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ORIGINAL RESEARCH

Sex Determination using Antegonial and Gonial Angle in Panoramic Radiographs: A Study on the Indonesian Population

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KEYWORDS

Sex Determination; Panoramic Radiographs; Mandible; Forensic Dentistry; Dental Anthropology

ABSTRACT

Sex determination is a crucial aspect of forensic identification. This study investigates the capability of Sex determination is a crucial aspect of forensic identification. This study investigates the potential of antegonial (AGA) and gonial (GA) angle measurements on panoramic radiographs (PANs) for sex determination in an Indonesian population using logistic regression. A cross-sectional study was conducted on 300 PANs from individuals aged over 20 years, with measurements performed by two observers. Statistical analysis included independent sample t-test and logistic regression, with performance evaluated based on accuracy values. The t-test revealed significant differences in both AGA and GA between sexes. However, logistic regression yielded accuracy rates of 58% for AGA and 60.3% for GA, indicating that these variables alone are insufficient for reliable sex determination in the Indonesian population using PANs. Future studies should explore the inclusion of additional anthropometric variables from PANs to enhance the accuracy of mandibular-based sex determination methods.

1. INTRODUCTION

Positive identification in forensic odontology (FO) relies on two crucial components: antemortem (AM) and postmortem (PM) data.[1] Without both, achieving positive identification is impossible. However, in Indonesia, only 26% of dentists maintain proper dental records that can be effectively used in the AM process.[2] This limitation poses a significant challenge to using FO as a primary identifier in mass disasters.[3] Consequently, there is a pressing need to optimize the use of PM data for creating dental profiles, particularly as a secondary identifier, with sex determination playing a critical role.[4]

Sex information is a vital component of forensic identification.[5, 6] For instance, knowing the sex of a victim can significantly narrow the search for AM data, potentially reducing the search scope by half and facilitating a more focused and efficient identification process.[7] Moreover, various dental age estimation methods require sex as a variable to produce more accurate and reliable results.[8]

Sex determination can be achieved by utilizing dimorphic characteristics of human morphology.[9] Commonly, the pelvic bone is the most frequently used structure for sex determination, followed by the cranium.[10] In cases where skeletal remains are severely fragmented or unidentifiable, the cranium can still provide valuable information.[11] Among cranial structures, the mandible is one of the key elements used for identification purposes.

Mandibular dimorphic characteristics can be analyzed through measurements of the antegonial angle (AGA) and the gonial angle (GA).[12] The AGA is the concavity formed at the junction between the ramus and the body of the mandible, while the GA is the angle formed by the intersection of two lines: the inferior border of the mandible and the posterior border of the mandibular ramus. These parameters can be measured using panoramic radiographs (PAN).

Numerous studies have analyzed the differences between male and female mandibular angles in PAN.[12, 13] However, relying solely on p-values from quantitative tests, such as t-tests, does not sufficiently the ability of a variable to distinguish between

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binary outcomes (e.g., male or female). In such cases, logistic regression is required to evaluate the accuracy of the AGA and GA for sex determination in PAN. Thus, this study aims to determine the accuracy and establish the cut-off values of AGA and GA for sex determination in the Indonesian population.

2. METHODOLOGY

This study was an observational analytical cross-sectional study. The sample collection was conducted retrospectively, with ethical approval obtained from the local ethics committee (409/EC/KEPK/FK-UNDIP/VIII/2024). No patients were exposed to radiation solely for the purpose of this research.

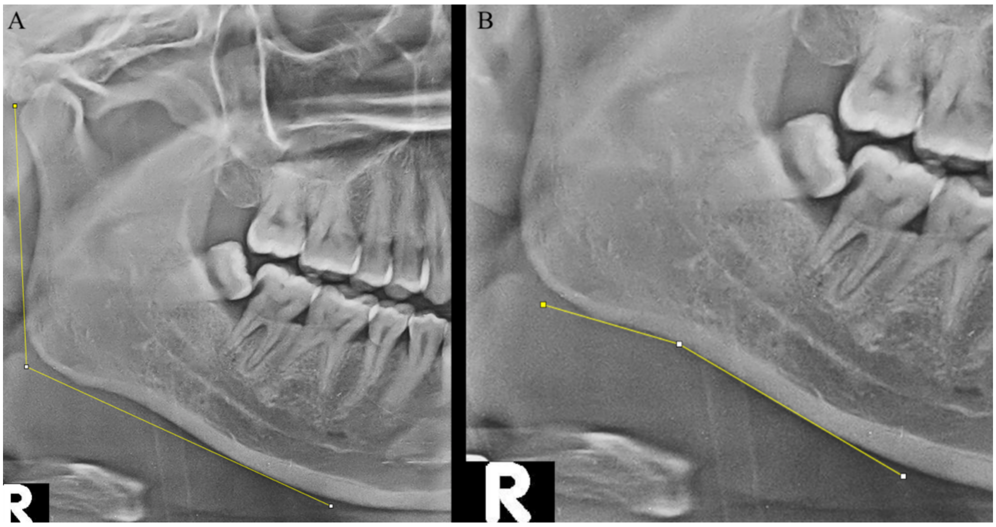
The sample consisted of 300 subjects, including 150 males and 150 females, sourced from Pramita Laboratorium, Semarang, Central Java, Indonesia. All PANs were taken from individuals aged over 20 years. The recorded data only includes sex. Age was not recorded due to its reported non-significant relationship with both the AGA and GA.[12] The inclusion criteria required PANs of good quality with a clear view of the mandible. PANs from individuals undergoing orthodontic treatment or with fractures, deformities, asymmetries, or edentulous jaws were excluded from the study.

