from the sample.

Radiographs used were standardized for lateral cephalometric technique and were part of digital archives saved in the "TIFF" (Tagged Image File Format) format. The technical data provided reported distances between the source of the X-ray and the mid-sagittal plane of 152 cm; the head position was maintained by a cephalostat device; the exposure time was set to 1 s and the magnification rate provided by the device was approximately 10. As the reported magnification does not alter angular measurement, no correction was necessary for making reliable angular measurements.

Radiographs were assessed using the program Image J (31), version 1.43n/JAVA 1.6 0_10 (32 bit). Sample images were renamed and identified according to the serial number of the file, initial, age and sex of each individual.

Once in Image J, with the aid of the pencil tool, the following points were selected and marked as described (Fig. 1):

a) Rhinion (Rhi): limit of the lower nasal bone or the lowest point of the nasal bone on the mid-sagittal plane;
b) Pronasale (Pn): the most prominent point of the nose in the soft tissue. To determine this point on the teleradiographs, an E line as recommended by Ricketts (32) was traced, which crosses the Pogonion (Pg') point in the soft tissue and forms a tangent with the Pronasale (Pn) point, using the "Straight line selections". As the most anterior point of the nose convexity, it coincides with the method described by other authors [35] that refer its location to a perpendicular projection of the Frankfurt plan crossing the tip of the nose soft tissue. This is possible as lateral cephalographs used were made in standardized position.
c) Prosthion (Pr): the lowest point of the upper alveolar ridge, located between the upper central incisors on the mid-sagittal plane.

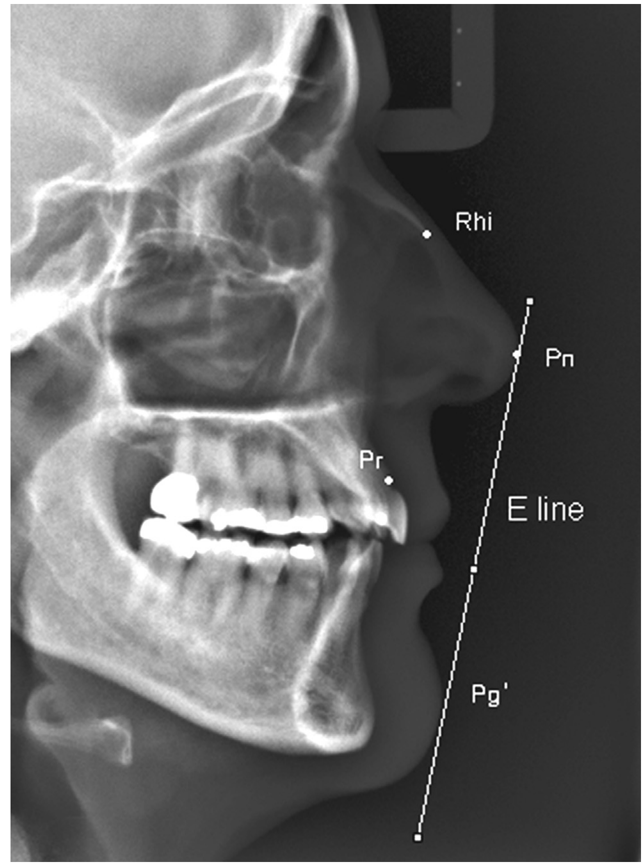

Fig. 1. Pr, Pn and Rhi points on the cephalometric radiograph.

The selection of this point was planned based on its easy location on the surface of a dry skull, which is ideal for practical application in forensic facial reconstruction.

Once the points were marked, the Angle tool was used to measure the angular relationship between the points Rhi.Pn.Pr. This real measure was stored as the Real Angle (RA).

From previous pilot studies of the first 20 images, results showed a mean value of 90° from the projection of Pronasale and Rhinion. The same mean value of the angle was observed after the collection of the RA of the entire sample. This supported the use of a Suggested Angle (SA) of 90° between the projections.

To establish a reproducible way for measuring the Real Pronasale point, the Rhi-line projection is a continuance of the angulation of the nasal bone, a clear reference in cephalometric images. The Pr projection is a linear trajectory from the alveolar ridge, starting at the Pr point and crossing the real Pn. Both projections were chosen as easily identifiable features in the bone surface of a dry skull (Fig. 2). The Suggested Pn position was estimated by fixing the angle of 90° between this lines, with the reference in the nasal bone projection. The perpendicular line is transported until it reaches the Pr point at the alveolar ridge.

