ORIGINAL ARTICLE

Mandibular gonial angle characteristics for age and sex estimation: a cross-sectional study

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ABSTRACT

Introduction: The mandibular gonial angle is a craniofacial parameter that reflects anatomical adaptation influenced by growth processes, masticatory function, and sexual dimorphism, making it relevant for age and sex estimation. This parameter has been widely applied in dental and craniofacial studies. However, evidence from community based Indonesian populations remains limited. Population specific data are important for improving the accuracy and applicability of craniofacial indicators. This study aimed to evaluate mandibular gonial angle characteristics for age and sex estimation in Semampir District, Surabaya. **Methods**: This analytical observational study employed a cross-sectional design involving 100 adults aged 21–50 years from Semampir District, Surabaya, consisting of 50 males and 50 females. Mandibular gonial angle measurements were obtained from digital panoramic radiographs using standardized anatomical landmarks. Bilateral measurements were averaged for analysis. Descriptive statistics were used to summarize gonial angle values, while inferential statistical tests were applied to evaluate differences related to age and sex. **Results**: Descriptive analysis showed variation in mandibular gonial angle values across different age groups without a consistent age-related pattern. In contrast, a clear difference in mean gonial angle values was observed between the sexes, with female subjects demonstrating higher mean values than male subjects. Statistical analysis showed a statistically significant difference in gonial angle values according to sex ($p<0.001$), while no statistically significant association was found between age and gonial angle measurements ($p>0.05$). **Conclusion**: The mandibular gonial angle demonstrates pronounced sexual dimorphism but limited applicability for adult age estimation in the studied population. These findings suggest that the gonial angle may serve as a supportive craniofacial indicator for sex estimation, while its role in age estimation should be interpreted with caution. Population-specific, community-based data are important for strengthening the forensic and dental applications of craniofacial parameters in Indonesian populations.

KEYWORDS

Mandible, panoramic radiography, forensic dentistry, age determination by skeleton, sex determination by skeleton

INTRODUCTION

Determining a person's age and sex from skeletal characteristics has long been an essential aspect of forensic odontology and forensic anthropology. The mandible, as the largest and most resilient bone in the craniofacial region, contains several anatomical landmarks that exhibit consistent variations related to age and sex.[1] One of the most frequently examined landmarks is the mandibular gonial angle, which is formed by the junction of the posterior border of the ramus

and the inferior border of the mandibular body.[2] This angle has gained particular attention because it can be easily identified on routine radiographic images and is closely related to masticatory function and skeletal adaptation.[3] Changes in the gonial angle throughout different stages of life and differences observed between sexes have therefore positioned it as a useful parameter for age and sex estimation in diverse populations, with significant relevance for both forensic odontology and medicolegal investigations.[4] However, the reliability of the gonial angle as a universal indicator remains debated across populations.

Recent advances in forensic odontology have highlighted the important role of digital imaging technologies in improving the precision of craniofacial measurements, including mandibular parameters such as the gonial angle, thereby supporting more reliable identification outcomes.[5] This imaging technique enables angular measurements to be performed using existing clinical radiographs without additional radiation exposure for research purposes.[6,7]

Several studies have supported the use of panoramic imaging to assess mandibular morphology, highlighting the potential of radiographically measured parameters, particularly the gonial angle, to reflect underlying biological differences associated with age and sex. However, factors such as image magnification, patient positioning, and projection characteristics may influence measurement accuracy. Therefore, standardized measurement procedures and population specific validation are necessary when panoramic radiography is applied for forensic and dental identification. [8]

Recent research highlights contrasting findings regarding the correlation between gonial angle values and age.[9] While some studies demonstrate significant associations, indicating systematic changes in angular morphology with advancing age, others report that the gonial angle may not consistently reflect chronological aging, particularly when evaluated independently of other craniofacial measurements. This inconsistency suggests that the gonial angle's relationship with age may be influenced by additional factors such as dental status, bone remodeling, and functional use of the mandible, further emphasizing the importance of context specific analysis.[10]

The question of sexual dimorphism in mandibular morphology has similarly yielded mixed evidence. Traditional anthropological frameworks propose that male and female craniofacial structures exhibit distinct patterns due to differential growth trajectories and hormonal influences. [12] In particular, the gonial angle has been proposed as one such dimorphic parameter, with some studies reporting larger mean values in one sex compared with the other. However, other investigations have failed to detect significant sex differences when controlling for age or dental status, indicating that the strength and direction of dimorphism may vary depending on the population studied and the measurement technique used.[14] This variability further complicates the application of gonial angle measurements for universal age and sex estimation and highlights the need for contemporary epidemiological data from underrepresented populations.[15]

