Comparison of craniofacial linear measurements of 20–40 year-old males and females using digital lateral cephalometric radiography in Indonesia

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Abstract. Craniofacial characteristics are one of the sex determination parameters of age after puberty. The aim of this study is to obtain linear measurements using lateral cephalometric radiography of adults aged 20–40 years based on sex in Indonesia. Ten linear craniofacial parameters on 100 digital lateral cephalometric radiographs were measured. Inter-intra observer reliability was tested using Technical Error Measurement. The independent t-test and the Mann-Whitney U test were used to evaluate the significance of the findings. There are significant differences between males and females on 10 of the linear measurements using lateral cephalometric radiography. Lateral cephalometric radiography showed that the linear measurements of 10 cephalometric parameters were higher in males than females, so it can be used to determine sex.

1. Introduction
Radiographic examination has been widely used in the field of dentistry. One of its benefits is to evaluate the craniofacial region to diagnosis diseases and disorders. Lateral cephalometric projection is one standardized type of radiography that is widely used. This form of radiography is used to assess the relationship between jaws and teeth. It is also used to conduct a lateral cephalometric analysis and to evaluate the morphology of the craniofacial structures [1,2]. Craniofacial measurements, both clinically and radiographically, can provide very useful information in dentistry. Measurements using cephalometric radiographs can provide objective data showing dental, skeletal, and soft tissue alterations [3]. The measurement results are very beneficial in orthodontics, pedodontics, and forensic dentistry. In orthodontics, dentists must know the normal craniofacial measurements to determine the growth and development pattern of individuals, which are important to support the success of treatment [4,5].

Individual craniofacial measurements are also influenced by gender, which is based on differences in the growth pattern and growth rate between males and females [6]. Linear and angular measurements of anatomical craniofacial structures can be used to distinguish between male and female craniofacial characteristics [7]. Accordingly, these measurements can also be used in forensic dentistry as a tool to determine a person’s sex. Forensic dentistry has been developed due to the high potential for natural disasters and the high crime rate in Indonesia [8]. Both phenomena can result in many victims that, sometimes, are difficult to identify. Sex determination is one of the initial identifications that are made. Craniofacial bones can be used in sex determination because their
structure consists of a large area of hard tissues that are not prone to disintegration and that have a high resistance under various extreme conditions [9]. One study conducted by Hsiao et al. in Taiwan regarding sex determination using 22 lateral cephalometric measurements found that nine of the 22 measurements had an accuracy level of 95% [10]. A similar study in India also reported a high accuracy level (81.5%) [6]. However, the sample size and the type of population studied varied in both of these studies.

Currently in Indonesia, there are no sufficient studies regarding craniofacial measurements using lateral cephalometric radiography. Pereira et al. conducted a study on Caucasians in a Brazilian population and found that craniofacial measurement could be used to observe differences in the craniofacial growth stages [11]. Another study on craniofacial measurements, conducted in 2009 by Hsiao et al., used linear measurements to compare sex in Taiwan children and adolescents [11]. However, the measurement results for different races or specific populations cannot be generalized due to numerous factors, such as environment and genetics [4]. Research on craniofacial measurements in Indonesia was conducted by Anggani in 1992; that study used cephalometric radiographs to measure the dento-craniofacial components of subjects aged 19–25 years [12]. Until now, no study has investigated craniofacial measurements in an Indonesian population aged 20–40 years. Hence, this study aims to use lateral cephalometric radiography to conduct a descriptive comparison of craniofacial linear measurements between Indonesian males and females aged 20–40 years. The outcomes of this study can be used to determine a treatment plan in orthodontics and as primary data to support sex determination in forensic dentistry in Indonesia.

