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Evaluation of Gonial Angle Measurements in Digital Orthopantomogram and its Application in Age Estimation – a Retrospective Study

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ABSTRACT

Introduction: age estimation is an important aspect in forensics for clearing legal disputes in young and elderly people. Tooth eruption pattern is mainly used for age determination in children which is not applicable for adults. Various methods are available for adult age estimation, however all methods provides age in a wide range and is not reliable when all/many teeth are missing. In such scenarios Gonial angle can be used as an alternative method for determining age in adults. OPG is a readily available radiographic method for gonial angle measurement and can be conveniently used by dentist even in a clinical establishment. Digitalization has also made it possible for better visualization and measurement in radiographs. The present research attempts to find whether gonial angle measured in digital OPG can be used for age estimation in adults.

Methods: Digital OPG of subjects with recorded date of birth and exposure is selected, gonial angle is measured bilaterally by drawing tangent to posterior and lower border of mandible. The data is subjected to statistics to arrive at a regression equation for dental age estimation and is correlated with chronological age.

Results: Difference between the gonial angle of right and left side was statistically significant, however large difference was noted between estimated dental age and chronological age.

Conclusion: Gonial angle may not be a good predictor of age and it should be used as the last resort for age estimation when no other alternate parameters are available.

Keywords: Gonial angle; Digtal OPG; Age estimation.

Introduction

Aging is an inevitable change which includes a complex dynamic process involving both physical and mental alterations. For a long time humankind has developed various methods for the estimation of age of an individual with varied level of success. Age estimation is an important leap in forensic sciences not for the identification of corpses, but also for living individuals to clarify legal queries in delineating juvenile and adults in spheres pertaining to retirement benefits, employment, labour acts, crimes and accidents, which can prove challenging on some occasions in a multicultural society. Literature reports shows that various effective methods using tooth eruption patterns for age estimation in children and adolescents are available, however it is limited to a certain age and cannot be used in adults[1].

Adult age estimation using dentition is based on the secondary changes which occur after eruption namely; length of apical translucent zone, attrition, secondary dentin deposition, periodontal attachment, cementum apposition and root resorption[2]. Which provides age in wide range. These methods become futile when many or all teeth are missing or extensively damaged. In such scenarios other morphometric variable of mandible such as gonial angle comes in help. Brocca defined Gonial angle as "the angle formed by a tangent to the lower border of the mandible and a tangent touching the posterior border of the ramus at two points, one at the condyle and one at the angle region"[3].

Izard G in 1927 postulated that gonial undergoes various changes with age: 135 to 150 degrees at birth; 135 to 140 degrees when the first dentition is finished; 120 to 130 degrees up to the time of eruption of the second molars; and 120 to 150 degrees in old age[4]. However as a sequelae of aging various other changes like tooth loss[5] and muscle activity[6] can have remodeling effect on gonial angle. Another factor to be considered is the change in lifestyle and food habits of people which can alter this remodeling process of mandible and thereby changes in the gonial angle.

Determination of Gonial angle is done using different method which includes mandibulometer requiring whole mandible and cannot used in live individuals.[7] Radiographs such as Lateral cephalogram, Lateral oblique radiograph and Orthopantomogram (OPG) can used for measuring Gonial angle in live people.[7,8] However due to the inherent error of overlapping in Lateral cephalogram, and Lateral oblique radiograph these are not commonly used for determining Gonial

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angle. Orthopantomogram [OPG], is a frequently used investigation tool for dental diagnosis9, and it is available even in the smallest part of town. OPG can be easily interpreted by any dentist and age estimation can be done even in clinical establishment. Recording of Gonial angle in Convention OPG is tedious and require manual tracing or digitalizing the conventional OPG prior to measurements. Presently digitalization have taken over dental radiography which aid in more accurate visualization, measurements and recording of data. In digital OPG Gonial angle can be readily measured and compared bilaterally and simultaneously which enable the practitioner to concise the methodology with better accuracy.

The present study aims to understand whether gonial angle measurement in digital OPG can be utilized for the forensic age estimation in the present population, and the reliability of this method. The objectives includes to measure the right and left gonial angle in digital OPG and analyze whether there is any difference in right and left gonial angle in a subject, and Compare the dental age obtained from both sides with chronological age and find which side has more correlation with chronological age.