Within the context of Indonesian populations, few studies have systematically investigated mandibular parameters such as the gonial angle in relation to age and sex. Some locally published research has identified sex related differences in gonial angle values using radiomorphometric techniques, but these analyses often involve relatively small sample sizes or lack comprehensive age stratification, limiting their generalizability for broader forensic and dental reference standards. As such, there is a clear gap in robust population specific data that could inform both clinical practice and forensic protocols within Indonesian populations.[16,17]

Despite the growing body of literature on mandibular gonial angle analysis for forensic age and sex estimation, the availability of community based and population specific reference data from Indonesian urban populations remains limited. Most existing studies have been conducted in hospital based or clinic based settings, which may not adequately represent the morphological

characteristics of community dwelling populations. Indonesia is characterized by considerable demographic diversity, and craniofacial parameters may vary according to environmental, socioeconomic, and functional factors that influence mandibular adaptation. These variations further justify the need for population-specific analysis in urban communities such as Semampir District.

Semampir District, Surabaya, represents a densely populated urban area with heterogeneous socioeconomic backgrounds and varying lifestyle patterns, which may influence masticatory function and craniofacial morphology. These characteristics make it a relevant setting for evaluating mandibular variation in a community based population that has not been previously investigated.

The novelty of this study lies in providing population specific reference data derived from a community based urban population using standardized panoramic radiographic assessment. This study aims to evaluate the mandibular gonial angle characteristics for age and sex estimation in adults from Semampir District, Surabaya.

METHODS

This study employed an analytical observational design with a cross-sectional approach to evaluate the mandibular gonial angle characteristics for age and sex estimation. The study was conducted in Semampir District, Surabaya, Indonesia, in 2025. The study utilized secondary data derived from digital panoramic radiographs obtained from Pramita Laboratory, Surabaya, where radiographic examinations were performed for clinical dental purposes. The study population consisted of community-dwelling adults aged 21 to 50 years. A total of 100 panoramic radiographs were included, comprising 50 male and 50 female subjects. Sampling was performed using a total sampling technique based on predefined inclusion and exclusion criteria. The outcome variable in this study was the mandibular gonial angle (in degrees), while the primary predictor variables were age (in years) and sex (male and female). Because this retrospective study used secondary radiographic data, all panoramic radiographs available during the study period were screened using total sampling. An a priori sample-size calculation was therefore not applied; of 120 radiographs assessed, the 100 radiographs that fulfilled the eligibility criteria were included in the analysis.

Inclusion criteria consisted of individuals aged 21 to 50 years with complete permanent dentition and panoramic radiographs of adequate diagnostic quality, allowing clear visualization of the mandibular angle region. Exclusion criteria included radiographs with positioning errors or distortion, the presence of mandibular pathology, a history of mandibular trauma or surgery, severe malocclusion, ongoing orthodontic treatment, and systemic conditions known to affect bone metabolism or craniofacial growth, to minimize potential confounding factors.

Mandibular gonial angle measurements were obtained from digital panoramic radiographs using standardized anatomical landmarks defined by the posterior border of the mandibular ramus and the inferior border of the mandibular body. Measurements were performed using ImageJ software (National Institutes of Health, USA). Bilateral measurements were recorded, and the mean value of the right and left gonial angles was used for analysis.

To ensure measurement reliability, two independent calibrated examiners performed the measurements. Intra-observer and inter-observer reliability were assessed by repeating measurements on 20% of the sample after a two-week interval. Reliability was evaluated using the intraclass correlation coefficient (ICC), demonstrating acceptable reproducibility. Potential sources of bias were addressed by applying strict inclusion and exclusion criteria, using standardized measurement protocols, and anonymizing all radiographic data prior to analysis. No missing data were identified, as all selected radiographs met the inclusion criteria and were complete for analysis.

Age was categorized into four groups (21–25, 26–30, 31–35, and 36–50 years) to represent different stages of early and middle adulthood, during which mandibular growth is generally complete and structural changes are relatively stable. This grouping was applied to facilitate comparison across adult age ranges while minimizing the influence of developmental growth and age-related degenerative changes. Statistical analysis was performed using SPSS software version 29 (IBM Corp., Armonk, NY, USA).

This study was conducted in accordance with the Declaration of Helsinki. All data were anonymized, and informed consent was waived due to the use of secondary data. Data normality was assessed using the Shapiro–Wilk test. Differences in mean gonial angle values between male and female subjects were analyzed using an independent t-test, while right and left measurements were compared using a paired t-test. The association between age and the gonial angle was evaluated using Spearman rank correlation analysis. A significance level of $p<0.05$ was applied.

