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Age estimation using mandibular dimensions: a preliminary study

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Abstract

Age estimation alongside determination of sex, height, and ancestry is of utmost importance for an accurate identification of the victim in forensic cases. On the other hand, reliable age estimation in living individuals is of significance in both judicial and ethical terms, especially with regard to the evaluation of criminal liability, and is becoming increasingly important as a result of rapid increase in immigration movements in the global scale. Most studies related to age estimation so far have investigated degenerations or developmental process of either tooth or skeletal system. Our aim in this preliminary study is to calculate regression equations to be used in age estimation using mandible size in children aged 18 or below and to evaluate its reliability. We evaluated 140 cephalometric images from patients with skeletal Class I closure. All images were obtained from the archive of Başkent University, Faculty of Dentistry, Department of Orthodontics. In every image, seven anthropometric measurements were performed: gonion-menton (Go-Me), gonion-gnathion, (Go-Gn) condylion-gonion (Co-Go), condylion-gnathion (Co-Gn), gonial angle, SNA, SNB, and ANB. The last three parameters were used to determine whether the skeletal development of maxilla and mandible were within normal limits, and not included in equations for age estimation. Statistical analysis results revealed that the distance from condylion to gnathion showed the highest level of correlation with age (71.3%) (*P*<0.001), and this parameter was the only parameter included in the model (R^2 = 0.508). As a conclusion, although it showed statistically significant correlation with chronological age, it can be said that the equation based on the aforementioned parameter is not sufficiently reliable for age estimation.

Introduction

Forensic anthropology can be described as the field of science mainly related to post-mortem identification of an individual using body or skeletal remains, and determination of the cause of death. Accurate identification of the victim in forensic cases is not only important for accurate documentation of the death certificate, but also for other judicial, ethical, and moral aspects (De Oliveira et al., 2015). The basic approach to identification is to determine a visual profile for the individual primarily by accurate estimation of the physical properties that are unique to the individual. In this regard, age estimation together with sex, height, and ancestry are of great importance, which are regarded as the four major features in forensic anthropology (De Angelis et al., 2015; Rai et al., 2008; Franklin et al., 2010). Reliability of age estimates in living individuals has always been of interest to forensic pathologists and forensic anthropologists. Considering that immigration movements around the world have increased considerably in recent years, the importance of age estimation in refugees who do not have a valid identity document cannot be denied with regard to assessment of their status and criminal liabilities in the face of laws of the corresponding country (De Angelis et al., 2015; Franklin et al., 2010). Bone age is an indicator of skeletal and biological development (Mughaletet al., 2014). It is of significance for pediatricians, especially pediatric endo-crinologists, as well as the dentists while planning and evaluating orthodontic treatment, and it does not always reflect the chronological age.

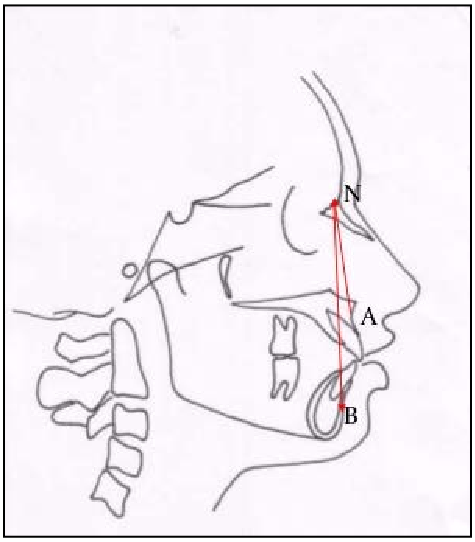
Studies related to age estimation have used many different methods that can yield quite reliable results (Schmeling et al., 2007; Franklin et al., 2010). Various approaches used in the context of age estimation include histomorphometric features such as morphological changes observed on the surface of symphysis pubis joint, degenerative changes at auricular face on the hip bone and at sternal edges of ribs, degree of closure at cranial sutures, osteon size, type and density, as well as biochemical approaches such as amino acid racemization at dentin and carbon-14 isotope level (Alkass et al., 2010; Harth et al., 2009; Dorandeu et al., 2008; Lovejoy et al., 1985, İşcan et al., 1984; İşcan et al., 1985, Miranker, 2016). In children and young adults who have not completed their developmental stage yet, morphological features of ossification centers, and closure processes at epiphyseal cartilage lines give quite reliable results. In this context, especially the wrist radiograms and clavicular medial epiphyseal closure process have been evaluated (Mansour et al., 2017, Franklin et al., 2010). Dental eruptions, the proportion of pulp chamber to the tooth size, or the degree of closure at apical parts of the dental roots observed in radiograms also have importance in terms of age estimation (Ge et al., 2015; Rivera et al., 2017).