Materials and Methods

Materials:

A total of 253 Digital OPG of age ranging from 25 to 81 (124 Males and 129 Females) taken from archive files taken for various diagnostic purpose. The Digital OPG image was obtained with panoramic radiograph machine (Carestream Dental CS8100). Gonial angle measurements were done using Carestream software (CS Imaging 8.0.5).

Inclusion criteria:

- Radiographic data of all the individual above the age of 25 years will be included
- OPG images with clear mandibular border is included
- Data with date of birth details of individuals will be only included in the study

Exclusion criteria:

- Individuals below the age of 25 years
- Patients with developmental anomalies and pathologies involving the gonial angle
- Faulty image

Methodology

The study was initiated after clearing the institutional ethical clearance. Radiographic consent forms were taken from all the subjects as per institutional protocol at the time of x - ray exposure. A total of 253 OPG's were randomly selected from the image archives which falls within the inclusion exclusion criteria, no new radiographs were taken solely for the purpose of the study. The demographic parameters along with the date of exposure and date of birth are recorded using a study performa.

Right and left gonial was measured by the following method:

- The digital OPT is opened using the Carestream software. Select the drawing and annotations toolbar to expose the various hidden toolboxes (Fig.1, upper panel).
- Gonial angle is measured with measure angle tool (hidden in the toolbox). By clicking on the icon, software in built angle measurement gets selected.
- Angle is measured between the lateral border of ramus and the lower border of mandible on both right and left side and the view is saved for future references. After obtaining the chronological age of the patient the data is subjected to statistical analysis to arrive at a regression equation for age estimation using gonial angle (Fig.1, lower panel).

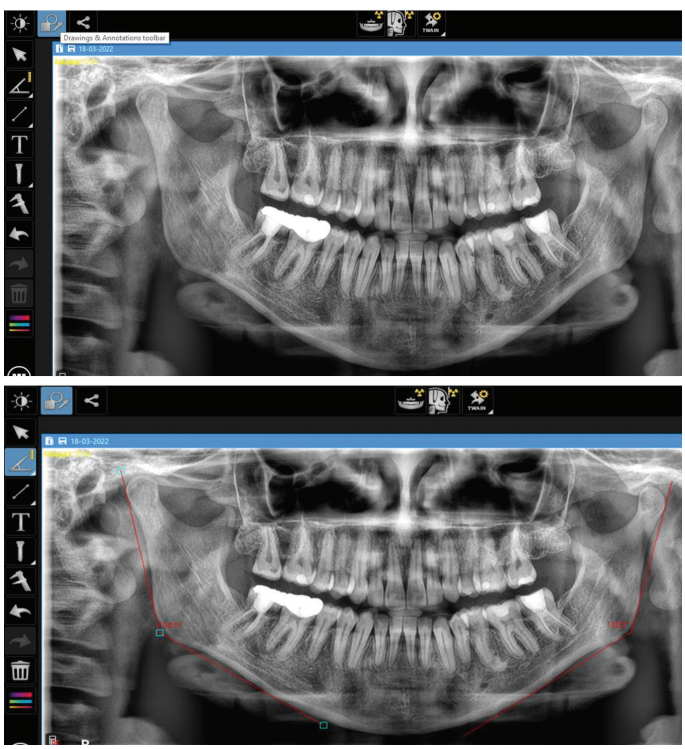

Figure 1. Drawing and annotation toolbar exposing the measure angle tool.

Statistical analysis:

First objective was to ascertain the difference between the gonial angle between right and left side. Shaprio Wilk test was done to know the normality of distribution, p value of the normality test is more than 0.05 and hence paired t test is used to compare the right and left angles for all the subjects.

Linear regression analysis was used to correlate the gonial angles with chronologic age, and derive specific regression equation using right and left gonial angle considered as independent variable to estimate the dental age which is taken as dependent variable.

The correlation between the chronological age and the dental age was determined using Pearson's r.

Results

a) Comparison of right and left gonial angle in total of 53 samples:

Shapiro test showed a normality in difference in the right and left gonial angle and paired t test showed that there is a significant difference in average gonial angle of right and left side, on an average the left side gonial angle is more than that of right side gonial angle (P value< 0.001). (Table: 1)

b) Pattern of distribution of right and left gonial angle respectively with age:

Figure 2 shows that there is no specific pattern followed in the distribution between the two variables right /left gonial angle with chronological age which indicates that changes in gonial angle does not clearly represents the changes in age.

c) Specific Regression Formula:

Tables 2 and 3 gives the summary of regression analysis carried out by considering age as the dependent variable and gonial angle as independent variable.

