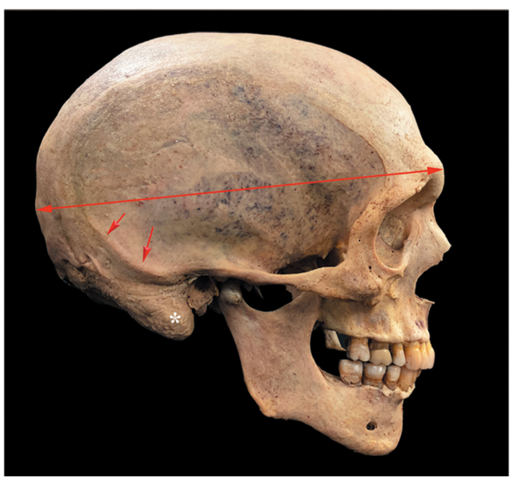


ANCESTRY AND SEX IN HUMAN CRANIA

A Comparative Photographic Atlas


Robert W. Mann, PhD, D-ABFA, F-CPP

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By

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CHARLES C THOMAS • PUBLISHER • LTD.
Springfield • Illinois • U.S.A.

Published and Distributed Throughout the World by

CHARLES C THOMAS • PUBLISHER, LTD.
2600 South First Street
Springfield, Illinois 62704

ISBN 978-0-398-09364-8 (hard)
ISBN 978-0-398-09365-5 (ebook)

Library of Congress Catalog Card Number: 2021005660 (print)
2021005661 (ebook)

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Printed in the United States of America
MM-S-2

Library of Congress Cataloging-in-Publication Data
Names: Mann, Robert W., 1949– author.
Title: Ancestry and sex in human crania : a comparative photographic atlas / by Robert W. Mann.
Description: Springfield, Illinois : Charles C Thomas, Publisher, Ltd., [2021] | Includes bibliographical references and index.
Identifiers: LCCN 2021005660 (print) | LCCN 2021005661 (ebook) | ISBN 9780398093648 (hardback) | ISBN 9780398093655 (ebook)
Subjects: LCSH: Skull–Anatomy–Atlases. | Skull–Examination. | Forensic anthropology–Atlases. | Forensic osteology–Atlases.
Classification: LCC QM105 .M36 2021 (print) | LCC QM105 (ebook) | DDC 611/.715–dc23
LC record available at https://lccn.loc.gov/2021005660
LC ebook record available at https://lccn.loc.gov/2021005661

INTRODUCTION

This atlas consists of 29 male and 21 female crania and is intended to serve as a reference source of documented-identity crania in the Mann-Labrash Osteology Collection at the John A. Burns School of Medicine (JABSOM) of the University of Hawaii, Manoa. This collection reflects the unique population diversity of contemporary Hawaii and was begun in 2014 as part of the JABSOM Department of Anatomy, Biochemistry, and Physiology under the direction of former Chair Dr. Scott Lozanoff. It is among the newest documented-identity human skeletal collection in the U.S. and has grown to more than 255 adult crania and 20 complete skeletons at the time of this writing. The primary purpose of the collection, as part of the Willed Body Program, is to train and instruct JABSOM medical students in gross anatomy. It also serves as a diverse reference collection of skeletal and dental disease, trauma, surgical intervention, bone healing, human skeletal variation, musculoskeletal anatomy, congenital malformations, DNA, and genetics.

The Mann-Labrash collection includes males and females of various ancestries and ethnicities including European (Caucasian, White), African American (African/American Black, Black, Ethiopian), Asian, Pacific Islander (e.g., Hawaiian, Micronesian, Samoan), and Hispanic. Donors range in age from 21 to 107 years old and are from Hawaii where they were either born, resided, or were visiting at the time of death. All donors died between 1974 and 2019. Most donors are accompanied by medical records that include cause of death and, occasionally, history of illnesses. As in most populations, the ancestry (race) of these individuals was assigned at birth and self-reported on their donor forms. The following table shows the population composition (1,420,491 people) of Hawaii as of July 2018:

TABLE 1.
Population of Hawaii as of July 2018 (United States Census Bureau, www.census.gov/facts/HI)

Ancestry	Percentage
White	25.6
Black or African American alone	2.2
Asia alone	37.6
Native Hawaiian or Other Pacific Islander	10.2

continued

TABLE 1—*Continued.*

Two or more races (mixed ancestry)	24.0
Hispanic or Latino	10.7
White alone (not Hispanic or Latino)	21.8