The mandible shows more profound development compared to the other facial bones with regard to both morphological and dimensional terms, therefore it is regarded as an excellent bone to be used in age estimation of particularly individuals at the developmental stage of life (De Oliveira et al., 2015). Measurements of the mandible, especially the mandibular ramus height, mandibular angle and bigonial width, have been evaluated in the context of estimation of age and sex (Laversha et al., 2016). In particular, ramus height has been proposed to have a strong correlation with individual’s age (Franklin et al., 2007; Norris, 2002).

Our aim in this study is to evaluate the correlation between mandibular dimensions and chronological age in Anatolian population, and accordingly, to evaluate the reliability of regression equations of age estimation derived from mandibular parameters.

Participants and methodology

In this retrospective study, a total of 140 cephalometric images from 84 female and 56 male patients aged between 8-18 years obtained from the archives of Başkent University Faculty of Dentistry were evaluated. The images used in the study were obtained from individuals who applied to Department of Orthodontics for treatment but did not receive treatment yet. All cephalometric images included in the evaluation were taken from patients with skeletal Class I relationship, and normal skeletal development of maxilla and mandible in relation to each other was confirmed with ANB angle. Individuals with ANB angle greater than null but smaller than four degrees were categorized as having skeletal Class I relationship [0^o<ANB<4^o] (Figure I). Individuals with more than one missing teeth were not included in the evaluation.



A: anterior nasal spine

N: nasion

B: The deepest point of symphysis mandibular concavity

Figure 1. ANB angle

The images were evaluated using 10 cephalometric points: Sella (S), point A, Nasion (Na), point B, Articulare (Ar), Gonion (Go), Menton (Me), Condylion (Co), Gnathion (Gn), and Basion (Ba). Using these cephalometric points, four linear measurements as a gonion-menton, gonion-gnathion, condylion-gonion, condylion-gnathion, and two angular measurements as gonial angle (Ar-Go-Me) and ANB were performed. The ANB angle was only used for the evaluation of the closure type.

All measurements were performed by the same researcher using the Dolphin Imaging software (11.9 Premium), and the reliability of the measurements was assessed with binary measurements performed on 30 individuals.

Statistical analysis

Normality of distribution of anthropometric measurements was assessed with Kolmogorov-Smirnov Normality test, and appropriate descriptive statistics were expressed at 95% confidence level as mean ± standard deviation for normally distributed variables or as median (minimum-maximum) for non-normally distributed variables. Normality of distribution of anthropometric measurements in sex groups was assessed with Kolmogorov-Smirnov Normality test, and descriptive statistics were expressed at 95% confidence level as mean ± standard deviation for normally distributed variables or as median (minimum-maximum) for non-normally distributed variables. Normality of distribution of anthropometric measurements in age groups was assessed with Shapiro-Wilk's Normality test, and descriptive statistics were expressed at 95% confidence level as mean ± standard deviation for normally distributed variables or as median (minimum-maximum) for non-normally distributed variables. The difference in means of anthropometric measurements between sex groups was analyzed with Student's t-test for parametric variables, or with Mann-Whitney U test for non-parametric variables. Chronological age in years was accepted as a dependent variable, and pair wise relations between age and anthropometric measurements were examined with Pearson's correlation coefficient estimates. In order to estimate age in years using anthropometric measurements, linear regression analysis was performed by applying stepwise method in a selection of variables, and appropriate models were established for both general population and sex groups. The term "age" used in the article represents chronological age. During all hypothesis testing, the probability of Type I error was determined as α = 0.05. In order to calculate reliability of measurements, intra-class correlation coefficient 3 (ICC3) was calculated for all anthropometric measurements (Table 1).