Right gonial angle: Regression equation is derived taking the intercept as 32.852 and slope as 0.087 to estimate the age. The age obtained is not statistically significant correlated with right gonial angle. (Table 2)

Table 1. Comparison of difference between the right and left gonial angle in 253 samples.

	N	Mean	SD	Test Statistics	p value	Mean Difference	95% CI for Mean Difference	
							Lower Limit	Upper Limit
RGONIAL	253	124.651	8.44	-5.57	<.001	-1.49	-2.02	-0.965
LGONIAL	253	126.143	8.52					

(R: Right; L: Left; N: Number; SD: Standard deviation; CI: Confidence Interval)

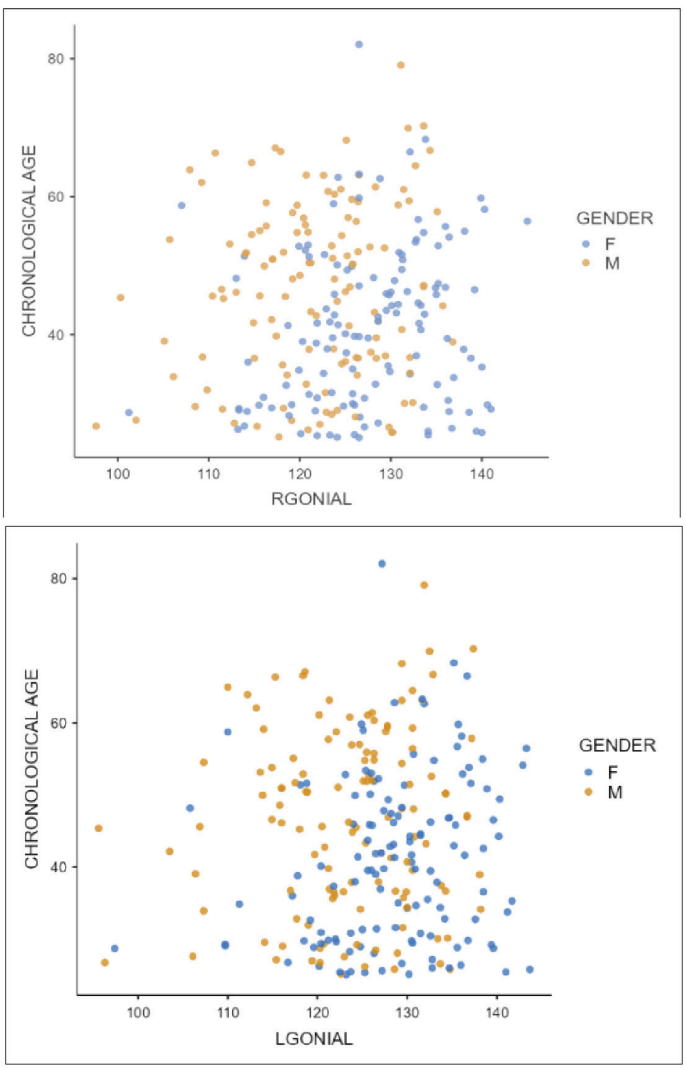

Figure 2. Gonial angle measured using the measure angle tool.

Table 2. Linear regression analysis taking right gonial angle as independent variable and age as dependent variable.

Predictor	Estimate	SE	t	p	R^2
Intercept	32.852	11.57	2.839	0.005	0.003
RGONIAL	0.087	0.093	0.936	0.35	

(R: Right; SE: Standard error)

Table 3. Linear regression analysis taking left gonial angle as independent variable and age as dependent variable.

Predictor	Estimate	SE	t	p	R2
Intercept	35.479	11.601	3.058	0.002	0.002
RGONIAL	0.065	0.092	0.707	0.481	

(L: Left; SE: Standard error)

Left gonial angle: Regression equation is derived taking the intercept as 35.479 and slope as 0.065 to estimate the age. The age obtained is not statistically significant correlated with left gonial angle. (Table 3)

• The two regression equations are:

Age = 32.852 + 0.087 RGONIAL

Age = 35.479 + 0.065 LGONIAL

d) Correlation between predicted age and chronological age:

Even though there is no statistically significant correlation between the age obtained and gonial angle (p value> 0.05) it can be inferred that age estimated from the right gonial angle has comparatively lesser error and more correlation with dental age than the age estimated from left gonial angle. (Table 4)

Table 4. Correlation between chronological age and predicted age.

