Bonnie E. Hoffman,[1] M.A.M.S.; Deirdre A. McConathy,[2] M.A.; Mark Coward,[2] M.A.; and Lewis Saddler,[2] M.S.

Relationship Between the Piriform Aperture and Interalar Nasal Widths in Adult Males

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ABSTRACT: The piriform aperture of 182 skulls of black and white males in the United States was measured and compared with soft tissue readings taken previously. Statistical analysis indicated that nose width prediction formulas currently utilized in facial reconstruction required modification. Two revised formulas are proposed to improve accuracy of reconstructions: an addition prediction formula for ease of use and a multiplication prediction formula for more precise results on those skulls outside of the mean range.

KEYWORDS: physical anthropology, facial reconstruction, human identification, musculoskeletal system, nose width prediction formulas, skeletal data, soft tissue thickness data

For various reasons, historical, legal and anthropological, there may be a desire from time to time to create a sculptural similitude of a person as he was when alive from a skull when no other evidence is available.

S.L. ROGERS [*1*]

Facial reconstructions on skulls based on scientific data were begun by Welcker at the turn of the century. Since then, acceptance of facial reconstruction as a valid technique has been hindered due to the nature of the skull itself: soft tissue thickness depth (STTD) data provide a gross contour of the face, but specific details of soft tissue features (eyelids, lower nose, mouth, ears) are not indicated by any bony landmarks. The shaping of these features is left to the anatomical and anthropological knowledge, artistic judgment, and skill of the sculptor [*2,3*]. Some, such as Montague [*4*], felt that "accurate reconstructions are . . . highly improbable." Stewart [*5*] states that "getting a recognizable likeness must be largely accidental when there is nothing to go on but the skull." And Suk [*6*] was adamant that "skeletons . . . can offer us no clues at all for any reconstruction that is true to life." Yet recently, B. P. Gatliff, in collaboration with C. C. Snow [*2*], has gained respect in forensic circles using a reconstruction method based on the skull. Gatliff[3] has reconstructed over 135 victims' faces with an approximate 72% identification rate. Her success indicates that, while there is always a factor of uncertainty, size and proportion

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[1]Medical sculptor and anaplastologist, private practice, Fort Worth, TX.
[2]Clinical assistant professor, research associate, and associate professor and head, respectively, Department of Biomedical Visualization, University of Illinois at Chicago, Chicago, IL.
[3]Gatliff, B. P., personal communication, 1988.

of soft tissues can be determined with acceptable accuracy through the use of reconstruction techniques (eyes, lips) and prediction formulas (nose).

Although recognition of a particular person depends most significantly on the whole pattern of the face, individual facial features are also very important [*7,8*]. Of these features, the nose is the most dominant and distinguishing and decisively influences the observer's visual impression of the face [*9–12*]. Several nose width prediction formulas are currently in use. Despite the previous criticisms against reconstruction, Gatliff's and others' successes using these formulas suggest that there may be some relationship between the soft tissue or interalar width (IAW) of the nose and the lower piriform aperture width (PAW) of the skull. This study has investigated the correlation between the IAW and PAW (Fig. 1) in an attempt to verify current formulas and contribute to more accurate reconstruction methodology.

In order for nose prediction formulas to be verified, a knowledge of soft tissue thickness depths (STTD) upon which they are based is necessary. Welcker [*13*] was the first to record such data. He began with a sample of 13 white male cadavers measured at nine midline points. The works of His [*14*] and Kollman and Buchly [*15*] were combined to provide a sample of 45 males and 8 females with ten midline and eight lateral points, which has been used as the basis for contemporary work. While these three have been credited with scientifically establishing average soft tissue thickness depths at specific points on the face, none noted interalar width IAW.

Schultz [*16*] measured the greatest breadth of the alae in 31 adult males and females and in 5 children. He noted that the breadth of the nose is always greater than the breadth of the piriform aperture, with average difference between them in whites of 9.9 mm and in blacks of 14.9 mm. However, because he averaged groups together, he did not feel there was any significant correlation between the two breadths. In 1935, Suk [*6*] specifically looked at nose breadth in 16 adult males and females of various ages. He concluded that "the external nose has almost nothing to do the bony nose [and] that the external proportions are nearly independent of the dimensions of the skeleton."