This atlas is intended for anyone who does not have access to a comparative reference collection of documented or known-identity crania in their laboratory. Researchers seeking to establish ancestry based on visual or metric analysis may also want to refer to or utilize databases such as Fordisc 3 (Jantz and Ousley 2005), OSTEOWARE (2018), the Macromorphoscopic Databank (Hefner 2018), and 3D-ID (Slice and Ross 2010).[1] Many other resources are available that utilize non-metric and macromorphoscopic (a term coined by Ousley and Hefner [Plemons and Hefner] 2016), cranial and postcranial traits to estimate ancestry. The author emphasizes that this atlas is not intended to present, replace, or cover the full spectrum of variation of cranial ancestry and sex features, a virtually impossible task. It is, however, intended to add to our knowledge of the complexity and range of cranial variation and to provide examples based on contemporary known-identity individuals (see Jantz and Meadows Jantz 2000, Jantz 2001, and Jantz and Jantz 2016 for information on secular trends in craniofacial morphology).

At times, a researcher must rely on multiple sources to find a sufficient number of examples of crania for comparison with unknown-identity crania. To aid in such analyses, this atlas provides large, color photographs for researchers to reference when estimating ancestry, sex, and, to a limited extent, age. As many readers are aware, the largest contemporary documented osteological collections in the United States include the Hamann-Todd Osteological Collection in Cleveland, Ohio, the Robert J. Terry Osteology Collection and George S. Huntington Anatomical Collection in Washington, DC, and the William M. Bass Donated Collection in Knoxville, Tennessee. These collections consist primarily of individuals of European and African ancestry and few Asians. The Atlas of Ancestry and Sex, therefore, increases our comparative reference samples and diversity to include individuals of Asian and Pacific Islander ancestry.

Most crania in this atlas are presented using six anatomical views: anterior, right lateral, left lateral, inferior (basilar), superior, and posterior (occipital) in the Frankfort horizontal plane. A superior view of each mandible is included to provide the reader with size and shape features of the teeth and bone. Additional photos are included to highlight other features such as dental morphology and anatomical variants. Many photographs are labeled to identify specific features, while others are not, leaving interpretation to the reader. Figure captions reflect the author's opinion but are intended to allow readers to interpret features for themselves and draw their own conclusions based on the photographs of each cranium.

1. For more information see the References and Recommended Resources sections of this book, specifically: Bass (2005); Brooks et al. (1990); Buikstra and Ubelaker (1994); Hauser and DeStefano (1989); Hefner (2003, 2009, 2015); Hefner and Linde (2018); Hefner et al. (2015); Hrdlicka (1928); Krogman (1939); Langley et al. (2016 and 2017); Moore-Jansen et al. (1994); Plemons and Hefner (2016); Stewart (1979).

This atlas contains full-page color photographs and as many as 24 standard landmark measurements[2] of some crania to aid readers in their assessment of ancestry and sex. The photographs are intended to provide readers with the most holistic and integrated perspective of each feature. In other words, each feature is viewed as part of the whole without requiring the reader to place them along a fixed continuum or sequence based on size or shape. Photographs also allow readers to examine each feature as an integrated piece of the "puzzle."

Cranial measurements were obtained using a Mitutoyo SC-6"C digital sliding caliper and a Paleo-Tech spreading caliper. All measurements are recorded in millimeters and rounded to the nearest millimeter. Fordisc (Versions 3.0 and 3.1) was used for the analysis. Nasal bone contour was obtained using a General contour gauge placed approximately 1cm from nasion. Photographs of the contour gauge afford readers an opportunity to compare nasal bone morphology with their own estimates of nasal bone contour and shape.[3]

Crania were selected not as exemplars, but as being representative of the complex diversity present in European (White, Caucasian), African American (African, American Black, Black, Ethiopian), Asian, Pacific Islander, and Hispanic adult crania. Each individual's ancestry is reported in the order it is reported on their Willed Body Donor forms: their primary, or first, ancestry such as Caucasian (i.e., "European" or "White" in this book), followed by all secondary ancestries (e.g., Portuguese, Spanish). Individuals of mixed ancestry, sometimes referred to as multiracial, mixed races, or racial admixture such as Chinese European are not hyphenated, in accordance with *The Chicago Manual of Style* (2010). See Hefner and Spradley (2018) for a discussion of ancestral diversity that goes beyond the traditional three-ancestry groups (Hooton 1930) and why some Hispanic crania may misclassify as Japanese (Dudzik and Jantz 2016), and recommendations and best practices as presented by the Scientific Working Group in Anthropology (SWGANTH 2013). A few crania exhibiting disease and trauma were included in this atlas to show how these conditions can alter cranial features and, as a result, confuse or obscure estimates of ancestry and sex.