2. Materials and Methods
This descriptive analytical study used a cross-sectional method. It was conducted from June to September 2016 at the Department of Dental Radiology, Dental Hospital of Faculty of Dentistry Universitas Indonesia (RSKGM FKG UI). The samples used in this study were lateral cephalometric radiographs obtained from the medical records of dental hospital patients aged 20–40 years. There were 50 male subjects and 50 female subjects. The study began by selecting the samples based on the inclusion criteria, and then the radiographs were separated based on the subject’s sex. Furthermore, every radiograph was calibrated by comparing the actual length of the subject’s nasal rod and the length of the nasal rod in the radiograph. This step was carried out to obtain scales that were then inputted into AutoCAD™ 2016 software. Scale measurement in the radiographs was done using Adobe Photoshop™ software.

In the next step, linear measurements of the radiographs landmark were taking using AutocAD™ 2016, then the average value of every measurement parameter was calculated, for both male and female subjects. The measurements were performed by two observers. Subsequently, the consistency of the measurement results between two observers (inter-observer reliability) was tested; the consistency of the results by one observer (intra-observer reliability) was also tested. In the final step, statistical analysis was used to compare the linear measurement results of the lateral cephalometric radiographs between the male and female subjects.

3. Results and Discussion
3.1 Results
This study, which used craniofacial linear measurements of lateral cephalometric radiographs for sex determination in subjects aged 20–40 years, was conducted from June to September 2016. This study used 100 digital lateral cephalometric radiographs obtained from the Department of Dental Radiology, Dental Hospital of Faculty of Dentistry, Universitas Indonesia. The subjects consisted of 50 males and 50 females who met the inclusion criteria. In this study, Technical Error Measurement (TEM) was done to test inter-observer reliability and intra-observer reliability. Inter-observer reliability tests are useful to verify the consistency of the test results between two observers. Intra-observer reliability tests are used to ensure the consistency of the observer’s valuation at different time points. As shown
in Table 1, the inter-observer and intra-observer TEM values of 10 measurement parameters are less than 1 mm; thus, those results are acceptable.

Table 1. TEM Values of the Intra-observer and Inter-observer Reliability Tests for the Lateral Cephalometric Radiograph Linear Measurements

| Parameter   | Intra-observer TEM Values (mm) | Inter-observer TEM Values (mm) |
|-------------|---------------------------------|---------------------------------|
| N-ANS       | 0.172                           | 0.354                           |
| N-Me        | 0.218                           | 0.226                           |
| FsHt        | 0.598                           | 0.789                           |
| Ar-Go       | 0.551                           | 0.610                           |
| ANS-Me      | 0.262                           | 0.327                           |
| Me-Go       | 0.627                           | 0.776                           |
| MaWd        | 0.518                           | 0.359                           |
| MaHt        | 0.339                           | 0.329                           |
| Ba-ANS      | 0.603                           | 0.822                           |
| Ba-N        | 0.490                           | 0.752                           |

Table 2. Unpaired T-Test Results of the Lateral Cephalometric Radiograph Linear Measurements on Subjects Aged 20–40 years

| Parameter   | Sig. (2-tailed) | Mean Difference | Std. Error |
|-------------|-----------------|-----------------|------------|
| N-ANS       | 0.000           | 0.4078960       | 0.0667266  |
| FsHt        | 0.000           | 0.6904000       | 0.1260870  |
| Ar-Go       | 0.000           | 0.4860380       | 0.1258539  |
| ANS-Me      | 0.000           | 0.6344180       | 0.0972565  |
| Me-Go       | 0.010           | 0.3043460       | 0.1161530  |
| MaHt        | 0.000           | 0.2307780       | 0.0403179  |
| Ba-N        | 0.000           | 0.6931500       | 0.0927373  |