Each PAN was observed and measured using the angle tool in ImageJ software. The AGA was measured as the angle of the concavity formed at the junction between the ramus and the body of the mandible, using panoramic radiographs. It was determined by drawing two lines parallel to the antegonial region, intersecting at the deepest point of the antegonial notch. Meanwhile, the GA was measured as the angle formed between a line along the inferior border of the mandible and a line along the posterior border of the mandibular ramus. The GA was obtained by measuring the angle between the tangent to the inferior border of the mandible and the tangent to the posterior border of the ramus. The primary measurements were taken from the right AGA and GA (Figure. 1). All data were recorded using Microsoft Excel 365.

Two observers, NJZ and RMB, were assigned to analyze the AGA and GA. NJZ is a dental student recruited for this study, and RMB is a forensic odontologist with over eight years of experience in radiographic research. To evaluate the consistency of the measurements, 20 PANs were randomly selected for Intraclass Correlation Coefficient (ICC) analysis to assess inter- and intra-observer reliability. Inter-observer reliability was determined by measuring the PANs twice, with a two-week interval between the first and second measurements.

The differences in AGA and GA between sexes were analyzed using an independent sample t-test. Additionally, the ability to determine sex based on both variables was assessed through logistic regression. All statistical analyses were conducted using R software (version 3.4.1).

Figure 1. Gonial Angle (A) and Antegonial Angle (B) measurement on panoramic radiograph.



3. RESULTS

The overall ICC results indicate reliable inter- and intra-rater reliability. The intra-rater reliability scores were 0.97 for the AGA and 0.98 for GA, while the inter-rater reliability scores were 0.78 and 0.80 for AGA and GA, respectively. The Kolmogorov-Smirnov test confirmed a normal distribution of data for both AGA and GA ($p > 0.05$).

The independent sample t-test revealed a significant difference in both AGA and GA between sexes. Higher AGA values were observed in females (165.354 ± 4.96) compared to males (163.285 ± 6.14). Similarly, females exhibited higher GA values (124.411 ± 4.69) compared to males (122.492 ± 5.21).

Further logistic regression analysis is presented in **Error! Reference source not found.**. The optimal cut-off values for i dentifying females were 157.77 degrees for AGA and 120.02 degrees for GA. These cut-off values suggest that individuals with measurements equal to or exceeding these thresholds are more likely to be female. The accuracy of these cut-off values was 58% for AGA and 60.3% for GA.

Variable	Sensitivity	Specificity	Cut-off Value*	AUC	Accuracy
AGA	0.946	0.213	157.77	0.589	0.58
GA	0.820	0.386	120.029	0.606	0.603

Table 1. The Model Performance for the Logistic Regression Analysis for both AGA and GA in sex determination. AGA = Antegonial Angle, GA = Gonial Angle, AUC = Area Under Curve, * = Values above or equal to the results indicates female.

4. DISCUSSION

As one of the sexually dimorphic bones in the human body, the use of mandibular angle measurements has been a topic of ongoing debate. Previous studies investigating both the AGA and GA have reported variable results.[12, 14, 15] To accurately assess the ability of these angles to differentiate between males and females, further statistical analysis, such as logistic regression, is required. Unlike t-tests or other statistical tests that only identify significant differences between variables and sex, logistic regression can evaluate the predictive capacity of these variables for sex determination. However, as noted by Anuja et al. (2023), basic statistical tests like t-tests remain essential for identifying variables with the potential for sex determination, as demonstrated by the significant differences observed in AGA and GA.[12]

The ICC analysis in this study demonstrated excellent reliability for both inter- and intra-observer measurements. These findings are consistent with the results reported by Dutra et al. (2004), whom reported intra-rater ICCs of 0.91 for AGA and 0.98 for GA, while inter-rater ICCs were 0.74 for AGA and 0.96 for GA [16]. Consistently, GA shows a higher reliability in this study. This outcome suggests that anatomical landmarks for GA are easier to identify compared to those for AGA, and better anatomical landmarks approach to analyse AGA is needed.

