SEX ESTIMATION USING DIRECT GONIAL ANGLE MEASUREMENT IN 16-24 YEARS OLD INDONESIAN POPULATION

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ABSTRACT

INTRODUCTION: Sex determination has an important role in post-mortem (PM) profile reconstruction, which enables to reduce the possibility of identification. Gonial angle (GA) of mandible is a reliable sex parameter through skeletal examination. However, given frequent limited resources in forensic setting, direct GA measurement approach on deceased's body is more practicable.

OBJECTIVES: This study aims to evaluate GA discriminative ability in sex estimation by using direct measurement method in 16-24 years old Indonesian population.

MATERIAL AND METHODS: One hundred individuals (M = 43, F = 57) between 16-24 years old from Jepara District, Central Java, Indonesia, were selected for the measurement of both left (LGA) and right (RGA) gonial angle using a goniometer. Inter-and intra-observer reliability were 0.906 and 0.936, respectively, after one month using intra-class correlation coefficients (ICC). Measured LGA and RGA from males and females were compared using Mann-Whitney U-test, and Pearson's correlation between LGA and RGA were calculated. Binary logistic regression and ROC curve models were applied to analyze GA capability in sex discrimination.

RESULTS: There was no significant difference between LGA and RGA measurements, and a high correlation was detected ($r = 0.73$). Both LGA and RGA had significant value to predict sex. AUC value of LGA was 0.615 ($p = 0.048$; 95% CI: 0.51-0.73) and RGA was 0.637 ($p = 0.015$; 95% CI: 0.53-0.74).

CONCLUSIONS: The proposed direct examination method of GA to predict sex shows a low discriminating performance on both LGA and RGA variables.

KEY WORDS: sex determination analysis, mandible, gonial angle, forensic anthropology, forensic dentistry.

INTRODUCTION

Determination of individual sex is the foremost step of a post-mortem (PM) identification process [1]. It enables forensic experts to identify an individual using a sex-specific examination, and helps to reduce the search from a missing person [2]. The process of obtaining sex information on unidentified bodies utilizes multiple sexually dimorphic features in human anatomical structure.

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Mandible is known as the strongest bone in the cranial area, and has multiple sexually dimorphic parameters, such as corpus growth [3], ramus [4], and gonial angle (GA) [5]. However, these parameters are usually acquired from radiographic or skeletal examination [6]. In some cases, PM radiograph or dental autopsy is not feasible due to ethics [7], law [8], or limited resources (e.g., limited radiograph equipment, electrical sources, mortuary, or human resources) in mass disasters [9]. Hence, a direct non-invasive examination process is needed. The importance of sex identification also plays a role in determining an individual age, especially in juveniles age group between 16 to 24 years old, where there is a significant third molar growth difference between males and females [10]. By acquiring individual sex, dental age estimation can be done accurately.

Among different parameters in the mandible, GA is the only parameter, which can be measured through a different approach, which is a direct examination with goniometer [11]. Therefore, obtaining sex information through GA measurement could resolve the need for radiographic examination [4, 12].

OBJECTIVES

This study aimed to assess the GA discriminative ability for sex estimation using a direct measurement method.

MATERIAL AND METHODS

The sample comprised of 100 individuals from Jepara District, Central Java, Indonesia, including 43 males
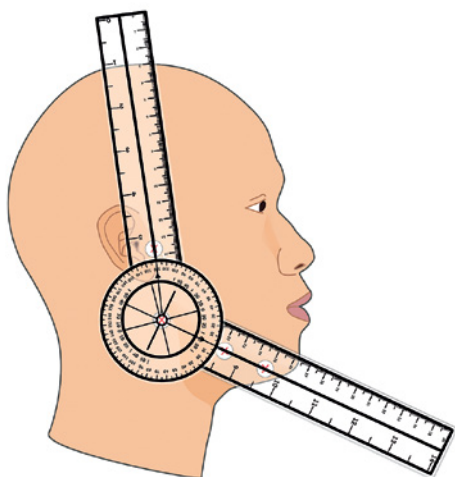

FIGURE 1. Illustration of the gonial angle measurement process. The placement of four reference points on the inferior mandibular corpus and posterior mandibular ramus (marked by white circle and red X), and the measurement of the gonial angle using a goniometer. Reference points were placed in supraglenoid, gonion, mid mandibular angle, and inferior border of the mandible below foramen mental

(20.19 ± 1.88 years old) and 57 females (19.56 ± 2.16 years old), with age ranged between 16-24 years old. Purposive sampling method was used based on inclusion and exclusion criteria. Selected individuals met the following inclusion criterion: seven permanent teeth present in mandible from the first incisor to second molar without history of tooth extraction; and exclusion criteria: medical history of skeletal development disorders, severe occlusal wear, or orthodontic treatment detected. All collected data were anonymized, and participants were required to sign informed consent. Participants aged below 18 years old were represented by their parents/guardians, and followed by approval from the participant. Ethical clearance was obtained from Universitas Diponegoro Health Research Ethics Committee, number: 225/EC/KEPK/FK-UNDIP/IX/2020.