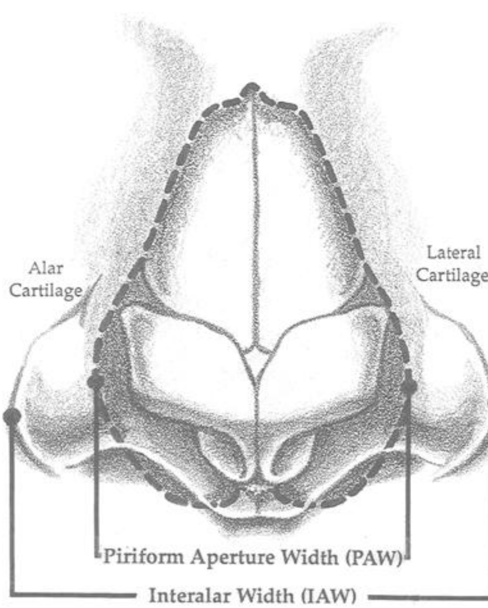

FIG. 1—*Relationship of piriform aperture and interalar widths. Note that PAW is approximately 3/5 of IAW. Black dots indicate placement of calipers when measurements are taken.*

Up to this point, data had been grouped by race and sex, but final conclusions still tended to look at data results in total and to deny correlations because they were lost when groups were added together. Rogers [*17*] points out that "noses in each race and ethnic group are basically different" and that it is "important to correlate a patient's ethnic origin with his contour anatomy."

Suzuki's work [*18*] was remarkable because he not only grouped 55 Japanese subjects by sex and nutritional state, but he did not average categories together. His soft tissue facial measurements totaled 23 and included alar points. Rhine and Campbell [*19*] analyzed data on 59 blacks in the United States by age and sex. Data for STTD of blacks, Europeans, and Japanese were compared and differences noted between racial groups and sexes. In an unpublished pilot study, Anderson[4] found a significant correlation between IAW and PAW in a sample of 18 black males in the United States between 20 and 40 years of age.

Many have felt that there is little or no correlation between soft tissue features and the underlying bone [*4,6,16,20*]. However, the data available to them had been averaged and validity was questionable for that reason. More recent works [*18,19,21*] have categorized data by age, race, sex, and nutritional status/body build and have refrained from averaging results. Using the data from these works, several of those involved in facial reconstruction have established or utilized the following prediction formulas for soft tissue nasal width with varying degrees of success:

1. piriform width + 16 mm in blacks; piriform width + 10 mm in whites,[5]
2. nostrils extend 2 to 3 mm beyond the lateral piriform edge (Angel, according to Ref *3*), and
3. the piriform aperture width, in whites, is 3/5 of the interalar width [*22*].

Each of these methods will be compared later to the data collected in this study.

Studies in other related disciplines offer alternative landmarks for determining the width of the nose. Plastic surgeons are concerned with the aesthetics of facial proportions. In analyzing the normal contemporary nose, Farkas and Monro [*23*] found the nasal width to be 3/5 the width of the distance between the irises or equal to the distance between inner canthal points. This relationship to the inner canthi is also supported by Krugman et al. [*12*].

Several studies in the field of prosthodontics indirectly give support to using dentition in determining interalar nasal width. Picard [*24*] proposed that dropping lines from the ala of the nose along the canine eminences would equal the dimension between the distal surfaces of the maxillary canines. Similarly, Wehner et al. [*25*] and Lee [*26*] found that the IAW seemed to be the same as the intercanine cuspid tip width (ICTW) when each was measured in a straight line.

In a comparison of measurements of 509 skulls, Kern [*27*] found piriform aperture width equal to or within 0.5 mm of the width of the four maxillary incisors in 470 (93%). Results were not reported by race or sex. Maxillary ICTW was again compared with IAW by Puri et al. [*28*], who determined that interalar distance was greater than intercanine distance by 1.08 mm in males, yet less in women by 0.62 mm. He averaged these data and arrived at a significant correlation. Smith [*29*] refuted Puri's work in his radiographic study of 80 subjects analyzing data by age and sex without averaging results and concluded the nose width was not a reliable guide for placing artificial teeth. He also compared ICTW to piriform width without obtaining a significant correlation. Mauroskoufis and Ritchie [*30*] compared the IAW with ICTW, the total width of the four maxillary incisors, and the straight distance width of the lateral maxillary incisors. While

[4]Anderson, M., Peabody Museum of Natural History, Yale University, New Haven, CT, personal communication, 1988.

[5]Photocopy of unpublished paper by W. M. Krogman provided by B. P. Gatliff.

there was no relationship with the incisors, there was a demonstrable one between IAW and ICTW. Hoffman et al. [*31*] also compared IAW and ICTW in 340 subjects, concluding that there was sufficient correlation to use IAW increased by 3% to approximate ICTW with artificial teeth. Although Smith's study [*29*] had negative results, consensus of the other studies indicates that "if the anterior portion of the maxillary arch shows no extractions and/or postmortem loss, then these observations can be used indirectly to determine the width of the nose" [*32*].