RESULTS

A total of 120 panoramic radiographs were initially assessed for eligibility. Of these, 20 radiographs were excluded due to poor image quality and the presence of exclusion criteria, including mandibular pathology and a history of orthodontic treatment. After applying the inclusion and exclusion criteria, 100 radiographs were included in the final analysis, comprising 50 female and 50 male participants aged 21 to 50 years.

All included radiographs fulfilled the required quality standards, allowing clear visualization of the mandibular body and ramus as well as accurate identification of gonial angle landmarks. No missing data were identified, and all selected radiographs were included in the analysis. Mandibular gonial angle measurements were obtained bilaterally for each subject, and the mean value of the right and left sides was calculated for further analysis.

The mean gonial angle measured on the right side was 119.54 ± 8.56 degrees, while the mean value on the left side was 120.22 ± 8.78 degrees. The overall mean gonial angle for the study population was 119.88 ± 8.30 degrees. Participant selection is summarized in Table 1.

Table 1. Participant selection and inclusion process

Selection stage	Number of radiographs
Assessed for eligibility	120
Excluded: poor image quality (n = 12); mandibular pathology or orthodontic history (n = 8)	20
Included in the final analysis	100

As presented in Table 2, the right and left gonial angle measurements were comparable, with only a small difference between sides. The overall mean gonial angle was 119.88 ± 8.30 degrees. These findings indicate minimal bilateral variation, suggesting relatively symmetrical mandibular morphology in the study population.

Table 2. Descriptive statistics of mandibular gonial angle measurements

Variable	n	Mean ± SD
Gonial angle right (degrees)	100	119.54 ± 8.56
Gonial angle left (degrees)	100	120.22 ± 8.78
Mean gonial angle (degrees)	100	119.88 ± 8.30

For age related analysis, participants were categorized into four age groups (21–25, 26–30, 31–35, and 36–50 years) with equal sample sizes to allow comparison across adult age ranges. The mean gonial angle values for each group were 119.34 ± 7.59 degrees, 121.16 ± 8.26 degrees, 117.11 ± 6.35 degrees, and

120.59 ± 10.02 degrees, respectively. As presented in Table 3, the distribution of mean gonial angle values across age groups did not demonstrate a consistent increasing or decreasing trend. This indicates the absence of a clear age related pattern in the studied population. Correlation analysis further confirmed that there was no statistically significant association between age and gonial angle (Spearman r=−0.002, p=0.983).

When analyzed according to sex, female participants demonstrated a higher mean gonial angle (124.97 ± 7.19 degrees) than male participants (114.13 ± 4.89 degrees), as shown in Table 4. An independent t-test confirmed that this difference was statistically significant (p<0.001), indicating sexual dimorphism in mandibular gonial angle morphology within the studied population.

Table 3. Mean mandibular gonial angle according to age

Age group (years)	n	Mean gonial angle ± SD (degrees)
21–25	25	119.34 ± 7.59
26–30	25	121.16 ± 8.26
31–35	25	117.11 ± 6.35
36–50	25	120.59 ± 10.02

Table 4. Mean mandibular gonial angle according to sex

Sex	n	Mean gonial angle ± SD (degrees)
Male	50	114.13 ± 4.89
Female	50	124.97 ± 7.19

DISCUSSION

Table 1 summarizes the participant selection process and demonstrates that the final sample was obtained after systematic eligibility screening. Of 120 panoramic radiographs assessed, 20 were excluded because of poor image quality, mandibular pathology, or orthodontic history, leaving 100 radiographs suitable for analysis. The equal distribution of 50 male and 50 female participants reduced imbalance between the sex groups and supported a direct comparison of mandibular gonial angle values. Nevertheless, the use of a community-based sample from a single district should be considered when interpreting the external validity of the findings. Averaging bilateral measurements may reduce random measurement variation; however, a single available side should still be interpreted cautiously in fragmented skeletal remains.[6]

The use of bilateral measurements and their averaged values proved appropriate, as the right and left gonial angles showed comparable mean values with minimal variation, as presented in Table 2. This finding suggests that mandibular angular morphology in healthy adults is generally symmetrical, reflecting a balanced structural adaptation between the right and left sides of the mandible.[20] It is also consistent with previous radiographic studies reporting that minor side differences are more likely influenced by functional habits, such as the preferred chewing side, rather than true structural asymmetry.[21] However, slight variations between sides may still occur and should be considered during measurement interpretation. The use of averaged bilateral values in this study helps to reduce measurement bias and enhances analytical reliability. From a forensic perspective, this approach allows the gonial angle to be utilized even when only one side of the mandible is available, such as in cases involving fragmented skeletal remains.[6]