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2. See Buikstra and Ubelaker (1994); Moore-Jansen et al. (1994).
3. For more on nasal bone structure with a contour gauge see Hefner (2003, 2009).

ACKNOWLEDGMENTS

First, and most importantly, I offer my sincerest thanks to our "silent teachers." This book would not be possible without the generosity and vision of our donors. They will be forever remembered for their kindness and their gift.

Special thanks to Steven Labrash for initiating the JABSOM osteology collection in 2004 and for serving as Director of the Willed Body Program. Thanks also to Stacy Lenze, Lee Labrash, Kiana Miller, Alex Wong, Wilson "Sully" Sullivan, Jesse Thompson, Michael Andrews-Newman, Jennifer Lai-Hipp, Jose ("Joey") Garcia III, Catherine Link, and Jessica Burden for their tireless efforts and contributions in helping to build and maintain this osteological collection. Chair of Anatomy, Dr. Takashi Matsui, former Chair Dr. Scott Lozanoff, and Dean Dr. Jerris Hedges were instrumental in resourcing and curating this collection for generations to come. Thanks to Beth Lozanoff for her talented medical illustrations. I thank Michele Tom and Mari Kuroyama-Ton for their years of dedicated service to the Department of Anatomy and Willed Body Program.

Thanks to Professor John R. DeFreytas, LtCol, USMC (ret.) for his in-depth editing, comments, and careful attention to detail during preparation of this book manuscript. Dr. Nicholas Passalacqua for suggesting the title of this atlas and Dr. Marin Pilloud and Dr. J DeMeo DMD for confirming the presence of palatoradicular grooves in one of the individuals. Dr. Michael W. Kenyhercz, one of the newest Diplomates (#141) of the American Board of Forensic Anthropology (ABFA) and, I am proud to say, one of my former Forensic Science Academy Fellows, for providing suggestions on relevant ancestry references. My thanks to Michael P. Thomas of Charles C. Thomas Publisher for his superb attention to detail and guidance. Thank you all for your contributions to this book.

All photos in this atlas were taken by the author. Most cranial measurements were performed by JABSOM osteology intern and research assistant Kiana Miller of Chaminade University of Honolulu and verified by the author.

My most profound thanks and love to Vara J. Mann, my wife, strength, and foundation.

CONTENTS

ANCESTRY AND SEX IN HUMAN CRANIA

I. CEPHALOMETRIC ANALYSIS OF THE DENTOALVEOLAR COMPLEX: A CLINICAL PERSPECTIVE ON ALVEOLAR PROGNATHISM

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The study of the proportions of the human skull can be traced back to early history with the ancient cultures of the Egyptians, Greeks, Chinese and Indians all developing complex systems (Moorrees 2006; Ghafari 2006). An accurate understanding of the ratios and relationships of the components of the skull and the face can enhance the realism of art, which was the impetus for this area of study. During the Renaissance, artists such as Leonardo da Vinci and Albrecht Dürer studied facial proportions to create systems that would allow for realistic representation of their subjects and these systems are the basis of many of our current methodologies. In particular, Dürer was able to utilize landmarks and facial features to create facial angles that differentiated between profile types or classes (Figure 1). Later work by Petrus Camper in the 1700s, elaborated on this concept and created a standard for craniology utilizing facial angles that led to the facial types of prognathic and orthognathic (Figure 2). These initial angular measurements have been fundamental to the categorization of craniofacial deformities and how they are treated in orthodontics and maxillofacial surgery (Duterloo and Planche 2011; Moorrees 2006; Ghafari 2006).

