A study on the effects of ageing on mandibular morphology: A digital radiographic assessment

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SUMMARY

The aim of this study was to determine, compare and differentiate the morphologically related changes of the mandible in dentate males and females among different age groups on digital panoramic images, and to assess their authenticity in age estimations to provide evidence in forensics. The panoramic images were made for 420 subjects of four age groups: 12-18 years, 19-40 years, 41-60 years, and older than 60 years. The gonial angle, condylar length, ramus length, cortical bone thickness, and ramal notch width were measured and evaluated. The data obtained were then subjected to descriptive statistical analysis followed by Paired t-test and Two-way ANOVA test. On measuring angular and four-linear measurements, statistically significant differences were found among all the age groups with $p < 0.05$, and also increased on aging except for the gonial angle. Among all the parameters, the gonial angle, ramus length, and ramal notch width depicted a statistically significant difference between the right and left sides with $p < 0.05$. It is found that all parameters except the gonial angle were reliable for age determination. Hence, this study positively recommends the use of all parameters except the gonial angle for the purpose of age estimation in the field of forensics.

Key words: Digital radiographic assessment – Age estimation – Orthopantomography – Linear and Angular measurements – Mandible

INTRODUCTION

According to evolutionary biology studies, humans are descended from ancient apes (National Academy of Sciences, 1999). There are exciting developments in all fields that contribute to our understanding of human evolution (Gluckman et al., 2011). Many studies have characterised the evolution of genetically based variations in personality between age and sex groups as well as their genetic components (Ngun et al., 2011).

In legal medicine and forensic anthropology, establishing the identity of the unknown deceased person in a crime, accident, suicide, or mass tragedy, as well as for criminals who are hiding their identities, is very critical (Weisberg et al.,

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2011), and skeletal traits are among the most commonly used traits to determine a person's gender and age (Maloth et al., 2016).

The mandible exhibits many anatomical and morphological changes with the progression of age. Changes in the size and shape of the mandible are noticed along with the gradual growth and the function of jaws, which vary according to age, gender, and dental condition (Okşayan et al., 2014). The gonial area, the antegonial region, the condyle, and the ramus are some of the remodelling areas in the mandible that alter (Ghosh et al., 2010). All these areas are best viewed, measured, and evaluated by Orthopantomography (OPG), which is a commonly employed method in scientific research and criminal investigations for age and sex determination (Maat et al., 2006).

The current study aims to evaluate the morphological alterations in the mandible with ageing and dental condition by considering one angular and four linear measurements across the body and ramus of the mandible.

MATERIALS AND METHODS

In the Department of Oral Medicine and Radiology, a prospective study was conducted with the sample size of 420. After critical reviewing, the research was approved by the Institutional Ethics Committee.

The clinical examination was carried out after obtaining written consent and assent from the selected subjects, and the clinical findings were recorded in individual proforma specially designed for the study. The panoramic digital radiographs were taken using the Planmeca Promax Digital Panoramic system, under standard exposure conditions as recommended by the manufacturer.

This study included groups of young and old dentulous individuals who had complete sets of medical records and whose teeth were all intact except for third molars (present or absent), over 60 years old with at least five teeth in each quadrant, except third molars. Old denture wearers and any patients with the presence of supernumerary teeth (erupted or impacted), any systemic disease affecting the jawbone, and subjects with history or evidence of orthodontic or orthognathic treatment were excluded from the study.

In our study, all 420 subjects were categorised into 4 different age groups. Group 1 of 12-18 years, group 2 of 19-40 years and group 3 of 41-60 years were comprised of 120 (28.6%) individuals each, except for group 4 of greater than 60 years, which comprised 60 (14.3%) individuals.

The first age group in our study consists of subjects up to the age of 18 rather than 20, because development in female subjects gradually ceases by the age of 18. As a result, this may make a greater difference when comparing various age groups.

All mandibular measurements were made bilaterally using ROMEXIS DICOM viewer software (Planmeca, Helsinki, Finland). The present study was performed for about 18 months.

The parameters that were measured in our study were as follows:

- **Gonial angle:** It is formed by drawing a line between two imaginary lines that extend from the inferior border of the mandible to the ramus of the mandible.
- **Condylar length:** It is the distance between two lines drawn tangentially, one at the superiormost point of the condylar head and the other at the deepest point of the sigmoid notch's concavity.
- **Ramus length:** It is calculated by drawing two lines, one perpendicular to the ramus tangent line at the level of the most lateral image of the condyle and the other perpendicular to the ramus tangent line at the level of the most lateral image of the ramus. The distance between these two lines is the ramus length.
- **Cortical bone thickness:** The thickness of the radiopaque band is measured at the lower border of the mandible's body, where the antegonial notch begins mesially.
- **Ramal notch width:** It is the distance between the ramus tangent line and the ramus notch concavity's deepest point.

