

MOUTH WIDTH PREDICTION IN CRANIOFACIAL IDENTIFICATION: CADAVER TESTS OF FOUR RECENT METHODS, INCLUDING TWO TECHNIQUES FOR EDENTULOUS SKULLS

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ABSTRACT

An understanding of the structural relationships between the soft tissue anatomy of the face and the hard tissue anatomy of the skull is significant for craniofacial identification methods employed in forensic anthropology and forensic dentistry. Typically, mouth characteristics have been predicted from the teeth but this proves problematic in edentulous skulls. Some clue may, however, be provided by non-dental features. This study investigates the usefulness of the infraorbital and the mental foramen position for determining mouth width and additionally reports on accuracy tests using two other recently proposed methods that depend on the teeth: i) Krogman and İşcan's radiating mouth width prediction guideline; and ii) Stephan and Henneberg's 75% rule. Dissections of nine human cadavers indicate that the most accurate mouth width prediction method is the 75% rule (mean error of -2.4mm) followed by the distance between the infraorbital foramen (mean error of -3.3mm). Krogman and İşcan's radiating method, as interpreted by Wilkinson, underestimated mouth width by 7.3mm on average, while the distance between the mental foramen underestimated mouth width by 12.9mm. These results suggest that the infraorbital foramen can be used as a relatively good predictor of mouth width in edentulous skulls, however, the 75% rule should be given precedence if the dentition is present.

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INTRODUCTION

Knowledge of the relationships between the soft tissues of the face and the skull is important for craniofacial identification techniques and for medical surgery.^{1,2} In craniofacial identification, the positional relationships of superficial soft tissue structures of the oral region (e.g. the cheilions and the vermilion border height) have typically been assessed in relation to the dentition.³⁻⁷ In contrast, the cheilion points have been used to

predict certain hard/soft tissue features in medical surgery (such as skull foramina to estimate nerve positions).² This "reverse" approach to predict hard tissue features has relevance to craniofacial identification since the logical sequence of the relationship can be inverted (i.e. the mental foramina can be used to predict the cheilion points) and because non-dental landmarks hold potential for soft tissue prediction on edentulous skulls.

In a study of fifty cadavers Song *et al.*² found that the infraorbital foramen lay within the same vertical plane as the cheilions in 50% of cases, and that the distance between the infraorbital foramen overestimated actual mouth width by 0.6mm (mean = 54.9mm; SD = 3.4mm in contrast to the actual mouth width values of 54.3mm, SD = 5.5mm). The distances between the mental foramina were, however, significantly shorter than the inter-cheilion distances (mean width = 47.2 mm, SD = 3.4mm, in the former).²

In terms of the teeth, it has been unequivocally shown that the chord length between the lateral aspects of the canines produces inaccurate estimates of mouth width.^{8,9} To accommodate for this, Stephan and Henneberg¹⁰ proposed a 75% rule where the inter-canine distance is taken to represent three-quarters of the total mouth width. Alternatively, Wilkinson^{11,12} claims that a direct relationship between the canines and the cheilions exists, so long as the cheilions are placed along reference lines which radiate from the canines at angles perpendicular to the contour of the dental arcade. This suggestion is based on the original directions by Krogman³ who first proposed the guideline but did not state at what angles the radiating guidelines should be positioned from the skull. Although Wilkinson indicates that this "radiating guideline" is accurate and thus "very useful",^{11,p.329} it has not been subject to formal

empirical tests. Furthermore, Stephan and Henneberg's rule has not been tested on other samples beyond those on which it was originally formulated. This study, therefore, aims to examine the feasibility of using the infraorbital and mental foramina to predict the mouth width and tests Stephan and Henneberg's 75% rule along with Krogman and İşcan's "radiating" guideline (as couched by Wilkinson).

MATERIALS AND METHODS

Nine embalmed cadavers of European extraction (6 males, 3 females) ranging in age from 62 to 94 years (mean = 78 years, SD = 10 years) were examined in this study. All heads were sectioned from the body just below the mandible and prior to and during investigation they were stored in an upright position without pressure to the face. Essentially all cadavers had their mouths in the closed position so that the gap between the superior and the inferior labia was less than five millimetres - only one subject was an exception to this observation.

