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TECHNICAL NOTE

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Predicting Mouth Width from Inter-Canine Width—A 75% Rule

ABSTRACT: It has been suggested that inter-canine width plus 57% of the cumulative distance between the lateral aspect of the canines and the pupil centers can be used to estimate mouth width (1). Evidence also suggests that the distance between the medial irises approximates actual mouth width fairly well (1). However, these soft tissue prediction guidelines are limited because they rely on accurate medio-lateral positioning of the pupils within the orbits, for which no systematic empirical evidence appears to exist at this stage. It would, therefore, be more appropriate to use only known hard tissue landmarks in mouth width prediction. This study reports the results of using inter-canine width as a percentage of mouth width for its prediction. This method seems favorable in comparison to the other guidelines because it is as accurate, uses known hard tissue landmarks, and does not rely on assumptions concerning pupil location. Estimating mouth width by using the canines alone, therefore, seems the best guideline to use in facial approximation techniques, at least given knowledge existing at this stage.

KEYWORDS: forensic science, facial reconstruction, facial reproduction, soft tissue prediction, hard tissue

Facial approximation is a technique used to build people's faces from their skulls to help establish identification of skeletal remains. Published soft tissue prediction guidelines are often used in the process to help guide practitioners in building the face (2,3); however, many of these guidelines are subjective and have not been systematically evaluated using empirical methods (1).

Traditional techniques used to predict mouth width from the skull include "rules" like mouth width is equal to: (a) pupil width (2,3); (b) medial iris width (4); and (c) width between the lateral aspects of the canines (2,3). Recently, these three soft tissue prediction guidelines have been systematically evaluated using empirical methods (1). That study also proposed an improved guideline that mouth width equals canine width plus 57% of the cumulative distance between the lateral aspect of the canines and the pupil centers on each side of the face (1). The mean error in prediction for this new guideline was found to be 0.1 mm, s.d. 3.4 mm, as compared to a mean error of: 11 mm, s.d. 4 mm for pupil width; 2 mm, s.d. 4 mm for medial iris width; and −13 mm, s.d. 3 mm for inter-canine width (1).

While it seems that the new guideline suggested by Stephan (1) improved upon traditional techniques, the guideline proposed is limited because it relies on pupil positioning that cannot be directly determined from the skull and must consequently be estimated with some unknown error. This limitation also applies to the other reasonably accurate guideline that uses distance between the medial iris borders to determine mouth width. Hence any error in eyeball positioning will result in inaccurate mouth width estimation when using these guidelines (1). Although there seems to be no problem if central positioning of the eyeball is highly accurate, this may not be the case. The central positioning guideline does not seem to have been based on any systematic empirical evidence, but rather on general impressions by Krogman (1962), which may be gross approximations of the truth rather than precise predictions.

Currently no consensus has been reached concerning the accuracy of central eyeball placement in the orbit since few systematic empirical studies have been conducted. Eisenfeld and colleagues (5) attempted to do so but power was low due to small sample sizes ($n = 9$), and hence results must be viewed with caution. Eisenfeld and colleagues (5) found large correlations between inter-pupillary distance and the distance between the centers of the orbits ($r = 0.93$); however, their data suggest a slight overrepresentation of interpupillary distance by central positioning of the pupils within the orbit. Some practitioners, apparently basing their conclusions on past experience, indicate that central positioning is accurate (6–8) or, contrary to Eisenfeld et al. (5), that it results in an underrepresentation of actual interpupillary distance (9). However, these claims should be regarded cautiously since they also appear to be personal impressions that have not been based on formal empirical measurements.

While the accuracy of pupil positioning is unknown, a better approach to predicting mouth width would be to rely on known bony landmarks alone. A simple mouth width prediction guideline that could be used would be calculating mouth width as a percentage of inter-canine width, as opposed to using a direct relationship, which has been shown to be highly inaccurate, i.e., on average results in a 13-mm underestimation (1). Correlations of ~0.50 between mouth width and inter-canine width are reported by Stephan (1), indicating that there may be some value in using the canines as a percentage of mouth width for a prediction guideline.

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It is also reported that inter-canine width is about 75% of actual mouth widths (1); however, error when using this relationship is unknown. This study aims to determine error rates in expressing mouth width as a percentage of inter-canine width in comparison to the more complex guideline (canine width plus 57% of the cumulative distance between the canines and pupils on each side) originally suggested by Stephan (1).

Materials and Methods

Data of Stephan (1) were used here. These data were originally collected using highly standardized photogrammetric methods as described in the original paper (1). Photographs of 93 participants in smiling and relaxed poses were measured for distance between the most lateral aspects of the canines and the width of the mouth (chelion to chelion). The smiling photographs were used for measuring the distance between the most lateral aspects of the canines, and the photographs of participants showing neutral expression were used for measuring mouth width.

Means and standard deviations were calculated for each variable as well as the mean ratio of inter-canine distance to mouth width. This ratio was used for estimating mouth width, and residuals were calculated along with their standard deviations and compared to the results obtained by Stephan (1) using inter-canine width plus 57% of the cumulative distance between the canines and the pupils. Data were compared using t-tests with statistical significance initially set at the 95% confidence interval but corrected using the Bonferroni adjustment, i.e., $p < 0.05/20 = 0.003$. This adjustment is a conservative one since it takes into account a number of different comparisons across the entire study.