The methods of determining nose width offered by these various disciplines each have merit when the comparison structure is present. However, each also has drawbacks in forensic reconstruction. The plastic surgeon has the advantage of using the iris or inner canthus of a living individual. When a skull is reconstructed, the lid shape is determined by the sculptor, and basing nose width on the inner canthus may compound error. Using dentition to establish nose width also has drawbacks. Teeth are often missing. When they are present, the canine cuspid may be loose or the tip chipped off. Only if the canine is firmly seated in the maxilla can the eminence of the tooth substitute for the tip. Determining soft tissue width from the piriform aperture may also be hampered by bone damage. But when intact, it offers the preferred method for reconstruction.

Methods and Materials

One hundred ninety-seven male skulls were selected from the Terry Collection at the National Museum of Natural History, Smithsonian Institution, Washington, DC, based on three criteria: (1) the nasal breadth (taken at the widest point using sliding calipers) was documented on the anthropometric data sheet found in each specimen's file folder; (2) the anthropometric data sheet was signed by one of the two coders designated A or B (an effort to provide some consistency in measurement technique); and (3) the bone surrounding the piriform aperture was intact.

Information collected from the file folders included specimen number, race, age, nose breadth (IAW), and coder letter. When available, weight and height were also recorded. Anthropometric data collected from each skull included the piriform aperture width (PAW). Each specimen was placed on a cork donut for support while it was being measured. Measurements were made using a digital sliding caliper and recorded to the nearest 0.01 mm. Each measurement was taken on three separate occasions, and the calipers were zeroed before each reading for accuracy. For PAW, the calipers were placed directly against the lateral borders of the aperture at its widest point perpendicular to the nasal height [*1,33,34*]. The same examiner performed all skull measurements and recorded all data.

The Pearson product-moment correlation coefficient was used to determine the relationship between the IAW and the PAW and to test intercorrelations of all variables (race, age, weight, and height). The effect of errors of measurement on correlation coefficients was also calculated. Analysis of variance (ANOVA) was used to test several hypotheses within the data.

Results

To ensure that methodological error was not a problem for the three PAW readings taken on each skull, the measurements were analyzed for inter-item reliability before determining correlations within the data. The inter-item correlation mean for white subjects was 0.9986 with a range of 0.0008 and for blacks was 0.9988 with a range of 0.0005, indicating a very strong internal consistency of measurement for PAW. Since only one measurement was recorded for IAW of each subject by either Coder A or B, no reliability was calculated.

Descriptive statistics are found in Table 1. All 197 subjects were used in compiling this table, but those thought to be suspect due to bone damage were later discarded, leaving a total of 182: 73 whites and 109 blacks. Data were broken out by race, since anthropological studies have established that each group has specific skeletal characteristics. Differences were noted in all variables between blacks and whites. Weight and height individually did not correlate with the other variables. They were not analyzed further since premorbid body build was not typed in the original records and the current investigator did not feel qualified to make such judgments. It is interesting to note that the IAW mean reported by Kollman and Buckly [*15*] on 21 Caucasian males was 35.65 mm in comparison with 35.86 in this study, lending validity to the measurements by Coders A and B.

Analysis of variance (ANOVA) was used to test several questions/hypotheses. Is there a difference in the average of the three PAW measurements between blacks and whites? The PAW average was found to differ significantly ($p < 0.001$) by race, but since mean age was also different between blacks and whites, an ANOVA was run to see if the differences were attributable to age or race or to a combination of age and race. Results showed no interaction between race and age and no main effect for age, so it was concluded that race only was responsible for the differences in the PAW average. This lack of effect of age on PAW is supported by Robison et al. [*35*], who found that, with age, the nose profile enlarges while in the frontal view the nose width is unchanged.

Having established the reliability of measurements and eliminated age as the reason for the differences in PAW average, we checked the assumption of linearity for the variables PAW and IAW. An influence plot of data for each race supported linearity (Figs. 2 and 3), although the relationship is more evident for blacks. A regression line has been laid in to facilitate interpretation. The size of each symbol plotted corresponds to the amount the correlation for the two variables would change if that individual case were deleted and supports the decision mentioned earlier to eliminate questionable data (due to possible bone damage.)

Although the plots corroborated linearity, the Pearson product-moment correlation coefficient yielded results indicating that blacks have a significant correlation, while the correlation for whites is not significant (Table 2). Since measurements were found to be reliable, lack of statistical significance in whites was puzzling. Further analysis of white data provided no satisfactory explanation.