Orthodontic cephalometry was derived from long-established anthropologic craniometric studies and converted for use by the advent of the radiograph by B. Holly Broadbent and Herbert Hofrath in 1931 (Duterloo and Planche 2011; Moorrees 2006). This cephalometer revolutionized the diagnosis and treatment planning of orthodontic patients and allowed for longitudinal growth studies that are fundamental to the understanding of human cranial growth and development. Subsequently, this led to a multitude of studies to try and quantify

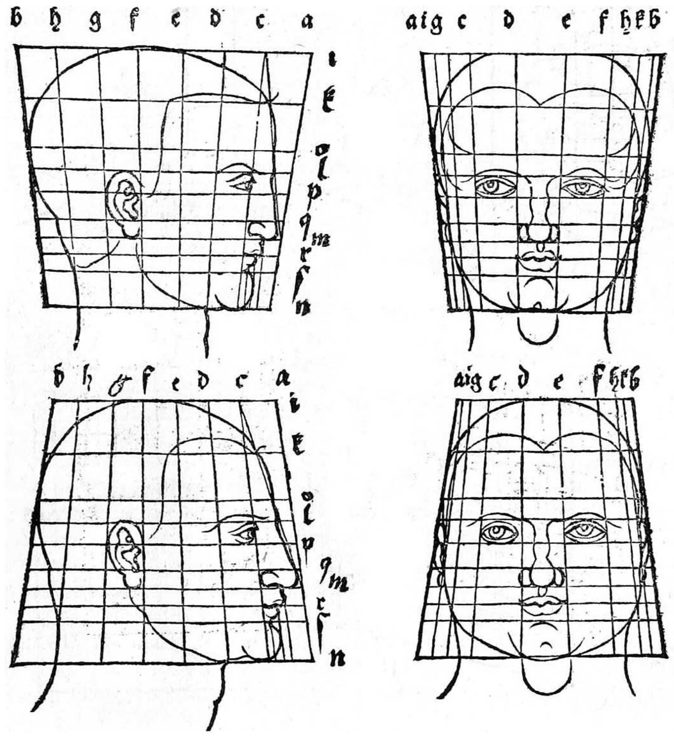

Figure 1. Albrecht Dürer's coordinate system constructed according to the location of landmarks and facial features. "Face Transformations" by Albrecht Dürer CC BY 4.0.

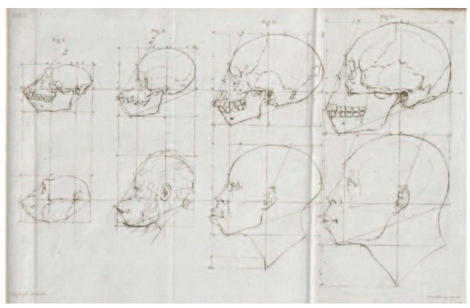

Figure 2. Petrus Camper's analysis of the facial form and facial angle in a tail monkey, a young orangutan, a native African, and a Kalmuk person. "Petrus Camper Facial Angles: Orangutan to Moor" by Adriaan Gilles CC BY 4.0.

normal values in populations to create a standard to treat patients and to differentiate between ethnic (ancestry) backgrounds. In addition, these studies were then combined with various analyses to describe the pathology of malocclusion including those by Steiner, Ricketts, McNamara, Wits, Tweed, and Downs (McNamara and Brudon 2001; Moorrees 2006). There are advantages and disadvantages to each of these analyses and this can be overwhelming and paralyzing to a novice. This is a testament to the fact that these analyses are trying to characterize a very complex, dynamic process into quantifiable, objective numbers. However, the end result is to compare the relationships of various components of the skull to each other to understand how a harmonious balance creates optimal function and esthetics.

The sagittal positioning of the jaws in relationship to the cranial base is fundamental to describing malocclusions and the subsequent effect on the esthetics of the face. In addition, the positioning of the teeth in dentoalveolar complex can have a distinct effect on masticatory function and facial esthetics. Therefore, when analyzing these positions, it is important to consider the position of the tooth in the jaw, the relationship of the jaw to the cranial base, and the relationship of the jaws to each other. The terminology used to describe these conditions is dependent on the analysis used and has changed over the course of time from early comparative zoology in the 18th century, to later orthodontic study, and finally to 19th century anthropologists in Europe (1).

The jaw position in relation to the cranial base can be described as too far forward or prognathic; too far backward or retrognathic; and in the correct position or orthognathic. This often relates to a facial type, such as the famous example of the Hapsburg family in Europe, which due to their familial trait of a large mandible (Figure 3), they were known to be prognathic or having a Class III malocclusion (5). However, this description is not illustrative enough because it does not give us an indication of which jaw is the etiology of the malocclusion or any indication of where the teeth are that support the lip profile. Nature tends to camouflage skeletal discrepancies with dental compensations so that teeth are in the best position for function. For example, a similar concept was seen by Begg in his study of Australian aboriginals and by Kaifu in his study of prehistoric Japanese populations where the teeth wore down due to diet and the anterior teeth compensated by retroclining to close any spacing (Kaifu 2000; Margvelashvili et al. 2013). Therefore, describing the jaws in relation to the cranial base as protrusive, retrusive, or normal gives a better indication of the problem and relates better to an etiology such as maxillary hypoplasia (small upper jaw) or mandibular prognathism (large lower jaw) or a combination of the two (McNamara and Brudon 2001; Nguyen and Profitt 2017; Proffit et al. 2012).