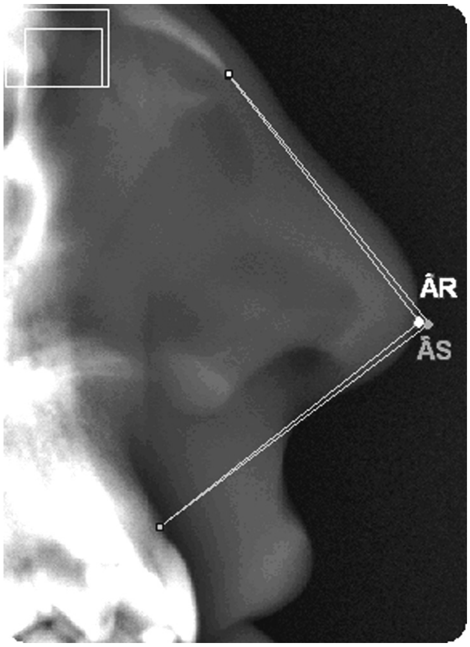

Fig. 2. Drawing of the Real angle (ÂR) for this individual, actual Pn in white and simulation of the positioning of the Pn point in gray for the suggested angle of 90° (ÂS).

The distance between the Real Pronasal (PnR) point and the vertices of the Suggested Angle was recorded in millimeters with the aid of the linear measuring tool after image scales were set, based on the 10 mm known distance present in the radiographs. This critical step eliminates the need for any compensation due to the magnification factor, as the scales are present during the acquisition process and go through the same enlargement as the rest of the image.

Two independent and sufficiently calibrated examiners measured the entire sample in order to assess the reproducibility of the method. The intra-examiner error was calculated by a second analysis, where all measurements were repeated on every radiographic image. After the first measurement, the image was closed and the points were deleted; the image was then reopened, and the whole process was repeated.

Descriptive statistics were based on the mean, maximum, minimum, median and standard deviation. The *t*-Student Test was used to compare the data between the female and male groups and the suggested angle of 90°. In order to obtain the error margin of the anthropometric measures, performed by the two examiners, the technical error of measurements (TEM) of the inter-evaluator measures was calculated for both sexes (REF).

In sum, the analysis of each radiograph considers four variables: age (age variable), Rhi–Pn–Pr angle (angular variable), the difference between the Real Pronasale point (PnR) and the Suggested Pronasale point (PnS) in millimeters (difference variable), and the equivalence of the difference between the actual (RA) and the suggested 90° angle (SA) - (equivalence variable).

3. Results

Two independent examiners measured the "angular variable." The "equivalence variable" and "difference variable" were obtained from the measurements of Examiner 1. The "equivalence variable" was calculated by using the Rule of Three to determine the measurement in mm of the equivalent difference to 1°.

The analysis of the angles measured, by both examiners, showed that the Pearson linear correlation between the measurements was 0.99 (r), very close to a perfect linear relationship ($r = 1.00$). The *t*-Student test showed that there is no significant difference in the means of the examiners' measurements (0.02120). The inter-evaluator relative TEM calculated for the male group (0.44%) and the female group (0.40%) was less than 1%, showing good inter-evaluator concordance.

Table 1 shows the descriptive summary of the four variables. The males had a mean age of 34 years and 10 months, ranging between 24 and 77 years, while females had a mean age of 36.5 years (ranging between 24 and 69 years.). For both sexes, the angles varied from 80° to 100° (mean 90°) with a sample composed of younger individuals.

For better understanding of the distribution of given measurements, male and female samples were grouped in age decade cohorts from 24 years onwards, as follows: level 1 (24–33.9); level 2 (34–43.9); level 3 (44–53.9) and level 4 (over 54 years).