Predicted Age Using RGONIAL		Predicted Age Using LGONIAL	
Pearson's r	**p-value**	**Pearson's r**	**p-value**
0.059	0.35	0.045	0.481

(Right; L: Left)

Discussion

Age is one of the key factor which help in identification of a person. Age estimation using different structures of body have been used as an important tool for both post and perimortem age calculations for clearing criminal or civil liabilities. Tooth development and sequence of eruption of teeth proves to be the most accurate method for age determination in children and adolescents. In adults various methods have been devised for age estimations which basically revolves around the changes that occur to the teeth post eruption which includes visual, histological and radiological method.[10] Even with usage of the various complex process involved, age determined falls in a wide range and the accuracy of adult age estimation using dentition is questionable[10]. In situations where there is severe damage to the teeth or completely edentulous cases age determination using dentition becomes impossible. Many longitudinal studies have been done which shows that aging have a notable influence on remodeling of mandible.[11] Gonial angle is a radiological and morphometric angular parameter, which forms a major landmark of mandible and changes in gonial angle is also influenced by age, muscle activity, systemic factors and tooth loss[12,13]. Therefor gonial angle can be implemented for age estimation when edentate mandible or mandible with extensive mutilated tooth/teeth is available.

Application of gonial angle obtained by different methods in age estimation have been previously studied[7,8,9]. However in the present era with the boom in the technology available, digitalization have made it possible for more accurate visualization and measurements of various radiological parameters.[14] Additionally there is a rapid change in the lifestyle of people which affects their food habits, dental hygiene awareness and the possible teeth rehabilitation methods available which could affect the remodeling of mandible and can have indirect effect on gonial angle.[15] Thus it necessitates for the study to confirm the effect of digitalization and modernization on age estimated from gonial angle.

Here in the present study a total of 253 radiographic samples (129 females and 124 males) with age ranging from 25 to 82 years was collected and gonial angle was measured and evaluated for age estimation. Digital Panoramic radiographs was used for assessing the gonial angle as it eliminate the process of digitalization and then measuring the gonial angle or manual measurement of gonial angle. All the radiographs are taken using the same radiographic machine with same standard protocol of patient positioning and exposure parameters. Digital OPG with inbuilt software's not only helps in easing the angular measurements but also helps in simultaneous bilateral measurements and comparison. Gonial angle measured from OPG have shown to be having a closer value similar to the gonial angle measured from dry mandible[16]. Reliability of angular measurements from OPG for the assessing gonial angle and its superiority over lateral cephalogram for the same is already a proven fact[17,18]. Because of the added disadvantage of superimposition of right and left sides of mandible in lateral cephalogram, digital OPG was considered for gonial angle measurements. Regarding the sample size, a sufficient number of sample with wide age range (25-82) was collected which can substantiate whether gonial angle from digital OPG can be used as effective tool for age estimation for the present era.

Out of the total 253 samples, the mean of the gonial angle in the left side was found to be greater than the mean of gonial angle in right side. It is noteworthy to mention that even though the difference in the mean of gonial angle of right and left side was small, it was statistically significant (Table 1). This difference could be due to the factors like inherent asymmetry of mandible, irregular increase in thickness in lower or posterior borders of mandible or even due to the favored use of one side for chewing[6]. However many studies such as done by Mandeep Kaur Bhullar *et al*[8] , Gungor Kahraman *et al*[19] and T.A.Larheim *et al*[18], have shown contradictory results showing that there was no statistically significant difference in gonial angle obtained from either sides. Gabriel, 1958[20] demonstrated that development of mandible in early stages are also affected by racial and regional difference. Another study done by Mbajiorgu,[21] 1996 also shows that gonial angle varies with population group, European population (128°) , which was greater than that of Indian mandible (119°), Chinese population (119°) and Neanderthals(110°).

In the present study gonial angle did not show any specific noticeable changes in accordance with age (Figure 2). This may be due to the fact that age as such does not directly influence variations in gonial angle but may be due to the action of muscles of mastication, pattern of tooth loss, bone mineral density and use of denture (sequel of aging process). Similar kind of reports was also obtained in studies done by Anna Cottle *et al* (2009)[22] H. Isreal *et al* (1973)[23], A.M. Raustia *et al* (2008)[24]. In opposition, study done by Shilpa B *et al* (2014)[25] implied that a strong association was present between gonial angle size and age, revealed a trend of increase in mean gonial angle values with increasing age. Author explains this trend by stating that the reduction in density of bone and decrease in activity of the medial pterygoid and masseter muscle activity with age results in widening of the gonial angle. Ram

Ballabh Upadhyay *et al* (2012)[7], Ashima Behl, *et al* (2022)[26] demonstrated a decrease in gonial angle with advancing age.