Figure 3. Portrait of Phillip II of Spain, a member of the Hapsburg house displaying their characteristic mandibular prognathia or Class III skeletal relationship. "Portrait of Phillip II, King of Spain" by Antonis Mor CC BY 4.0.

This concept can also be applied to the teeth but with an additional complexity of rotation. The teeth can be too far forward or protruded; too far backward or retruded; and in the correct position or normal. Continuing, they can also be too flared or proclined; too upright or retroclined; and in the correct position or normal. This is a simplistic description of a complex cranial anatomy as the teeth and jaws can also be described in the vertical and transverse dimension with three dimensional interactions that can be described by tip, roll, and yaw (Nguyen and Profitt 2017; Proffit et al. 2012). However, the sagittal dimension for both teeth and jaws is a classic starting point for descriptions of facial types regardless of the system of analysis.

The analysis of cephalometric points in anthropology can be done using photographs, radiographs, or computed tomography (CT) scans (Kaifu 2000; Utsuno et al. 2018; Margvelashvili et al. 2013; Luthur 1993; Pajevic et al. 2019). There are a multitude of different cranial landmarks that have been developed to augment different analyses of the cranium. Two traditional reference planes that can be utilized to represent cranial base are the Frankfort horizontal plane and the Sella-Nasion (S-N) line. Frankfort horizontal was developed by anthropologists utilizing dried skulls to represent the natural head position but suffers from inconsistencies in identification on a radiograph (Proffit et al. 2012; Ghafari 2006; Caufield 2006). The Frankfort horizontal plane is defined by a line through Porion (Po), the most superiorly positioned point on the external auditory meatus, and Orbitale (Or), the lowest point on the inferior rim of the orbit (Caufield 2006). On the other hand, the S-N line is only identifiable with a radiograph and is noted to have a high variability between individuals (Ghafari 2006). Sella (S) is defined as the geometric center of the pituitary fossa and Nasion (N) is located on the anterior most aspect of the frontonasial suture (Caufield 2006). Whenever possible, it is pertinent to utilize both lines and correlate them through an average measurement of about 7-9° between each other, which helps to ensure validity of derived measurements (Proffit et al. 2012; Ghafari 2006).

The next landmarks utilized give a representation of the position of the jaws; they are Point A, subspinale, and Point B, supermentale (Figures 4 and 5). Point A is defined as the posterior most point on the concavity between the anterior nasal spine (ANS) and the most inferior point on the alveolar bone above the maxillary incisor. Point B is defined as the most posterior point in the concavity of the mandible between the alveolar bone covering the mandibular incisor and pogonion (Pog), the most anterior point on the chin (Caufield 2006). From these points, the angles SNA, SNB, and ANB can be calculated. Alternatively, the Frankfort horizontal can be used to calculate corresponding angles (using the intersection of N-A and N-B, respectively) and the geometric relationship with S-N used to relate them. The ANB angle relates the jaws to each other, with a large value indicating a Class II relationship and a negative number indicating a Class III relationship. Continuing, a large value of SNA or SNB indicates protrusion or prognathia of the corresponding jaw, while a negative number indicates a retrusive or retrognathic jaw. Thus, utilizing all three of these angles can give an understanding of the relationship of both jaws to the cranium and the relative relationship to each other. True prognathism or bimaxillary protrusion, a forward or anterior jutting of the jaws, is when both the maxilla and mandible are prominent in relationship to the cranium. These relationships have a significant impact on facial esthetics and function however, with any of them the subject could still have a normal occlusion and harmonious facial esthetics. In addition, they should not be taken as absolutes because factors involved in the vertical growth of the face can affect the geometry and resulting angles (McNamara and Brudon 2001; Nguyen and Profitt 2017; Caufield 2006; Jacobson 2006).