Results and Discussion

The results are presented in Table 1. Overall, inter-canine width averaged 39.5 mm, and mouth width averaged 52.5 mm. Inter-canine width was therefore equivalent to 75.8% of mouth width (or mouth width was about 133% of canine width). Even though canine width (c-c) and mouth width (ch-ch) differed at statistically significant levels between the European sexes (two-tailed, two-sample t-test, $p < 0.001$) and between European and Central/South East Asian females (two-tailed, two-sample t-test, $p < 0.001$), c-c to ch-ch ratios for all samples were fairly consistent. When canine width was used as a percentage to estimate mouth width for the total sample (canine width/0.758), the average residual was −0.2 mm, s.d. 3.5 mm. Table 1 presents data across sub-samples when using the independent canine percentages and when the 0.758 rule is generally applied. It seems that the 75.8% inter-canine width rule worked least best for the "female Central/South East Asian" and the "other individual" groups, suggesting that their independent ratios (79.9 and 73.1%, respectively) may be of some value. However, none of the predicted mouth widths, determined using either the independent or the general percentage guidelines, differed from actual mouth widths at statistically significant levels (two-tailed paired t-tests, $p > 0.003$), indicating that the general guideline is sufficient. While the Bonferroni adjustment used here was rather conservative, we consider the importance of these differences between predicted and actual values to be minimal irrespective of the statistical significance obtained since actual differences in magnitude were small. Further research in this area appears useful since larger sub-samples may act to weaken or strengthen these differences.

These findings indicate that the general inter-canine width percentage guideline (0.758) predicts mouth width essentially as accurately as the other more complex guideline previously suggested by Stephan (1). Average error is barely more when using the inter-canine percentage guideline (−0.2 mm, s.d. 3.5) than when using the more complex rule (1) (0.1 mm, s.d. 3.4 mm). However, the canine width percentage guideline is advantaged because, unlike other guidelines, it does not rely on subjective estimation of pupil location in the orbits. It, therefore, seems more logical to use the distance between the most lateral points of the canines as a percentage since guideline error is similar to that previously obtained and anatomical landmarks used for prediction are known. Since the 95% confidence range of the population mean for the c-c to ch-ch ratio (calculated from the sample mean reported in this study) is from 74.7 to 76.9%, we suggest that it is valid to simply use 75% as the prediction rule, as opposed to 75.8%. This seems useful since 75% is an even number that is easy to remember and apply in practical situations. The adjustment of the ratio by 0.8% slightly increased the inaccuracy of mouth width prediction in the sample reported here, but not by more than 0.6 mm on average for any of the groups studied.

The limitation of using the canines alone, as is the case when using other guidelines, is that asymmetry in horizontal mouth position is not indicated. At this stage, it therefore seems best if the mouth is placed symmetrically over the teeth. As further soft-to-hard tissue relationships are determined, mouth width prediction and positioning accuracy may be increased.

Further studies are required to assess the accuracy of central eyeball placement in the orbit since this rule has not only been used to determine mouth width in some facial approximations but is practically used by almost all practitioners for its primary pur-

TABLE 1—*Means and standard deviations of measurements and calculations made from photographs.*

	Male Central/South East Asian (n=12)		Female Central/South East Asian (n=15)		Male European (n=17)		Female European (n=44)		Other Individuals (n=5)		All Groups (n=93)	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Mouth width (ch-ch)	54.2	5.6	51.2	3.5	55.0	3.2	51.4	3.3	52.5	4.4	52.5	4.0
Inter-canine width (c-c)	41.2	1.5	40.8	1.9	41.2	1.5	38.3	1.7	38.4	3.2	39.6	2.2
Ratio c-c to ch-ch	76.6	8.2	79.9	5.0	75.2	4.1	74.7	4.4	73.1	2.6	75.8	5.3
Mouth width estimation:												
c-c as a % of ch-ch (=c%)	53.7	1.9	51.0	2.4	54.9	2.0	51.3	2.3	52.4	4.4	52.3	2.9
Average residual of c% to ch-ch	−0.5	5.6	−0.2	3.1	−0.1	2.9	−0.1	2.9	0.0	1.7	−0.2	3.5
Mouth width estimation: c-c/0.758	54.3	1.9	53.8	2.5	54.4	1.9	50.5	2.2	50.6	4.2		
Average residual of c-c/0.758 to ch-ch	0.1	5.6	2.6	3.1	−0.6	2.9	−0.9	2.9	−1.9	1.7		

pose—positioning the eyes. The finding that traditional eyeball positioning in the antero-posterior plane is inaccurate (9), and even misreported (10,11), suggests that other eyeball positioning guidelines may also need to be reevaluated and reassessed.

As indicated by several authors many years ago (12–14), there is a clear need for much of the facial approximation technique to be systematically and empirically evaluated. It seems that a general lack of methodological rigor in the past has led to the use of many guidelines that have not been formally tested apart from soft tissue depths. Consequently, the claimed accuracy of many soft-tissue prediction guidelines remains to be demonstrated (as does the overall accuracy of the method). The lack of critical reviews and empirical tests of facial approximation methods may have even led to misleading quotes of facial approximation guidelines in the literature (10,11). To date, the results of empirical studies specifically testing facial approximation methods (1,9,15,16) have justified concerns that some subjective guidelines used are not very accurate or reliable and have provided support to critical arguments. However, some progress seems to be being made in testing and developing new guidelines for which error rates are known. Ideally this may lead to facial approximation techniques that are more accurate and reliable in the future.

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