GA was measured for both left (LGA) and right (RGA) gonial angle using a goniometer. Consistency in the measurement was standardized with four reference points, which were placed on the inferior mandibular corpus and posterior mandibular ramus (Figure 1). Reference points were placed in supraglenoid, gonion, mid mandibular angle, and inferior border of the mandible below foramen mental. One examiner performed all the measurements, followed by a second measurement by the first and second examiner to verify the inter- and intra-observer reliability after one month from 10% of randomly selected participants using intra-class correlation coefficient (ICC). All data were collated using Excel, version 360 (Microsoft, Redmond, USA), and statistical analysis was completed using R, version 4.0.3.

Measured LGA and RGA from males and females were compared using Mann-Whitney U-test, and Pearson's correlation between LGA and RGA was calculated. From each significant ($p < 0.05$) measurement parameter, binary logistic regression models were made. Area under curve (AUC) with 95% confidence interval (CI) of receiver operating characteristic (ROC) curves and Brier score were calculated to understand how well the binary logistic regression model distinguishes between the two sexes. Both AUC and Brier score value of 1 represented a perfect accuracy, and 0 showed complete inaccuracy.

RESULTS

The mean ICC values showed reproducibility of the measurement method, with 0.906 and 0.936, respectively for inter- and intra-rater agreements. Overall, the measurement of LGA and RGA in both sexes showed that male was higher than female. Furthermore, there was no significant difference between LGA and RGA measurements ($p > 0.05$, Table 1).

Both LGA and RGA parameters had a significant value in sex ($p < 0.05$). Pearson's correlation coefficient reported a high linear relationship between LGA and

TABLE 1. Mean left (LGA) and right (RGA) gonial angle measurement in males and females using Mann-Whitney *U*-test

Parameter	*n*	Males		Females		Significance
		Mean	Standard deviation	Mean	Standard deviation	
LGA	100	120.20	3.25	119.40	3.66	0.59
RGA		120.60	2.78	119.20	3.46	

TABLE 2. Binary logistic model and sex discriminating performance of each predictor variable

Parameter	Binary logistic model	Significance	Accuracy	AUC (95% CI)	Brier score
LGA	$logit(y) = -14.48 + 0.12\times$	0.048	0.60	0.62 (0.51-0.73%)	0.23
RGA	$logit(y) = -19.63 + 0.16\times$	0.015	0.61	0.64 (0.53-0.74%)	0.23

*AUC – area under curve, CI – confidence interval*

RGA ($r = 0.73$). Binary logistic regression model was derived separately with both predictors' variables. Binary logistic model and the performance of each predictor variable are presented in Table 2.

None of the variables has reached an optimal AUC value of 0.75. AUC of LGA and RGA ranged between 0.62 and 0.64, with a lower bound of 95% CI ranged between 0.51 and 0.53%. ROC curve is illustrated in Figure 2. Although the parameters had significant value in sex, the accuracy of parameters' prediction of individual sex was almost 50-50, or considered poor.

DISCUSSION

It is essential to understand the accuracy of direct GA measurement because it upholds the value of acquiring GA information when radiographic images or dental autopsy cannot be done due to law, ethical values, or logistical reason. Sahelangi *et al.* reported that it is appropriate to comply with ethical, religious, and cultural aspects in a mass disaster identification process; therefore, an invasive autopsy on human remains might be impractical due to these considerations [7]. A goniometer was chosen as a measurement tool in the present research, as Ohtani *et al.* reported difficulties in accessing a victim's mouth in Tsunami victims due to law prohibition in incising dead bodies without a permit [8].