Table 3. Average Values of Lateral Cephalometric Radiograph Linear Measurements of Male and Female Subjects Aged 20–40 years

| Parameter   | Male Mean± SD (cm) | Female Mean± SD (cm) |
|-------------|--------------------|----------------------|
| N-ANS       | 6.118±0.355        | 5.710±0.311          |
| FsHt        | 4.015±0.672        | 3.324±0.586          |
| Ar-Go       | 5.431±0.723        | 4.946±0.518          |
| ANS-Me      | 7.661±0.523        | 7.027±0.446          |
| Me-Go       | 7.837±0.585        | 7.532±0.576          |
| MaHt        | 0.955±0.217        | 0.724±0.185          |
| Ba-N        | 11.619±0.455       | 10.926±0.472         |
Table 4. Mann-Whitney U Test Results for the Lateral Cephalometric Radiograph Linear Measurements of Male and Female Subjects Aged 20–40 years

|       | Female |       | Male |       |
|-------|--------|-------|------|-------|
|       | Median | Min.  | Max. | Median | Min.  | Max. |
| N-Me  | 0.000  | 12.614| 10.875| 13.861| 13.644| 12.154| 14.905|
| MaWd  | 0.000  | 1.551 | 0.997 | 2.328 | 1.934 | 1.178 | 2.904 |
| Ba-ANS| 0.000  | 10.011| 9.134 | 11.335| 10.763| 8.883 | 12.235|

As shown in Table 2, the significance levels (p) are above 0.05 for all seven parameters. This means that there are significant differences between the lateral cephalometric radiograph linear measurements for the male and female subjects. Table 3 shows the average values and the standard deviation for seven of the 10 measurement parameters. The Mann-Whitney U was then performed to determine the differences between the male and female subjects for the abnormal distribution data (N-Me MaWd, and Ba-ANS). As seen in Table 4, the test results have a significance level (p) < 0.05. This indicates a significant difference between the lateral cephalometric radiograph linear measurements for the male and female subjects. Table 5 also presents the median, minimum, and maximum values of the parameters.

3.2 Discussion

Craniofacial linear measurements can provide a significant amount of information in orthodontics and forensic odontology. In orthodontics, the measurement results can be used to assess the growth and development of craniofacial structures; it is also helpful in determining a treatment plan. In forensic odontology, craniofacial characteristics are beneficial as a parameter to determine an individual’s sex. The main reason why craniofacial characteristics are chosen as the strongest parameter is the prominent differences in the size and shape of the craniofacial features between men and women; for example, in males, the craniofacial area is broader and in females, it is rounder [13]. A variety of craniofacial parameters can be used to determine an individual’s sex, including the size of the mastoid processes, the mandibular bone and the orbital margin, as well as angular measurements, such as the gonial angles, and linear measurements, such as upper facial height, length of the craniofacial basis, and anterior facial height [6, 13]. In this present study, the morphometric method was chosen because it is more objective than morphological methods. A morphological method is more subjective, so the accuracy of the results obtained from a less-experienced observer will be low [10].

Based on the data reported in the previous studies mentioned above, this present study was conducted as initial research on the populations in Indonesia. This study aims to determine the sex of subjects aged 20–40 using specific craniofacial linear measurements from lateral cephalometric radiographs. The samples in this study consisted of 100 lateral cephalometric radiographs from 50 male and 50 female subjects. The lateral cephalometric radiographs used in this study are digital radiographs that met the inclusion criteria. Digital lateral cephalometric radiographs have several advantages over other types of radiographs; they do not require a chemical process; it is possible to minimize errors when determining the reference point; it is possible to analyzed the images directly using computer software; image storage can be simplified; and data can be transmitted without damaging the image quality. In addition, the image quality can be improved to obtain better clarity, so identification of the landmarks is more precise [1, 14]. According to previous study, in general, there are no significant differences between manual and computer-assisted measurement of lateral cephalometric radiographs [15].

In this study, the lower age limit of the samples was 20 because using craniofacial parameters to determine sex is typically only possible after the formation of different sexual characteristics, which are influenced by hormones after puberty (generally 14 years) and after active growth is completed [7]. Hormones that affect the growth of the mandible, maxilla, the upper face, the craniofacial base, and the height of the head will create extreme differences between the sexes. In women, active growth
occurs at the age of 13–15, while in men the growth continues from puberty into early adulthood [16]. Moreover, at the age of 18, maximum bone density has been achieved; at the age of 20, the active growth of the upper facial bones and mandible is complete [17]. The upper age limit of the samples was 40 because, at the age range of 25–40, the size of the craniofacial structures is still increasing; however, that process stops at 40 due to the aging process [17]. In this case, the age range was selected to obtain the perfect time when bone growth is stable. In this study, the age groups were divided into two groups: 20–24 years and 25–40 years. This was supported by research conducted by Kanchan et al. regarding sex determination with craniofacial measurements in lateral cephalometric radiographs [18]. That study showed no significant differences between age groups with an age range of 25–54 [18].