Table 1. Reliability of the measurements

Anthropometric measurements	Intra-class correlation
Gonion-menton	0.977
Gonion-gnathion	0.978
Condylion-gonion	0.953
Condylion-gnathion	0.985
Mandibular angle	0.995
ANB	0.942

This study was approved by Başkent University Medical and Health Sciences Research Committee and Ethics Committee (Project no: K17/66).

Results

Descriptive statistics related to participants are given in Table 2.Although all linear measures were greater in males compared to females, no significant difference was observed between both sexes except for mandible length (Co-Gn).

Table 2. Descriptive statistics related to mandibular measurements

	Females (*n* = 84)	Males (*n* = 56)	*P*
Gonion-menton	64.69 ± 4.99	65.20 ± 5.50	0.571
Gonion-gnathion	71.79 ± 5.10	72.40 ± 5.80	0.511
Condylion-gonion	51.23 ± 5.23	52.58 ± 5.54	0.147
Condylion-gnathion	103.83 ± 6.89	106.56 ± 7.01	0.024*
Mandibular angle	125.65 ± 6.58	127.12 ± 6.90	0.204
ANB	2.14 ± 1.08	2.22 ± 1.23	0.673

* = P<0.05

The correlations between chronological age and each linear measurements of mandible and r angle were evaluated both for the whole study sample and for male and females separately (Table 3, 4, 5).

Table 3. Correlations between age and anthropometric measurements in the general population

Variable	r
Gonion-menton	0.560**
Gonion-gnathion	0.573**
Condylion-gonion	0.615**
Condylion-gnathion	0.713**
Gonial angle	-0.198*

r = correlation coefficient
* = *P*<0.05
** = *P*<0.01

Table 4. Correlations between age and anthropometric measurements in females

Variable	r
Gonion-menton	0.526**
Gonion-gnathion	0.536**
Condylion-gonion	0.598**
Condylion-gnathion	0.696**
Gonial angle	-0.180*

r = correlation coefficient
* = *P*<0.05
** = *P*<0.01

Table 5. Correlations between age and anthropometric measurements in males

Variable	*r*
Gonion - menton	0.617**
Gonion - gnathion	0.624**
Condylion-gonion	0.629**
Condylion-gnathion	0.715**
Gonial angle	-0.230*

r = correlation coefficient
* = *P*<0.05
** = *P*<0.01

All mandibular measurements showed statistically significant correlation with age at 95% confidence level, both when the population was evaluated as a whole and when male and female individuals were evaluated separately. Among all measurements, mandibular length (Co-Gn) showed the strongest association with age (71.3%). This was followed by mandibular ramus length (Co-Go) (61.5%). These results did not change when female and male populations were evaluated separately (Table 4 and 5). However, correlations between age and all mandibular measurements were found to be stronger in males compared to females.

A multiple regression model was created with the inclusion of five variables to obtain a significant and sufficient model, and selection of variables was performed with Stepwise method. The model was only based on mandibular length (Co-Gn). The regression equation created to estimate age using mandibular length is given below:

$$\text{Age (years)} = 12.556 + 0.239 * \text{mandibular length (Co – Gn)}$$
$$R^2 = 0.508$$
$$\text{SEE} = 1.6616$$

Discussion

In the context of the age estimation at the pre-adult period, morphological and dimensional properties of skeletal structures are often utilized. In this regard, the most commonly used method involves wrist radiograms (Schmeling et al., 2016; Franklin et al., 2010). The rationale for using wrist radiograms for age estimation is the ability to visualize multiple bones in a relatively small area, and changes observed in morphological features and dimensions of each of these bones, and their ossification processes. The atlas published by Gruelich and Pyle, which charts developmental processes in wrist radiograms according to sex are effectively utilized today (Franklin et al., 2010). Braga and Trail (2007) proposed that the size of ossification centers in facial skeleton can be used in age estimation during childhood, with an error margin less than 2.1 years. Franklin et al. (2008) noted that age estimation is possible with an error margin of 1.3-3.0 years by assessment of morphological and dimensional properties of the mandible.