The 100 subjects selected in the current study were individuals aged 16-24 years, with an average age of 20.19 ± 1.88 and 19.56 ± 2.16 years old for men and women, respectively. The sample of juveniles were taken based on minimum variability on GA and its' role in dental age estimation. The variability in GA's sexual dimorphism is affected by tooth [13], edentulous status [14], and masticatory musculature [15]. Bulut *et al.* observed no significant difference in GA between sexes, except for old adults (60-80 years old) [16]. Furthermore, acquiring sex information on juveniles could provide additional information for dental age estimation
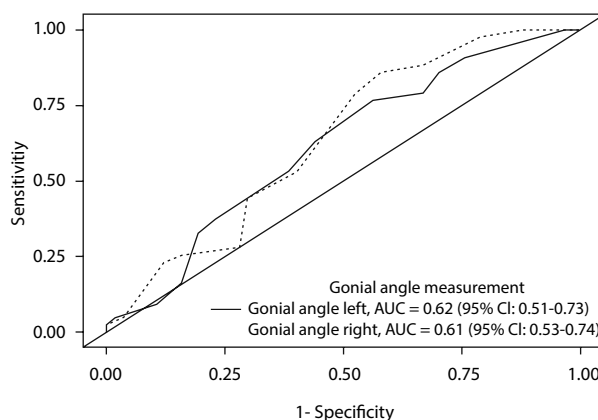
FIGURE 2. Receiver operating curve and area under curve for each predictor variable

methods, as third molar development differs significantly between sexes [17, 18].

The measurement taken from goniometer implies that males had a greater overall GA than females (Table 1). This result is in line with various research using multiple methods of GA measurement. Upadhyay *et al.* stated that men presented a larger GA (135 ± 1.16) than women (133 ± 2.57) using skeletal and lateral cephalometric measurements [12]. Similar findings were also found by Kharoshah *et al.* using computer tomographic scan (M = 122.8 ± 4.3, F = 121.1 ± 3.9), and Sandeepa *et al.* who applied orthopantomogram (M = 128.89 ± 6.02, F = 124.41 ± 3.18) [19, 20]. However, it must be noted that the acquired GA value differed between measurement methods and populations, as various factors, such as habits, race, ethnic, etc., may affect GA measurements [19]. Further research comparing GA value between radiographical images, craniometric, and direct measurements are needed.

Although both variables had significant differences between males and females, the measurement between LGA and RGA was not significantly different (Table 1). A similar finding was found by Bhullar *et al.* [21], and

another approach suggested by Saikiran *et al.* was to measure LGA only [22]. Furthermore, a high correlation coefficient was found between LGA and RGA, which indicated that both parameters would create multi-collinearity if used as an independent variable in logistic regression model. Therefore, we opted to derive a binary logistic regression model from both LGA and RGA separately [23]. The results for the accuracy of the method were considered inadequate, which was shown in low accuracy, AUC, and Brier score. Capitaneanu *et al.* indicated that for a sex determination method to be usable, AUC value needs to be higher than 0.75 [24]. Furthermore, other study reported varied accuracy using gonial angle. Abu-Taleb *et al.* obtained an overall accuracy of 79.6% of GA measurement in panoramic radiographs [25]. On the contrary, in Belaldavar *et al.* study, cephalography achieved an accuracy rate of 56.3% only [26].

The approach of conventional goniometer as a measurement tool in the present research proved that it was not a sufficient tool to discriminate between the two sexes in the terms of sensitivity. However, the results of measurements showed a significantly different value between the two sexes. Therefore, advanced approach using an electro-goniometer with higher reliability and accuracy could be considered to enhance similar methods [27].