The linear regression analysis was done with gonial angle as independent variable and age as dependent variable and equation for right and left side was obtained. Correlation of right and left gonial angle to age was done independently and results showed that gonial angle was poorly correlated with age (p value<0.05). The application of the regression equation in real life scenario using the sample also showed large errors which proved that age cannot be predicted using gonial angle. Similar study done by Elisabeth ohm *et al*[27] in 1999 and Vinicius Dutra *et al*[28] in 2004 also reported that age was less clearly related to size of the gonial angle. This was attributed to the fact that most of the changes in gonial angle only occurred after the loss of all the teeth. In complete dentition all the muscles takes part in mastication whereas in partial or complete edentulous cases masseter muscle become weak which may possibly be related to changes in gonial angle[29].

Gonial angle undergoes various changes from obtuse at the early infantile stage, with the eruption of teeth and mandibular growth it becomes more acute and as age increases gonial angle become obtuse[3]. Extensive tooth loss or complete edentulousness can have effect on the mandibular angle unless dentures are fitted which decelerates the changes in angle. In edentulous condition as there is a loss of the occlusal table an attempt to oppose the jaws bring only the anterior mandible in contact with the maxillary arch. Continuous resorption of alveolar bone also reduces the vertical height of the face. Both these factors causes the masseter and medial pterygoid to configure the mandibular angle so as to adapt to new mandibular position and function (maintain parallelism of occlusal table)[6]. Studies done by Keen (1945)[6], Casey DM *et al* (1988)[30] and Nuran Yanikoglu *et al* (2008)[31] showed that prosthetic rehabilitation improved the functioning of masticatory muscles, maintains the normal mechanism of mandibular movements and thereby reduces the rate by which these changes occur in mandibular angle. Recent studies (Amit Kumar Mishra *et al* in 2021)[32] have also revealed that most of the elderly people are at least aware of the various rehabilitation modalities available and are willing for replacement or already have prior experiences with denture. It could be said that early prosthetic replacement becoming a common scenario which prevents the obvious changes in gonial angle that would otherwise take place. However in due course of time the alveolar bone continues to be resorbed (disuse atrophy)[33] which will eventually lead to similar changes in angle.

In dentate and partially edentate state (unilateral and posterior tooth loss), no statistically significant difference in gonial angle was found by Ceylan *et al* (1998)[34] but Oettlé *et al* (2009)[22] stated that more uniform masticatory forces and chewing was present for dentate or bilaterally partial edentulous group when compared to unilateral partial edentulous molars resulting in more acute angle in dentate or bilateral edentulous state. Poul Erik Petersen *et al* (2020)[35] did a 10 year survey on public health intervention against oral diseases among all age groups which revealed the reduced prevalence of tooth loss by avoiding the incidence of caries, periodontal problems and improving the general health of people through community, school based awareness programs and introduction of fluorides. Prolonging the time period prior to complete tooth loss prevents significant changes in gonial angle.

The variations in gonial angle are not abrupt and is in accordance with the variation in function the bone was submitted to. According to a report by Casey DM *et al* (1988)[30], after adulthood the average gonial angle did not change until at least 70 years of age, except when teeth were lost extensively. Even after tooth loss if there is immediate replacement by denture, it would slow down the moulding of angle. This could explain the indefinite correlation between age and gonial angle in the present study.

Conclusion

Gonial angle was measured using digital OPG in a total of 253 sample and was correlated with age in this study. First objective was to measure the gonial angle using digital OPG. Gonial angle can be effectively and simultaneously measured from Digital OPG. The measured gonial angle was slightly higher in the left side when compared to the right side and there was no specific pattern in presentation of angle with advancing age. The age estimated from right and left gonial angle had huge difference from the actual age which could be attributed to the changes in lifestyle and food habits of the present population. Further studies can be done in other ethnic groups or different populations to better understand the changes in gonial angle with age. Therefore it can be said that gonial angle may not be a good predictor of age.

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Ethics Statement

All radiographs were taken following the institutional protocol for radiation exposure and no new radiographs were taken solely for the purpose of the study. All radiographs were obtained from the image file archives taken previously for various other diagnostic purpose after obtaining consent from the patients to use radiographs for research purpose with disclosing their anonymity.

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