At dissection, almost all of the lower lip, except its lateral edges near the cheilion, and the soft tissue covering the chin was removed (Fig. 1). This enabled a clear view of the cheilion points and the maxillary teeth. Dissection windows were also cut superficially to the mental and infraorbital foramina to allow observation of these skeletal features (Fig. 2). Special care was taken during these manoeuvres so as not to move the mandible or compress the intact soft tissues of the lips.

When removing the lower lip, it was found that the true anatomical position of the cheilion, i.e., where superior and inferior labia meet at the lateral points of the labial commissure,¹³ was not evident from a frontal view because these points were obscured by overhang of the lips in the mouth shut position. The true junction of the labium superius and inferius was therefore located posteromedially to the "visible" cheilion point (as identified superficially in a frontal view). Since the "visible" cheilion is commonly used in facial approximation, we based all of our measurements to this point by following out from the anatomical cheilion, a tangent that bisected the curve of the dental arcade and which crossed the vermillion border of the upper lip (Fig. 1). This method enabled a precise determination of the cheilion within the soft tissue funnel at the lateral aspects of the mouth.

Upon dissection many of the specimens were found to have reabsorbed mandibles associated with tooth loss. Only three subjects were found to have intact dentition from which the position of the canine/premolar junction could be identified and the mental foramina could not be measured on one specimen due to obliteration of these landmarks in a prior study (partial removal of the mandible). Sample sizes, therefore, fluctuate in this study depending on which mouth width prediction method was being considered.

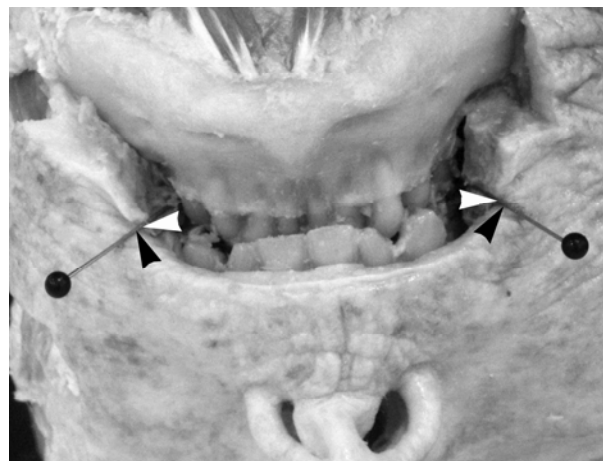


Fig.1: Inferior view of a cadaver specimen after removal of the center region of the lower lip leaving cheilion points intact. The white arrows point to the cheilion point as anatomically determined from the junction between the superior and inferior labia. The black arrows point to the "visible cheilion" points which are evident in a frontal view when the upper and lower lips are closed and obscure the anatomical cheilion points.

The following distances were measured to enable targeted comparisons: i) mouth width; ii) distance between the lateral extents of the canine teeth; iii) inter-infraorbital foramina distance; and iv) inter-mental foramina distance (Fig. 2). The predicted mouth width according to the "radiating guideline" was also measured after this distance was established by placing pins at the canine/1st premolar junction and at angles that bisected and radiated out from the dental arcade (Fig. 2), thus following directions of Wilkinson.^{11, p.329; 12, pp.116 & 117} Note here that the positions of the cheilion points and the foramina of the skull were also measured along a Cartesian grid with the zero point registered on the anterior nasal spine. All measurements were made using GPM[®] sliding calipers to the nearest half a millimetre.