CONCLUSIONS

The proposed direct examination method of GA shows a significant difference between males and females in Indonesian population between 16 to 24 years old. However, binary logistic model shows a low sex discriminating performance on both LGA and RGA variables. Future research should consider adding other sexually dimorphic dental parameters, such as a cranio or odontometric evaluation to improve the sex estimation performance on the predictive model.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Sweet D. INTERPOL DVI best-practice standards – an overview. Forensic Sci Int 2010; 201: 18-21.
2. Scheuer L. Application of osteology to forensic medicine. Clin Anat 2002; 15: 297-312.
3. Loth SR, Henneberg M. Sexually dimorphic mandibular morphology in the first few years of life. Am J Phys Anthropol 2001; 115: 179-186.
4. Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, Tripathi SK. Mandibular ramus: an indicator for sex in fragmentary mandible. J Forensic Sci 2011; 56 Suppl 1: S13-16.
5. Lewis AB, Roche AF, Wagner B. Growth of the mandible during pubescence. Angle Orthod 1982; 52: 325-342.
6. Leversha J, McKeough G, Myrteza A, Skjellrup-Wakefiled H, Welsh J, Sholapurkar A. Age and gender correlation of gonial angle, ramus height and bigonial width in dentate subjects in a dental school in Far North Queensland. J Clin Exp Dent 2016; 8: e49-e54.
7. Sahelangi P, Novita M. Role of dentists in Indonesian disaster victim identification operations: religious and cultural aspects. J Forensic Odontostomatol 2012; 30 Suppl 1: 60-71.
8. Ohtani M, Oshima T, Mimasaka S. Extra-oral dental radiography for disaster victims using a flat panel X-ray detector and a hand-held X-ray generator. J Forensic Odontostomatol 2017; 35: 28-34.
9. Merdietio Boedi R. Post-mortem dental profiling in Palu earthquake and tsunami victims – procedures and limitations. Aust J Forensic Sci 2020; https://doi.org/10.1080/00450618.2020.1805013.
10. Thevissen P, Willems G, Van de Voorde W, Solheim T. Dental age estimation in sub-adults: striving for an optimal approach. PhD Thesis KU Leuven; 2013. Available at: https://limo.libis.be/primo-explore/fulldisplay?docid=LIRIAS1800755&context=L&vid=Lirias&search_scope=Lirias&tab=default_tab&lang=en_US&fromSitemap=1 (Acceseed: 10.11.2021).
11. Hariemmy M, Merdietio Boedi R, Utomo H, Margaretha MS. Sex determination using gonial angle during growth spurt period: a direct examination. Indo J Dent Med 2018; 1: 86-89.
12. Upadhyay RB, Upadhyay J, Agrawal P, Rao NN. Analysis of gonial angle in relation to age, gender, and dentition status by radiological and anthropometric methods. J Forensic Dent Sci 2012; 4: 29-33.
13. Kiliaridis S, Johansson A, Haraldson T, Omar R, Carlsson GE. Craniofacial morphology, occlusal traits, and bite force in persons with advanced occlusal tooth wear. Am J Orthod Dentofacial Orthop 1995; 107: 286-292.
14. Huumonen S, Sipila K, Haikola B, et al. Influence of edentulousness on gonial angle, ramus and condylar height. J Oral Rehabil 2010; 37: 34-38.
15. Jensen E, Palling M. The gonial angle. Am J Orthod 1954; 40: 120-133.
16. Bulut O, Freudenstein N, Hekimoglu B, Gurcan S. Dilemma of gonial angle in sex determination: sexually dimorphic or not? Am J Forensic Med Pathol 2019; 40: 361-365.
17. Gunst K, Mesotten K, Carbonez A, Willems G. Third molar root development in relation to chronological age: a large sample sized retrospective study. Forensic Sci Int 2003; 136: 52-57.
18. Zandi M, Shokri A, Malekzadeh H, Amini P, Shafiey P. Evaluation of third molar development and its relation to chronological age: a panoramic radiographic study. Oral Maxillofac Surg 2015; 19: 183-189.
19. Kharoshah MA, Almadani O, Ghaleb SS, Zaki MK, Fattah YA. Sexual dimorphism of the mandible in a modern Egyptian population. J Forensic Leg Med 2010; 17: 213-215.
20. Sandeepa N, Ganem AA, Alqhtani WA. Mandibular indices for gender prediction: a retrospective radiographic study in Saudi population. J Dent Oral Health 2017; 9: 95-101.
21. Bhullar MK, Uppal AS, Kochhar GK, Chachra S, Kochhar AS. Comparison of gonial angle determination from cephalograms and orthopantomogram. Indian J Dent 2014; 5: 123-126.
22. Ch S. Can gonial measurements predict gender? A prospective analysis using digital panoramic radiographs. Foresic Res Criminol Int J 2016; 3: 287-290.
23. Wheeler D, Tiefelsdorf M. Multicollinearity and correlation among local regression coefficients in geographically weighted regression. J Geo Syst 2005; 7: 161-187.

24. Capitaneanu C, Willems G, Jacobs R, Fieuws S, Thevissen P. Sex estimation based on tooth measurements using panoramic radiographs. Int J Legal Med 2017; 131: 813-821.

25. Abu-Taleb NS, El Beshlawy DM. Mandibular ramus and gonial angle measurements as predictors of sex and age in an Egyptian population sample: a digital panoramic study. J Forensic Res 2015; 6: 5. DOI: 10.4172/2157-7145.1000308

26. Belaldavar C, Acharya AB, Angadi P. Sex estimation in Indians by digital analysis of the gonial angle on lateral cephalographs. J Forensic Odontostomatol 2019; 37: 45-50.

27. Shiratsu A, Coury HJ. Reliability and accuracy of different sensors of a flexible electrogoniometer. Clin Biomech 2003; 18: 682-684.