Figure 1 is a panoramic image showing the gonial angle (green line), condylar length (pink line), ramus length (blue line), ramal notch width

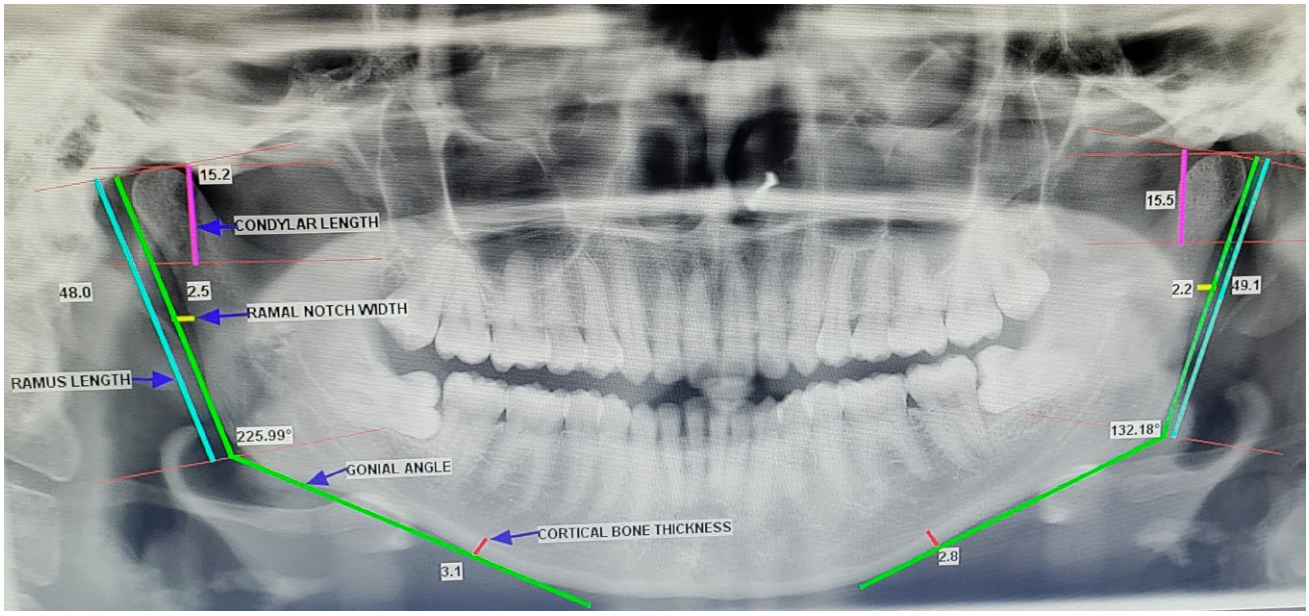

Fig. 1.- Panoramic image using Planmeca Romexis Software.

(yellow line) and cortical bone thickness (red line), which are measured using Planmeca Romexis Software.

For each variable, descriptive statistics followed by Two-way ANOVA test were determined. The difference in measures between the left and right sides of the mandible were analysed using a paired t test.

RESULTS

Gonial angle

The mean value of the Gonial Angle among groups 1 (12-18 years) was 180.8372, group 2 (19-40 years) was 180.0166, group 3 (41-60 years) was 180.6042, and group 4 (greater than 60 years) was 180.4131.

The mean value of the gonial angle was comparatively higher among the younger age group and lower among the older age group. Therefore, the gonial angle decreases as age increases.

The mean value of the gonial angle showed no significant differences between all age groups. Thus, this was found to be statistically insignificant with a p value ($p = 0.568$) (Table 1).

The right and left sides of the gonial angle showed a significant difference and were found to be statistically significant with $p < 0.05$. The gonial angle on the right side showed a significantly higher value than the left side (Table 2).

Condylar length

The mean value of the condylar length in group 1 (12-18 years) was 20.9397; in group 2 (19-40 years), it was 22.1681; in group 3 (41-60 years), it was 22.2246, and group 4 (older than 60 years) it was 22.1692.

The mean value of the condylar length was comparatively lower among the younger age group and higher among the older age group. Therefore, the condylar length increases as age increases.

The mean value of the condylar length showed a significant difference between all age groups. Thus, this was found to be statistically significant with a p value. ($p = 0.035$).

The right and left sides of condylar length showed no significant difference and were found to be statistically insignificant with $p > 0.05$.

Ramus length

The mean value of the ramus length among group 1 (12-18 years) was 65.9610, group 2 (19-40 years) was 69.8940, group 3 (41-60 years) was 70.1633 and group 4 (older than 60 years) was 70.8367.

The mean value of the ramus length was comparatively lower among the younger age group

and higher among the older age group. Therefore, the ramus length increases as age increases.

The mean value of the ramus length showed a significant difference between all age groups. Thus, this was found to be statistically significant with a p value (p = 0.000).