For the female sample, the median values for the angles were: level 1 ($n = 147$) - 94.56°; level 2 ($n = 84$) - 92.42°; level 3 ($n = 45$) - 92°; and level 4 ($n = 24$) - 91.51° (Fig. 3). In Figs. 2 and 3, each box of the graph represents a level of age stratification. The central line of

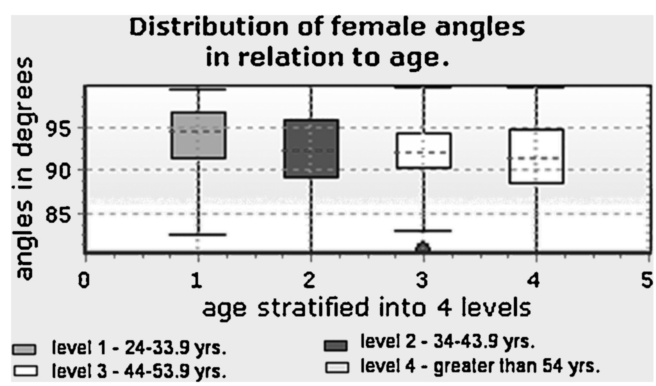

Fig. 3. Box graph showing the distribution of values found for the Rhi–Pn–Pr angle according to age in the female sample.

Table 1
Descriptive statistics.

Variable	Gender	Mean	Minimum	Median	Máximum	Std Deviation
Age	F	36 Y 5m	24 y	34 y 2m	69 y	10 y 3m
	M	34 y 10m	24 y	32 y 3m	77 y	9y 9m
Angle (degrees) Examiner 1	F	92.89	80.21	93.31	99.96	4.37
	M	90.87	80.29	90.74	99.85	4.48
Angle (degrees) Examiner 2	F	92.93	80.04	93.42	99.97	4.35
	M	90.91	80.25	90.95	99.98	4.40
Difference (mm)	F	0.98	- 3.60	1.25	3.58	1.52
	M	0.22	-4.23	0.00	3.99	1.76
Equivalence (mm)	F	0.31	0.00	0.34	0.86	0.14
	M	0.32	0.00	0.37	0.68	0.17

the boxes indicates the median value. The external points that appear in the third level of the female sample (between 44 and 53.9 years) are discrepant values; in this case, the discrepant angle was 80.48° of a 50-year-old individual.

In the male sample, the majority of individuals was concentrated in level 1 ($n = 171$), which had a median angle of 91.40°; level 2 ($n = 80$) had a median of 90.33°; in level 3 ($n = 33$) it was 88.81°; and for level 4 ($n = 16$), it was 89.69° (Fig. 4).

The Pearson linear correlation model was used to test the influence of age on the angle for each sex. A value of 0.0022 (r = - 0.17) was obtained for females, while for males, the Pearson value was 0.0028 (r = - 0.17).

The distribution of the angle was different between sexes. In Table 1, it is possible to note that the amplitude (maximum and minimum values) of the intervals is very similar between the sexes; however, the means and medians between these groups were not, due to the sample distribution. For males, it is closer to a symmetrical distribution centered at 90.88°, while in females there is a higher frequency of values greater than or equal to 90°, with a mean of 92.89°, showing that the distribution of the angle is influenced by sex.

To test the influence of sex on the suggested angle, the Student t-test was used with a 95% confidence interval. The value of p resulted in 0.0010, which means that the null hypothesis was rejected. The same test was used to assess whether the measured values approached 90° for each group separately. For females, with a confidence interval of 95%, p was 0.0004, and for males, p was 0.0008.

The "difference variable" (Real PnR - Suggested Pn) had distinct values between sexes. The average difference between Real Pronasale RPn and SPn, in millimeters, was close to 1 mm (0.98 mm) for females. It was a higher value than in males, who presented a more coincidental position of the suggested and real points (mean 0.22 mm – Table 1).

On the other hand, males had higher amplitude of variation. Table 1 also shows that the highest difference for males was 3.99 mm and the lowest was -4.23 mm; and for females the differences were 3.58 mm and -3.60 mm, respectively.

The "equivalence variable" was not measured; it was calculated from the values found for the difference in millimeters between the actual (RA) and suggested angle of 90° (SA). The values were similar for both sexes, as the minimum values were zero, and the median was 0.34 mm in the female sample and 0.37 mm in the male sample.