In this study, females exhibited a larger mean AGA (165.354° ± 4.96) compared to males (163.285° ± 6.14). This finding aligns with studies by Purba et al. (2023), who reported a higher mean AGA in females (159.07° ± 5.25) than in males (155.36° ± 5.85) [13]. Similarly, Singh et al. (2016) observed larger AGA values in females within a North Indian population [14]. However, contrary results were reported by Anuja et al. (2023) in a South Indian population, where males had larger AGA values than females.[12] These differences may be attributed to hormonal variations, as estrogen in females reduces bone resorption, leading to a larger AGA.[13] Additionally, inter-population differences may exist, as seen in the distinct AGA measurements in North and South Indian populations. Supporting this, Dermawan et al. (2013) found that Javanese females exhibited larger AGA values than males.[17] Given these variations, it is recommended that AGA measurements be population-specific to achieve more accurate sex determination outcomes.

The present study also found significant sex-based differences in GA, with females displaying a larger mean GA (124.411° ± 4.69) compared to males (122.492° ± 5.21). This finding is consistent with Saikiran et al. (2016), who observed a higher mean GA in females (124.361° ± 9.2387) than in males (121.995° ± 7.7358) in panoramic radiographs. Similar results were reported by Ingaleshwar et al. (2022), with females having larger GA values (125.29° ± 6.38) compared to males (120.5° ± 8.50).[18] However, GA measurements have shown inconsistency across different populations. For instance, Upadhyay et al. (2012) reported higher GA values in males (135° ± 1.16) than in females (133° ± 2.57) using lateral cephalometry and skeletal anthropometry in an Indian population.[19] Kharoshah et al. (2010) found that Egyptian males had a larger GA (122.8° ± 4.3) than females (121.1° ± 3.9) when using spiral computed tomography (CT).[20] Similarly, Ghazani et al. (2022) reported larger GA values in Indonesian males (120.1° ± 2.77) compared to females (118.7° ± 3.36), with a predictive accuracy of 60% using clinical measurements.[21] To address the inconsistencies in GA measurements across populations, it is essential to standardize the measurement methods and media used in studies, ensuring consistent and comparable results.

In this study, the accuracy of the AGA and GA for sex determination was 58% and 60.3%, respectively. These accuracy rates are considered low for forensic odontology purposes. Capitaneanu et al. (2017) suggest that a method must achieve an accuracy rate of over 80% to be deemed reliable for sex determination.[22] Previous studies have shown that combining multiple anthropometric parameters can improve accuracy. For instance, Kharoshah et al. (2010) reported an overall prediction accuracy of 83.9% when using gonial angle, ramus length, bicondylar width, and minimum ramus width in an Egyptian population, with correct identification rates of 83.6% for males and 84.2% for females.[20] These findings highlight the limitations of using AGA and GA alone for sex determination, as their accuracy is insufficient. It is recommended to incorporate additional anthropological features and employ logistic regression to assess the predictive capacity of these parameters. This approach would provide a more robust assessment of the accuracy and reliability of sex determination methods in forensic odontology. However, it should be noted that adding additional variables requires a larger sample size to maintain statistical power and generalizability.

5. CONCLUSION

The measurement of the AGA and GA in PANs revealed significant differences between males and females. However, the accuracy of sex determination using these angles alone was insufficient, with accuracy rates below 60%. These findings highlight the limitations of relying solely on AGA and GA for sex determination. Future studies should incorporate additional anthropometric variables or combine multiple anatomical landmark measurements from PANs to improve the accuracy of mandibular-based sex determination methods. Furthermore, the application of logistic regression models with larger, population-specific datasets is recommended to enhance the generalizability and robustness of the findings.

Conflict of Interest

The authors declare no conflicts of interest in this study.

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Authors Contribution

Conceptualization: JRK; Methodology: NJK, JRK, IAK, Formal Analysis: NJK, Data Curation: NJK, JRK; Data Curation: NJK, Original Draft Writing: NJK, Supervision and Editing: IAK, JRK, Administration: NJK

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