Keeping in mind that the correlation of IAW and PAW is linear in both groups but significant only in blacks, we calculated the mean difference (IAW minus PAW) with three extreme outliers excluded. The difference was found to be 16.85 for black subjects and 12.19 for whites. The population values of the difference were tested for corroboration of the prediction formulas mentioned earlier. First, they were tested against the most commonly used addition prediction formula (APF): PAW + 16 mm for blacks and PAW + 10 mm for whites[6] (Table 3). Results were found to be significantly different, with $p < 0.012$ for blacks and $p < 0.001$ for whites. This automatically indicated that the second formula of PAW + 4 to 6 mm, or 2 to 3 on each side (Angel, according to Ref *3*), was not corroborated and thus was not tested further.

In the last formula, PAW is ⅗ the width of IAW, which translates to the multiplication prediction formula (MFP) of IAW = PAW × 1.66 (Table 4). This was reported by Krogman [*22*] for estimating nasal width in whites only; however, it has been used by others for reconstructing non-white visages [*36*]. An ANOVA found the value of the ratio of IAW to PAW to differ by race [$F(1180) = 23.32$; $p < 0.001$]. Both black and white data were tested for a value of 1.66 and were found to be significantly different ($p < 0.001$ for whites, $p < 0.022$ for blacks). Sample IAW/PAW mean ratios were 1.511 ± 0.170 for whites and 1.630 ± 0.158 for blacks.

[6]See footnote 3.

TABLE 1—*Descriptive statistics: mean values of variables.*[a]

Race	*N*	IAW, mm	PAW, mm	Age, year	Weight, kg	Height, cm
Whites	83	35.86 ± 3.52	23.73 ± 1.63	58.75 ± 11.44	51.26 ± 13.04	170.58 ± 7.85
Blacks	114	43.45 ± 4.30	26.71 ± 2.32	45.28 ± 15.33	52.01 ± 11.99	173.20 ± 7.98
Total	197	40.25 ± 5.47	25.45 ± 2.53	50.95 ± 15.32	51.69 ± 12.42	172.09 ± 8.01

[a]Plus or minus (±) is standard deviation.

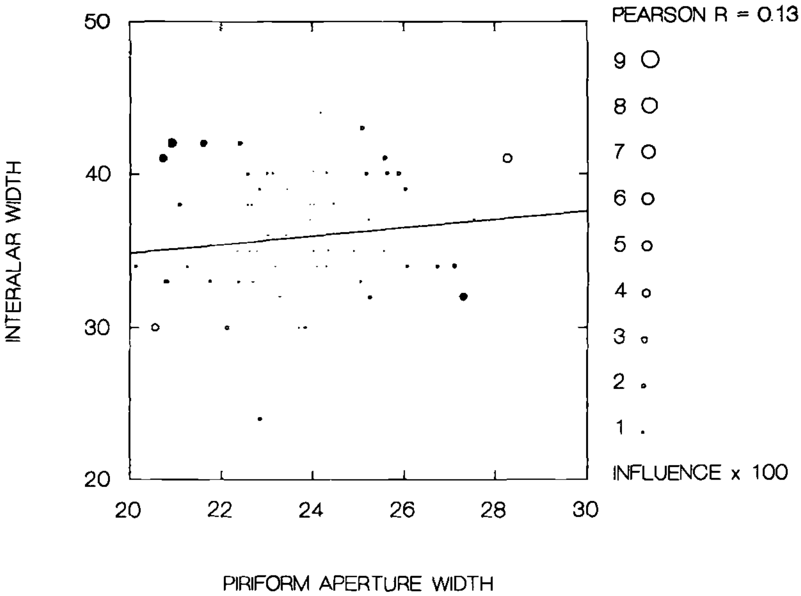

FIG. 2—*Influence plot, white subjects. The influence of a point is the amount the correlation would change if the case it represents were deleted. The scale to the right aids in judging the extent of influence. White and black circles represent positive and negative influences on the correlation, respectively. A regression line has been superimposed to facilitate interpretation of linearity.*