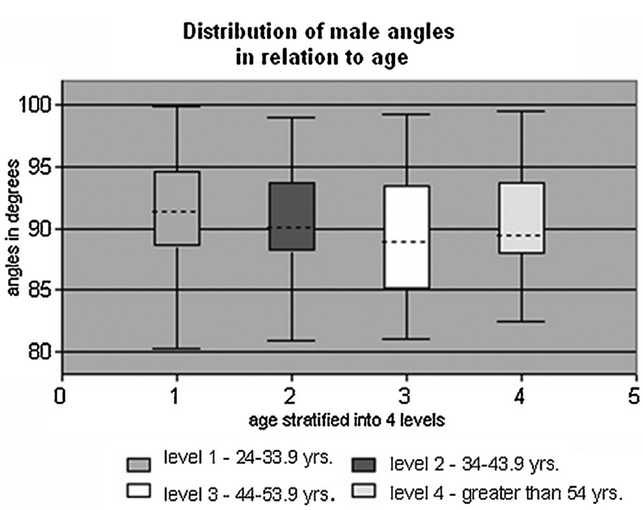

Fig. 4. Distribution of values for the Rhi–Pn–Pr angle according to age in the male sample.

Only the maximum values differed; these were 0.86 mm for females and 0.68 mm for males (Table 1). The greatest relative frequency had values close to the mean; these were 0.31 mm for the female sample and 0.32 mm for the male sample. This means that each degree of difference between the actual angle (RA) and the suggested angle of 90° (SA) measured on the cephalometric radiographs corresponds to approximately 0.31 mm in linear measurement.

4. Discussion

Nose tip and shape are constantly studied due to their importance and difficult to predict [36]. We highlight the importance of this study as there is no previous research that relates the described craniometric points, that were chosen to be easily identifiable in radiograph, digitalized models or onto a dry skull, which adds applicability to the method. In addition, the sample size of 600 individuals is important to return findings more representative of the population as expected from larger numbers of tested individuals [2]. It is also the first nasal soft-tissue length for use in forensic research among the Brazilian population.

The nose is one of the most subjective steps of facial reconstruction, and only bone references are available to predict shape [36] and individual features [19]. Obtaining a linear correlation result, close to perfect values, emphasizes the choice of trustworthy reference points supported by strong statistical data, a necessary outcome in the facial reconstruction research field [15]. Reproducibility of the linear correlation and TEM also contribute to the proposed prediction method. The standardization of measurement and reproducibility are one of the efforts of today's facial reconstruction [2,3,34].

This study considered the sample individuals differently. Divided according to sex, the results were within expectations, as the linear measurements of the projection were higher for males. The angle measured is inversely proportional to nasal projection, and as it was higher for women, a nose with smaller projection is expected for females. As for the males, a more prominent nose should be expected.

The age ranged from 24 to 77 years in the male sample and 69 years for females, considered as old by the World Health Organization (WHO). The Rhi–Pn–Pr real angle value remained between 80° and 100° in both sexes for all age groups, which shows that this average suggested angle has a frequency of distribution regardless of age (Figs. 3 and 4). The angle amplitude may seem relevant, but it returned a linear difference that should not impair the facial approximation of individual characteristics.

About 49% of the female sample and 57% of the male sample were in level 1 (between 24 and 33 years and 11 months). When level 2 is added to level 1, the percentages increase to 77.00% for females and 83.66% in males, encompassing individuals between 24 and 43 years and 11 months. Only the study of Bishara et al. [20] covered the same age group; however, they measured different parameters.

The age of the individual is likely to affect nasal projection, as this structure continuously grows, and it is expected that older people will have a greater nasal projection. However, the Rhi–Pn–Pr angle remained within the same range, suggesting that the changes that occur with age either do not affect the Rhinion and Prosthion points in their relationship with the Pronasale or that the changes occur in the same proportion and direction in these points conserving the relationship between them. As this sample had a majority of younger individuals, the effects of age should be better investigated in the future with more homogeneous sample sizes.

According to the literature [13,20–24], nasal projection increases in a downward and forward direction, and by examining