Age related analysis revealed descriptive differences in gonial angle values across the examined age groups. However, these variations did not follow a consistent or progressive pattern, as presented in Table 3. Spearman rank correlation analysis showed a negligible and statistically non significant correlation between age and the gonial angle (r=−0.002, p=0.983). The absence of a clear correlation between age and the gonial angle suggests that mandibular angular morphology remains relatively stable throughout early and middle adulthood.[22]

This finding is consistent with previous studies reporting a limited association between the gonial angle and age in adult populations, although some evidence indicates that age related changes may be observed when additional craniofacial parameters are included. Consequently, the gonial angle alone appears to have limited value for adult age estimation and should not be interpreted as an isolated chronological age marker.[23]

The findings of this study demonstrate that mandibular gonial angle morphology in the Semampir District population differs significantly between males and females, as shown in Table 4, indicating the presence of sexual dimorphism in adult mandibular anatomy. Female participants exhibited higher mean gonial angle values than males, supporting the role of this parameter in sex estimation.[18] These findings are consistent with previous forensic odontological studies, which have reported that mandibular angular morphology continues to exhibit sexual dimorphism even after the completion of craniofacial growth. However, the magnitude of these differences may vary across populations, suggesting that population-specific data are essential for accurate interpretation.[19]

Compared with the limited influence of age, sex differences in gonial angle measurements were more evident and reached statistical significance, as demonstrated in Table 4. Female participants exhibited consistently larger and more obtuse gonial angles than male participants.[1] This pattern is biologically plausible and reflects differences in masticatory muscle strength, hormonal regulation, and mandibular growth patterns between sexes.[2] Male mandibles are generally subjected to greater functional loading, which tends to produce a more acute gonial angle, whereas females typically exhibit a wider angle due to lower muscular forces. Similar patterns have been reported in various populations, supporting the presence of sexual dimorphism in mandibular morphology, although the magnitude of these differences may vary across different demographic groups.[5]

The magnitude of sexual dimorphism observed in this study exceeds the degree of random individual variability, indicating that the gonial angle has meaningful discriminative value for sex estimation and may serve as a supportive parameter in forensic identification.[8] This finding is particularly relevant in forensic contexts where skeletal remains are fragmented or incomplete, and more sexually dimorphic structures such as the pelvis or skull are not available. In such conditions, mandibular fragments can still provide useful morphological information, and gonial angle measurements may assist in establishing the biological profile of unidentified individuals.

In disaster victim identification (DVI) scenarios, mandibular fragments are often preserved and can be compared with antemortem dental records or radiographs to assist in identification. 27 Panoramic radiography offers a practical advantage in these situations due to its widespread availability, standardized imaging technique, and routine clinical use in dental practice. The present study also provides population specific data that may improve sex estimation accuracy within Indonesian forensic settings and emphasizes the importance of using local reference values to enhance diagnostic precision. However, this parameter should be interpreted cautiously and ideally combined with other skeletal indicators to improve the overall accuracy and reliability of forensic analysis.[28]

The absence of an age association, together with the significant sex difference, defines the appropriate scope of interpretation for this parameter. Gonial angle measurements appear more informative for supporting sex estimation than for determining chronological age among adults aged 21–50 years. This distinction is important because overinterpretation of a single morphometric feature may reduce the accuracy of the biological profile. A multifactorial approach that integrates several mandibular measurements, dental characteristics, and other skeletal indicators is therefore preferable in forensic practice.[3]

From a methodological perspective, these findings highlight the importance of population-specific reference data and the need for cautious interpretation when applying gonial angle measurements beyond their validated context. Future research should include broader age groups, multiregional populations, and the use of 3D imaging techniques, as well as the integration of additional mandibular parameters, to improve the generalizability and forensic applicability of mandibular morphometric analysis.

This study has several limitations. The sample was restricted to adults from one urban district, and the findings may not represent populations with different ancestry, environmental exposures, dietary patterns, or socioeconomic characteristics. Although the sample was balanced by sex, the number of participants remained modest. Panoramic radiography is also susceptible to magnification, distortion, and positioning errors, despite the use of standardized landmarks and image-quality criteria. In addition, variables such as occlusal status, tooth loss, parafunctional habits, and masticatory muscle activity were not measured directly and may have contributed to residual confounding.[4]

CONCLUSION

Mandibular gonial angle variation among adults is more strongly influenced by sex than by chronological age within the studied population, indicating the persistence of sex-related differences in mandibular morphology throughout adulthood while remaining relatively stable across the examined age range. In relation to the research objectives, the findings indicate that the gonial angle has limited applicability for adult age estimation but may serve as a supportive parameter for sex estimation. The implication of this study is that mandibular gonial angle analysis can be used as an adjunctive tool in forensic odontology identification, particularly in situations where other sexually dimorphic skeletal structures are unavailable or fragmented.

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