Next, the positions of the teeth need to be evaluated in both relative position and angulation to the jaw. A line can be created from N-A and N-B, which act as references to the incisors for both jaws, respectably. The long axis of the tooth from incisal edge to root apex can be created and the relationship of this line to the N-A or N-B line indicates the relative proclination or retroclination of the tooth in degrees (Fig. 4 and 5). Continuing, a measurement from the long axis measured from the facial surface of the tooth to the respective N-A or N-B line is an indication of the relative protrusion or retrusion of the tooth in millimeters Caufield 2006). When both the maxillary and mandibular teeth procline and protrude, the resulting condition is described as bimaxillary dentoalveolar protrusion often mistakenly called bimaxillary protrusion. Bimaxillary protrusion is a term used by anthropologists to describe faces in which both jaws are prominent (protruded) in relation to the cranium (Proffit et al. 2012; Ghafari 2006). Another term often used by anthropologists is midfacial alveolar prognathism which, when described using cephalometric terminology, would be maxillary protusion (Fig. 4 and 5). This would result in a Class II skeletal relationship due to the maxilla being too far forward in comparison to the cranial base and mandible. However, the teeth

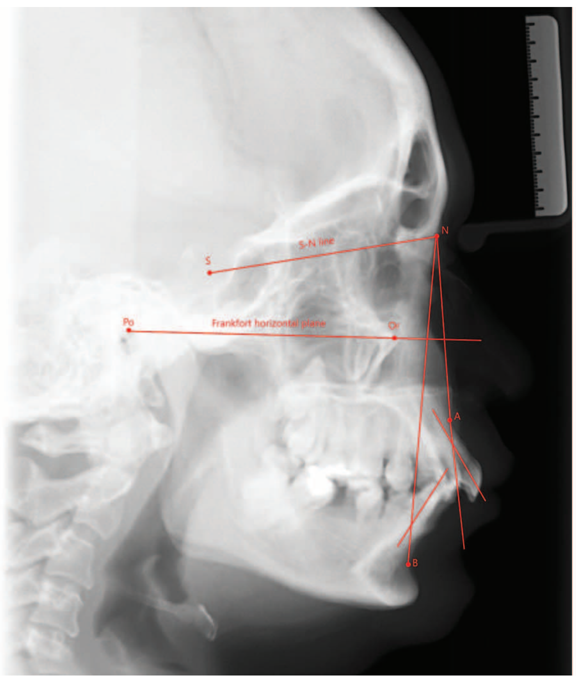

Figure 4. A lateral cephalogram of a Class II patient due to maxillary protrusion or midfacial alveolar prognathism. Frankfort horizontal, S-N line, A-point, B-Point have been traced to create angles and measurements used for analysis of the dentoalveolar complex. The upper and lower teeth are protruded and proclined. Private practice, Dr. J. DeMeo.

Figure 5. The skull of a Class II Pacific Islander male (JABSOM) due to maxillary protrusion or midfacial alveolar prognathism. Frankfort horizontal, A-point, B-Point have been traced to create angles and measurements used for analysis of the dentoalveolar complex. The upper and lower teeth are protruded and proclined. Mann-Labrash Osteological Collection, John A. Burns School of Medicine, University of Hawaii Manoa.

may be retroclined, proclined, or normal and can, therefore, lead to a variety of facial appearances despite the commonality of skeletal growth.

This measurement of the relationship between the jaws and the cranium can be powerful indications of function and esthetics. They also play a role in forensics in trying to establish an identification of an individual through ethnic, ancestral, or age-based comparative normal values (Albert et al. 2007; Machado et al. 2019; Cericato et al. 2016). In addition, they can be used for reconstruction or reproduction of the face to help identify a subject (Utsuno et al. 2018). Numerous groups have had normal values created including South African Bantus and Whites, African Americans, people of Northern European descent, Puerto Ricans, Koreans, Chinese, and Japanese (McNamara and Brudon 2001; Nguyen and Proffit 2017; Proffit et al. 2012; Hayashi et al. 2012; Ghafari 2006). It is important, though, to realize when applying this analysis to forensics that the differences between individuals is greater than the difference between populations. It is, thus, important when trying to assign an individual to a race or ancestry that the definition of race is not precise considering population overlap and genetic drift (Jorde and Wooding 2004). Consequently, understanding the characteristics of that individual or population is more important (Cericato et al. 2016). Therefore, it is imperative to utilize these analyses appropriately and with an aim of inclusion rather than exclusion when performing a forensic analysis using cephalometrics.