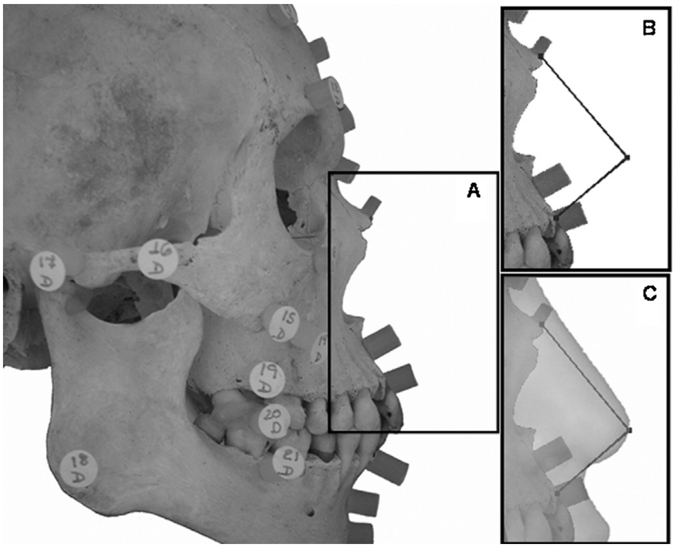

Fig. 5. Rhi−Pn−Pr = 90°,angle in the facial reconstruction.
(a) Craniometrical points, with known soft tissue thickness
(b) 90° angle between Prosthion and Rhinion
(c) 90° angle and craniometrical points superimposed.

only the median values represented in Figs. 3 and 4, one can observe a slight decrease in its value that can be interpreted as an increase in nasal projection with age. However, the Pearson linear correlation did not suggest a significant change related to age, indicating that for forensic approximation of the face, the technique described can be applied to all ages.

Nevertheless, the small variation found with age was considered to be relevant for the use of the Forensic Facial Reconstruction technique. When examining older adult's skulls, the estimation of age is hampered by the closure and fusion of the cranial sutures (25) loosing accuracy as age increases. The possibility of using a parameter to determine nasal projection by only distinguishing infant from adult skulls could certainly bring convenience to the reconstructive technique.

Nowadays, there is a strong trend among the scientific community to use computer graphics for studies on Facial Reconstruction with the aim of identification [4,14,29,31,37–43]. The results of these studies may not yet be considered perfect, but they have only become possible thanks to advances in imaging and 3d acquisition with the use of computerized tomography or magnetic resonance imaging [5,7,44–48], among others. The choice of computer tools for the measurement of the proposed angle has the additional aim of increasing the usage of this technique in computerized methodologies of Facial Reconstruction that are being developed. The adaptation of the reproduction of this 90° angle on both manual and computerized methods signals an advantage, as it can be easily applicable.

The nasal projection determination methods proposed by Gerasimov [28], Krogman and Íscan [29], George [30], or even Prokopec and Ubelaker [33] when implemented in bi-dimensional reconstructions using skull lateral radiographies or pictures may be difficult to perform directly over tridimensional skull shapes. It