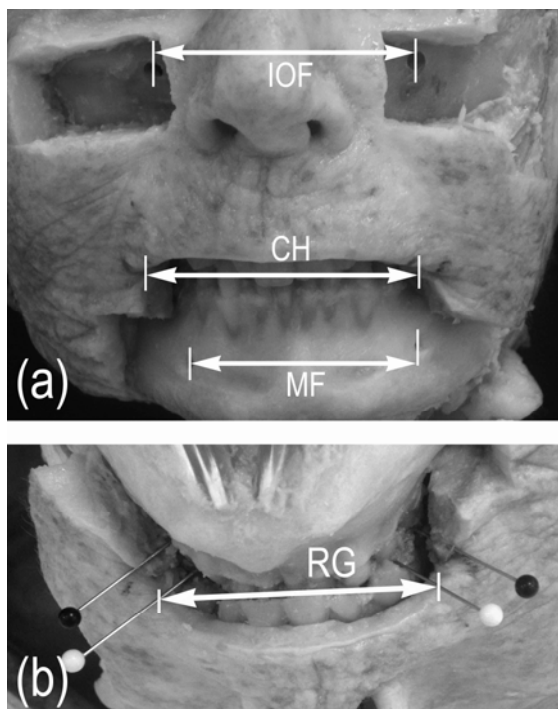


Fig.2: Linear distances recorded in this study. (a): IOF represents the distance between the center points of the infraorbital foramina; CH represents the distance between the “visible” cheilion points; MF represents the distance between the center points of the mental foramina. (b): RG represents the mouth width determined according to Krogman and İşcan’s⁴ and Wilkinson’s^{11,12} directions. The dark pins represent those used to determine the actual (non-predicted) cheilion position in the cadavers. Note here that positioning of the tangents was very carefully determined on the specimens. Impressions from the photographs that small deviations may have been made from Wilkinson’s recommended angulations are the result of photographic angle. “Straight-on” views proved to be insufficient for illustration purposes because other pertinent landmarks (such as the teeth in the dental arcade) were shielded from view by the mandibular border.

To insure internal repeatability of the measurements, a second set of measurements were taken six days following the first to determine intra-observer error. The intra-observer error was calculated by taking the sum of the squared differences between test and retest and dividing it by two times the number of remeasured individuals. The square root of the result (i.e., of the technical error of measurement¹⁴) was then divided by the mean of the test/retest result of the first individual to generate a coefficient of variation of the error.

RESULTS

Measurement errors for all variables assessed in this study were less than 3%. The mean mouth width for all nine cadavers was 55.1mm, SD 4.4mm. This value is in the same vicinity as that reported by other authors^{8,9,15,16} although it is towards the upper end of the spectrum. The mean width between the lateral aspects of the canines as measured in three individuals was 40.8mm, which falls well short of typical mouth widths noted in other studies.^{8,9} In this sample, the canine width represented 72% of the mouth width (see Table 1), approximating the 75% reported by Stephan and Henneberg.¹⁰ The error resulting from use of the 75% rule was -2.4mm for the three individuals for whom mouth width and canine width could be measured.

The “radiating guideline” produced mouth width estimates of 49.5mm, which underestimated the measured mouth width by 7.3mm in the three individuals where these values could be taken. If the radiating lines from the canine/first premolar junction were forced to cross at the true cheilion points to reduce the error, then their angulations would clearly need to be increased in contrast to the “perpendicular” angles recommended in the literature (see Fig. 2). The distance between the infraorbital foramina underestimated actual mouth widths by a mean value of 3.3mm, while the distance between the mental foramina underestimated the mouth width by 12.9mm (see Table 1). These values are slightly larger than those reported by Song and colleagues,² but follow the same general pattern with the mental foramina distance diverging most from the mouth width. The positions of the cheilion points, infraorbital foramina and mental foramina relative to the anterior nasal spine are illustrated in Figure 3.

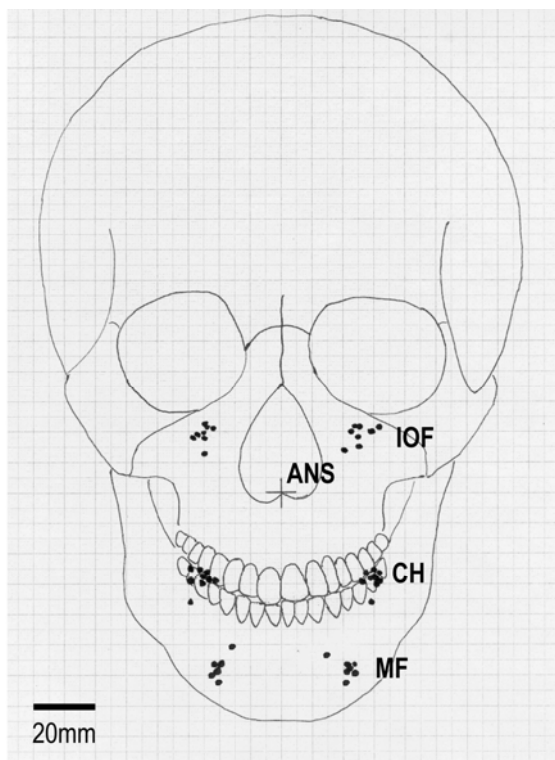


Fig.3: The position of the infraorbital and mental foramen recorded in this study in reference to the position of the anterior nasal spine.