Linear measurement of digital lateral cephalometric radiographs was done using AutoCAD™ 2016 software. Previously, the magnification size of the lateral cephalometric radiographs was calibrated by comparing the nasal rod scale in the cephalometric X-ray device with the nasal rod scale displayed on the computer [19]. The use of AutoCAD software is based on a study on AutoCAD reliability [20]. That study concluded that there are no significant differences in lateral cephalometric radiograph measurements when using AutoCAD or Viewbox 3.1 [20]. In this present study, 10 cephalometric radiograph parameters were measured linearly: upper face height (N-ANS), total facial height (N-Me), frontal sinus height (FsHt), mandibular ramus height (Ar-Go), lower face height (ANS-Me), mandibular body length (Me-Go), mastoid width (MaWd), mastoid height (MaHt), the depth of the face (Ba-ANS), and the length of craniofacial base (Ba-N). These parameters were used in previous studies in India with a sample size of 105 and in Taiwan with a sample size of 100. Those previous studies deduced that the measurements of these 10 parameters were significantly different between men and women [6].

In this present study, Dahlberg’s TEM was used to test the reliability test of the measurement results obtained by the observer. The TEM test was performed in 25 sub-samples to assess the conformity of the measurements between two observers and the measurements of each observer at two different times. The results showed that all the intra-observer and inter-observer TEM scores are less than 1 mm; thus, it can be concluded that all the data in this study can be used for later analysis [21]. Furthermore, a normality test was performed on the 10 linear measurement parameters. Based on the results of the unpaired t-test and the Mann-Whitney U test the significance value of the lateral cephalometric radiograph linear measurements for all 10 parameters on was <0.05. Moreover, a significant difference was found between the male and female subjects. Furthermore, the average value of the seven parameters that have normal data distribution. As seen, the values for the males were greater than the values for the females. The median value of the three parameters that are not normally distributed (N-Me, MaWd, and Ba-ANS). The results show that the measurements of these parameters are larger in males than in females.

The measurement results obtained in this study demonstrate that craniofacial features are more spacious in men than in women. This finding is accordance with the concept of growth in humans [13]. The study conducted by Venkatesh et al. and Kanchan et al. on an Indian population also obtained the same result, the measurements of all 10 parameters were larger in males than in females [6, 18]. The craniofacial size differences between genders are caused by differences in growth patterns and rates. In women, craniofacial growth slows down after the age of 13, while in men, it continues until adulthood [22]. The results of this present study are similar to the findings reported by Kanchan et al. and Venkatesh et al., which concluded that there are significant differences in nine of the linear measurement parameters obtained from lateral cephalometric radiographs, except for ANS-Me [18]. In Venkatesh et al., the ANS-Me had no significant difference in a Tibetan population [6]. That study also stated that Ba-ANS, Ar-Go, and Me-Go were the most significant gender discriminators due to their stable condition after puberty [6].

This present study’s findings are also consistent with the results reported by Schuller in a study that investigated sex determination using the frontal sinus parameters [23]. That study concluded that the average size of the frontal sinus is greater in males than in females [23]. Other studies, such as those
conducted by Taniguchi et al., Tang et al., and Goyal et al., showed that the frontal sinus can be used as a parameter of sex determination, and the frontal sinus was larger in males than in females, but it varied for each individual. Furthermore, many studies have investigated the size of the mastoid process as a single parameter in sex determination. The results reported in Fatma's research on mastoid process measurements for sex determination in an Egyptian population were the same as the results obtained in this present study; both studies found significant differences in the size of the mastoid process between men and women. These differences may have occurred due to the structural development of the mastoid process, which is greater in men with respect to the response to muscle activity such as the sternocleidomastoid muscle; that muscle is attached to a larger area in men than in women [24].