The primary reason for using mandible for age estimation in morphometric studies in the field of forensic anthropology is that the mandible can be spared in many conditions where body integrity is compromised (Damer et al., 2016). Moreover, mandible shows a more rapid and profound growth in comparison to other facial bones during development, and the dimensional and morphological changes accumulating over the years accurately reflect the skeletal developmental state (De Oliveira et al., 2015; Rai et al., 2008). Mandibular development has been reported to progress rapidly until the age of 8, after which the rate of growth begins to decline, reaching 85% of the adult size by the age of 15-17 (Franklin et al., 2008). Franklin and Cardini (2008) studied African Americans and South African Bantu people and reported a standard measurement error of 2.3 – 2.4 years. However, exclusion of children aged older than 10 years from the sample resulted in a lower measurement error of 1.1 – 1.4 years. Mohitte et al. (2011) noted that mandibular ramus height increased until the age of 50, which was not very significant in the context of age estimation, and that this height remained more or less the same after the age of 50.

Many researchers have proposed a strong correlation between chronological age of the individual and morphological properties of the mandible, particularly the mandibular ramus height (Franklin et al., 2007; Norris, 2002). Dhaka et al. (2015) stated that variation in mandibular body length (Go-Gn) was the greatest while variation in mandibular ramus length (Co-Go) was the smallest in all age groups. In the present study, we observed a statistically significant correlation between mandibular ramus height and age ($r = 0.615$). However, the strongest correlation was found with the distance between condylion-gnathion ($r = 0.713$). In their study, De Oliveira et al. (2015) used cephalometric radiograms, and found highly strong correlation between age and mandibular ramus height ($r = 0.9$), and the authors noted that mandibular ramus height longer than 7 cm meant that the individual must be aged 18 years or older with a probability of 81.25%. Such an evaluation was beyond the scope of our study since it includes individuals aged between 8-18 years. Nonetheless, we observed that mean mandibular length at the age of 18 was 55.5 mm. Jangam et al. (2014) studied cephalograms of individuals with an age range of 10-25 years and evaluated mandibular ramus length (Co-Go), mandibular body length (Go-Gn) and mandibular length (Co-Gn) with regard to age estimation, and they noted that there was no significant difference between these parameters. Their regression equations had R^2 values ranging between 0.950 and 0.966. Similarly, in the present study, we did not observed significant difference between various linear measurements from mandible with regard to their correlations with age; however, the regression equations calculated in the present study ($R^2 = 0.313$-0.510) are less reliable compared to those reported by Jangam et al (2014). This may be explained by greater heterogeneity in the Anatolian population. In contradiction to the majority of the literature knowledge, Mohitte et al. (2011) reported that from among mandibular measurements, mandibular ramus length did not show correlation with age.

In the present study, the mandibular angle was found to be the anthropometric variable showing the lowest correlation with age ($r = -0.180$), and the observed correlation was in the negative direction. There are contradicting reports in the literature regarding the association between mandibular angle and age. The general view is that mandibular ramus height decreases while mandibular angle increases with age (Laversha et al., 2016). Mohitte (2001), Ohm (1999) and Dhaka (2015) support this view in their studies.

Studies suggest that there is no significant difference between both sexes regarding mandibular ramus length at childhood and early adolescent period (Rai et al., 2008; De Oliveira et al., 2015). However, after the age of 16, the difference between the sexes regarding mandibular ramus length becomes more prominent, with males having longer mandibular ramus than females (De Oliveira et al., 2015). Leversha et al. (2016) also reported longer mandibular ramus height in males, but their study included only adult individuals older than 18 years. In our study, which was conducted on individuals aged between 8 and 18 years old, we compared mandibular measurements between the two sexes without regard to age, and we did not find a significant difference between both sexes. However, it should also be noted that the strongest correlation with age was observed with mandibular length (Co–Gn).

In conclusion, we found statistically significant correlations between anthropometric measurements from mandible and the individual's age. Among all mandibular measurements, the strongest correlation with age was found with mandibular length (Co-Gn). In multivariate regression analysis performed for age estimation, only the mandibular length (Co-Gn) was included in the model. However, the calculated regression equation did not have sufficient power ($R^2 = 0.508$).

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