In summary, this study found that Stephan and Henneberg's 75% prediction rule underestimated mouth width in this sample by 4%, the inter-infraorbital distance underestimated mouth width by 6%, Wilkinson's interpretation of Krogman and İşcan's radiating guideline underestimated mouth width by 13%, and the inter-mental foramina distance under-represented mouth width by 23%.

DISCUSSION

Since the findings of this study are based on a small sample the results cannot be generalized to the larger population, however, these data irrespectively provide useful indicators about the errors involved in mouth width prediction and therefore hold pertinence to craniofacial identification methods. First, they lend support towards Stephan and Henneberg's 75% prediction rule as being accurate and support its continued use when the dentition are present. Second, they suggest that mouth width can be accurately predicted using non-dental cranial landmarks (i.e., the infraorbital foramen). Third, they demonstrate that the radiating mouth width prediction guideline is probably not as Wilkinson propounds^{11, p. 329} "a very useful

facial reconstruction standard" - in all three individuals examined here, this guideline performed well outside the typical 5% level for error tolerance in scientific investigations.

It may be possible to further improve the prediction of mouth width using the distance between the infraorbital foramina by adding 3.3mm to the measured distance in anticipation of its underestimation. However, the value of such an adjustment is difficult to comprehensively assess in a small sample where reliable correlation coefficients cannot be generated. Further studies in larger samples are necessary to verify any benefits of such an approach. Adjusting Krogman and İşcan's guideline in a similar fashion does not seem to be of value, since it is already complex, subjective, and not easily applied. Its greatest limitations are that the cheilion points are not located on tangents which radiate from the dental arcade at angles that bisect its curvature and that this guideline depends on soft tissue depth values at cheilion which have never been empirically quantified (for a review of the measured facial soft tissue landmarks in over sixty studies see Stephan and Simpson¹⁷).

It is worth noting here that while the interpupillary distance has been found to over estimate the mouth width by 11mm,⁸ recent studies have found that traditional methods for eyeball placement in facial approximation underestimate interpupillary distance by c. 5mm.^{18,19} Therefore, the use of the interpupillary distance to estimate the mouth width in past facial approximation methods is likely to produce smaller errors (c. 5mm) than those reported for investigations of living persons, but the problem of erroneous eyeball positioning remains inherent to these facial approximation techniques. In addition, the underestimation of the interpupillary distance in traditional facial approximation methods exacerbates the underestimation of the mouth width if the medial limbus or edge of the iris is used for mouth width prediction. Thus, while in living subjects the distance between the medial edges of the iris approximates the mouth width rather well,⁸ the accuracy of the method is diminished when the eyeballs are inaccurately placed in facial approximation - the total error will approximate 7mm, with the 5mm error introduced by central globe positioning summing with the 2mm underestimation that results from use of the medial iris edges.^{see 8, 18, 19}

Further studies elucidating the exact nature of the anatomical relationships between the hard

and soft tissues in other regions of the face are needed to reduce the subjectivity of the facial approximation method. Recent findings of considerable inaccuracies in traditional face prediction/assessment methods sets a track record that supports continued efforts in this direction.^{8, 9, 18, 20-23} While computer analysis has been heralded as a silver bullet to circumvent many of the problems inherent to facial approximation methods (especially subjectivity),²⁴ blind use of abstract-mathematical procedures (such as warping of

surface meshes) risks the production of faces that are anatomically implausible in their detail. Thus, while computerized approaches are widely recognized to hold many advantages, care should be taken to ensure that the generated faces hold internal anatomical validity. This further justifies anatomical studies of craniofacial relationships in an attempt to improve craniofacial identification techniques.

Table 1: Mean mouth widths and descriptive statistics for variables measured in this study.

	Inter-canine distance	75% rule	Radiating Guideline	Inter-infraorbital foramina distance	Inter-mental foramina distance
Sample Size (n)	3	3	3	9	8
Mean	40.8	54.4	49.5	51.8	42.0
Standard deviation	0.8	1.0	0.9	3.6	1.7
Median	41.0	54.7	50.0	51.5	42.0
Min.	40.0	53.3	48.5	47.0	39.0
Max.	41.5	55.3	50.0	57.0	44.0
Mean Mouth Width	56.8	56.8	56.8	55.1	54.9

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