The results obtained in this present study were impacted by several factors. Differences in the number and distribution of samples that are not evenly distributed in both gender groups can affect the statistical results. This can be due to the fact that the availability of digital cephalometric radiographs is limited; moreover, other factors, such as ethnicity or race, might not be considered. In addition, this study did not obtain medical record information, so the medical histories of the samples, which can influence the measurement results, were not considered. Furthermore, inter-population variations, such as genetic and environmental factors, epigenetics, socio-economic status, diet, and physical activity, can also affect the results of a study [9]. One study in Albanian showed craniofacial characteristics of men with a delicate structure of the mastoid and tapered orbital margin, even though those are the characteristics of women [25]. Based on that study, the genetic and environmental conditions of populations may affect the craniofacial form.

In terms of gender determination, some studies have been conducted using a specific population standard, and their findings could not be generalized due to inter-population variations [25]. This may lead to differences in the results of studies of different populations. A study conducted in Australia in 2013 by Franklin et al. [26], compared data on craniofacial size between Australians and South Africans and an American population; the results showed that the craniofacial size of Australians was 1–4% larger; thus, the data of the American population cannot be used for sex determination in Australia because doing so may lead to ambiguous results [26]. Therefore, it can be concluded that the general use of craniofacial measurement data for all populations may decrease the measurement accuracy. The current conditions while conducting research, such as the ability of the observers to determine the point of reference and the clarity and quality of the radiographs used, can also affect the research outcome [2]. This limitation can be anticipated by using digital cephalometric radiographs, which can reduce biased measurement results. However, according to Wenzel, digital radiographs will not be reliable if the original picture quality is too low; in such instances, improvements must be made to obtain better images [27].

As explained above, the quality of the radiographs can affect the accuracy of the anatomical structures that will be interpreted and the results of the measurements, especially the boundaries of the anatomical structures. These must be clearly seen so measurement consistency can be achieved. In addition, the quality of the monitor and the monitor’s light could influence the determination of the points on digital radiographs. Thus, optimal calibration of the display monitor beforehand is needed. The study conducted by Hellen et al. stated that when evaluating digital radiographs, it is necessary to evaluate the monitor to ensure that it meets specific standards [28]. One test used to calibrate the monitor's brightness and contrast is the Association of Physicists in Medicine images test, i.e., the Society of Motion Picture and Television Engineers (SMPTE) and Digital Imaging and Communications in Medicine [29]. This calibration is required to ensure detailed visibility of the structures being viewed and to differentiate the quality of the monitor’s display for medical or general purposes. In this present study, monitor evaluation and calibration were not performed. This could, possibly, have affected the measurement results. The data results of this research are expected to be used to determine the ratio and the size range of male and female craniofacial structures as a basis for determining the proper orthodontic treatment plan and as basic data for further research on sex determination in forensic cases.
4. Conclusion
Based on this study results, it is concluded that there is a significant difference in the craniofacial linear measurements in lateral cephalometric radiographs between men and women for the following parameters: upper face height (N-ANS), total facial height (N-Me), frontal sinus height (FsHt), mandibular ramus height (Ar-Go), lower face height (ANS-Me), mandibular body length (Me-Go), mastoid width (MaWd), mastoid height (MaHt), the depth of the face (Ba-ANS), and the length of craniofacial base (Ba-N). The measurement results for all 10 of these craniofacial parameters were greater in males than in females. To enhance this study, further research on sex determination in Indonesia using this method is required, with a larger and proportional sample. The cultural diversity in Indonesia is also worth considering. Moreover, further research is also needed to determine the size of craniofacial features for males and females in the age groups below 20 and above 40 to determine the cut-off value for the 10 craniofacial parameters in men and women.

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