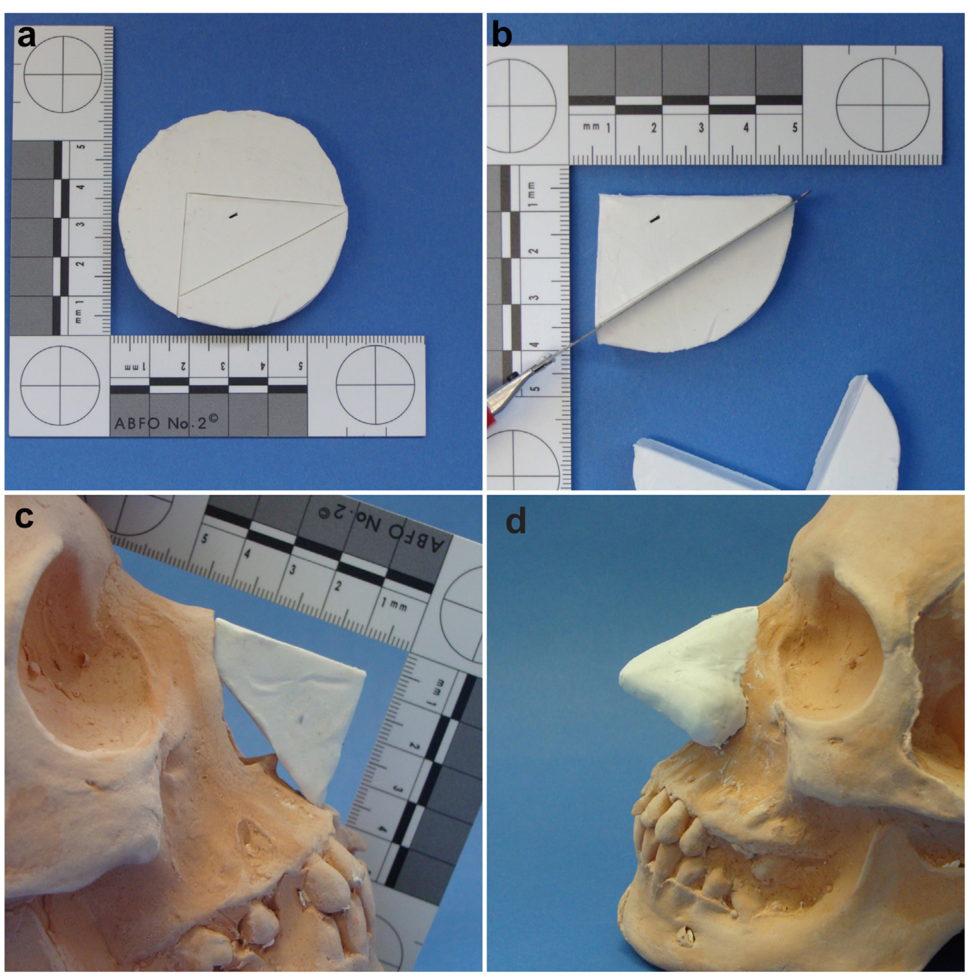

Fig. 6. Example of a Forensic Facial reconstruction practice using the 90° to predict the nose projection.

uses a number of lines so that, in a dry skull, the access for tracing and measuring is also hampered.

We selected the described craniometrical points, seeking a more practical and reproducible way of reconstructing nasal projection. Rhinion, the free end or edge of the nasal bone, is a point that is easy to locate and accessed, and it is generally well preserved. Prosthion, located in the maxilla, follows the patterns of facial bone growth, and even when there is post-mortem loss of the central incisors, its location is maintained.

After the soft tissue thickness is determined over the usual reference points, a pre-formed steel wire guide, clay or a plastic material block can be used to join the projections of Rhinion and Prosthion points in a perpendicular relation, defining the suggested Pronasal point (Fig. 5).

The results for the Rhi–Pn–Pr angle demonstrated the relationship between these points and the projection of nasal bone in soft tissue. In the same way that other soft tissue points are used in facial reconstruction, by using mean depth values, we suggest the use of an angle fixed at 90°, as it was obtained from the average of a sample that varied from 80° to 100°. The use of the 90° angle instead of the male (90.87°) or female (92.93°) mean value is a simplification for practical facial reconstruction purposes, as we believe that there is no difference in results and that they are suitable for daily practice (Fig. 6).

Besides the difference between the mean angles for females (92.89°) and for males (90.88°), the use of a 90° angle would make the reconstruction of nasal prominence just as practical. Considering that the mean values for the "difference variable" (RA–SA) use the proposed 90° angle, they would add no more than 0.98 mm for females and 0.22 mm in males to the estimated nasal projection. This inaccuracy is accepted as within the standards described in the literature (30,33,36,39) for what is called facial approximation.

Using the "equivalence variable" of 0.31 mm for each different degree from 90° gives a maximum error of 3.10 mm (considering the maximum variation of 10° at above or lower than 90°) for the real nasal projection values. These values are even lower than those found in other methods evaluated by Stephan et al. [34], who observed a mean error of 11.00 mm for the method proposed by Gerasimov [28] and an error of 5.00 mm for the best study performance in the methodology used by Prokopec and Ubelaker [33].

For computerized reconstructions, even with the current trend to combine data acquired in living individuals with the three-dimensional reconstruction of the skull to be identified, methods used by Berar et al. [45], Mang et al. [47] and Claes et al. [5] — the use of mean values for the proposed angle — can be useful and more easily reproduced using tools of the usual software.

We believe that for a thorough understanding of how the shape and projection of the nose in the soft tissue are related to the bone matrix of the skull, as well as how its external appearance is determined, new studies should be carried out.

5. Conclusions

Projection of the nose while working on dry skull and forensic reconstruction can be challenging, as few features offer references to the estimation of this soft tissue characteristic of the human face. The analysis of the sample allowed the establishment of an average 90° angle between projections of Prostion and Rhinion points that enable the suggestion of the nasal prominence within 3 mm maximum absolute distance from the real Pronasale point. Those points are easily identifiable on the surface of the skull and, despite a slight statistical difference between males and females, it can be applied to most forensic facial reconstruction with satisfactory results.

Conflict of interest and bioethical norms

This research was submitted to the Ethics Committee in Research of the Faculty of Dentistry, University of São Paulo under number FR 289336 and approved under protocol 131/2009.

There was no conflict of interest in developing this study.

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