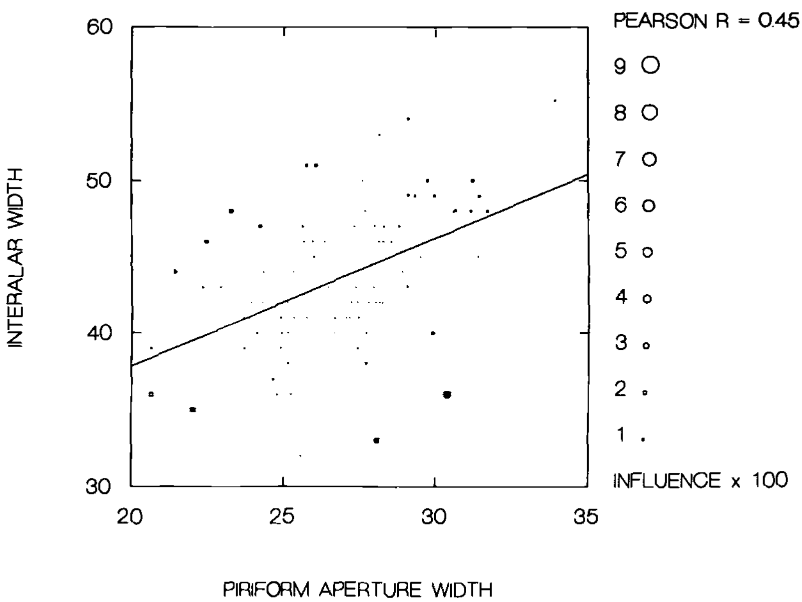

FIG. 3—*Influence plot, black subjects. Explanation of influence plots is found in Fig. 2. Note the difference in angle of the regression lines between blacks and whites.*

TABLE 2—*Correlation of IAW with PAW.*

Race	*N*	Pearson Correlation	*P*	Linearity Confirmed
Whites	73	0.110	0.354	yes
Blacks	109	0.476	0.001	yes

TABLE 3—*Addition prediction formulas (APFs).*

Race	Revised	Currently Accepted
Whites	PAW + 12.2 mm (or 6.1 mm each side)	PAW + 10 mm (or 5 mm each side)
Blacks	PAW + 16.8 mm (or 8.4 mm each side)	PAW + 16 mm (or 8 mm each side)

TABLE 4—*Multiplication prediction formulas (MPFs).*

Race	Revised	Currently Accepted
Whites	IAW = PAW × 1.51	IAW = PAW × 1.66
Blacks	IAW = PAW × 1.63	none[a]

[a]Since none has been reported, the same 1.66 is generally used with this method.

Discussion

Correlations of IAW for PAW are statistically significant for black males in the United States but not for white males. This was surprising, since the investigator who collected the data felt that she was able to measure white skulls more accurately because of the sharper delineation of bony borders in comparison with black skulls, on which lateral borders of the piriform aperture begin to roll out and gutter below the crista. Also, the STTD for mean IAW of whites reported by Kollman and Buchly [*15*] substantiated the measurements of Coders A and B (35.65 compared with 35.86). To explain this difference in significance, white data were tested for clustering of subgroups, with negative results.

Although the correlation of IAW and PAW in whites was linear, no satisfactory explanation was found for the lack of statistical significance. Therefore, the following results for whites must be looked at critically when choosing between popularly used nose width prediction formulas and those proposed here. Black data, however, were statistically significant in all instances, and results concerning these figures should be considered valid.

While the differences between these revised and accepted APFs are statistically significant, practically speaking, the amount per side in blacks is moot (8.0 versus 8.4). That amount of clay can be lost or gained during sculpting or finishing without noticeable change in the visage.

The revised MPF for whites must be accepted with reservations, as previously discussed. But it is noteworthy that it is the proposed multiple for blacks, not whites, which most closely corresponds to the white multiple of 1.66 reported by Krogman. Interestingly, the addition and multiplication prediction formulas correspond to each other quite closely when a subject falls in the mean range. This indicates that either formula could be used when doing a reconstruction, and since it is easier, one might opt for the addition formula. However, if the skull falls outside the mean, the multiplication prediction formula would be more precise as the resulting nasal width would be individualized to the specific skull.

Conclusions

One hundred eighty-two adult male subjects in the United States were measured and analyzed for the relationship of interalar width to piriform aperture width of the nose to verify nose width prediction formulas currently utilized in facial reconstruction. Results indicate that prediction formulas should be modified in the following ways to improve the accuracy of reconstructions:

	APF	MPF
Whites	IAW = PAW + 12.2 mm	IAW = PAW × 1.51
Blacks	IAW = PAW + 16.8 mm	IAW = PAW × 1.63

The addition method is easier to use, but the multiplication method is more accurate in cases where the PAW is outside the normal range.

Future studies should collect data from female subjects. Since differences have been noted between male and female data in other studies [*18,28,29*], prediction formulas for female reconstruction may also be expected to be different from those of males. If isolated ethnic populations are obtainable, an analysis of Caucasian subgroups might yield variations in the formulas and improve statistical significance of results.

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Address requests for reprints or additional information to
Bonnie Hoffman
4200 S. Hulen, Suite 400
Fort Worth, TX 76109