The right and left sides of the ramus length showed a significant difference and were found to be statistically significant with $p < 0.05$. The ramus length on the right showed a significantly higher value than on the left.

Table 1. Comparison of four Age groups (Group 1, Group 2, Group 3, Group 4) with mean values and standard deviation of gonial angle (°), 1) ramus length (mm), condylar length (mm), cortical bone thickness (mm) and ramus notch width (mm). Two-way ANOVA test for all parameters.

Descriptive Statistics				**Two-way ANOVA test**		
Variables	**Ages** (in years)	**Mean**	**Std. Deviation**	**Mean Square**	**F**	**Sig.**
Gonial angle	12-18	180.8372	6.35736	14.399	0.674	0.568
	19-40	180.0166	5.20161			
	41-60	180.6042	2.44684			
	60+	180.4131	1.92699			
Condylar length	12-18	20.9397	3.88782	58.004	3.584	0.014*
	19-40	22.1681	4.44695			
	41-60	22.2246	3.70023			
	60+	22.1692	4.06674			
Ramus length	12-18	65.9610	9.78409	522.762	7.731	0.000*
	19-40	69.8940	8.07540			
	41-60	70.1633	7.99625			
	60+	70.8367	7.07502			
Cortical bone thickness	12-18	3.3413	0.62294	5.794	11.531	0.000*
	19-40	3.6350	0.59964			
	41-60	3.8704	0.73088			
	60+	3.7517	0.91614			
Ramal notch width	12-18	2.5629	0.94160	8.275	8.419	0.000*
	19-40	2.8821	1.01761			
	41-60	2.9317	0.86233			
	60+	3.3858	1.08460			

*$P<0.05$ significance at 5% level of significance.

Table 2. Comparison of right and left sides of gonial angle (°), ramus length (mm), condylar length (mm), cortical bone thickness (mm) and ramus notch width (mm) with mean values and standard deviation. Paired T-test for all parameters.

Variables	**Sides**	**Mean**	**Std. Deviation**	**Paired differences**		**p**
				Mean	**Std. dev**	
Gonial angle	Right	236.0962	8.19937	111.24123	15.46445	0.000*
	Left	124.8550	9.76338			
Condylar length	Right	21.8139	4.19556	-0.03900	2.69601	0.767
	Left	21.8529	4.35044			
Ramus length	Right	69.2093	8.78312	0.45469	3.06425	0.003*
	Left	68.7546	8.76774			
Cortical bone thickness	Right	3.6179	0.75727	-0.03429	0.46712	0.133
	Left	3.6521	0.76497			
Ramal notch width	Right	2.7962	1.03384	-0.16167	0.69174	0.000*
	Left	2.9579	1.07159			

*$P<0.05$ significance at 5% level of significance.

Cortical bone thickness

The mean value of cortical bone thickness of group 1 (12-18 years) was 3.3413; for group 2 (19-40 years), 3.6350; for group 3 (41-60 years), 3.8704, and for group 4 (older than 60 years), 3.7517.

The mean value of the cortical bone thickness was comparatively lower among the younger age group and higher among the older age group, and again, after 60 years, the cortical bone thickness starts decreasing. Therefore, the cortical bone thickness increases as age increases, and after 60 years it starts to decrease.

The mean value of cortical bone thickness showed a significant difference between all age groups. Thus, this was found to be statistically significant with a p value ($p = 0.000$).

The right and left sides of cortical bone thickness showed no significant difference and were found to be statistically insignificant with $p > 0.05$.

Ramal notch width

The mean value of the ramal notch width for group 1 (12-18 years) was 2.5629; for group 2 (19-40 years), 2.8821; for group 3 (41-60 years), 2.9317, and for group 4 (older than 60 years), 3.3858.

The mean value of the ramal notch width was comparatively lower among the younger age group and higher among the older age group. Therefore, the ramal notch width increases as age increases.

The mean value of the ramal notch width showed a significant difference between all age groups. Thus, this was found to be statistically significant with a p value ($p = 0.000$).

The right and left sides of the ramal notch width showed a significant difference and were found to be statistically significant with $p < 0.05$. The ramal notch width on the left showed a significantly higher value than on the right side.

DISCUSSION

This study's discussion centres on a number of methodological challenges that frequently occur when attempting to estimate age at death or when providing osteological evidence that may aid in confirming identifications (Konigsberg et al., 2008). The identification of the person and the assessment of the cause of death are the two basic issues that arise when human skeletal and dental remains are discovered (Mann et al., 1990). In forensic science, determining age and gender from skeletal remains is the first step (Sairam et al., 2016).

To aid forensic identification, recent research has focused on using multiple skeleton features to assess variation linked to age and ethnicity (Franklin et al., 2008). Bones change constantly during a person's life, and those changes in the skeleton follow a chronological pattern. Knowing what changes occur in the bones can aid in determining the age of the skeleton. The skull and mandible, in addition to the pelvis, are the few additional skeletal remains that display the highest sexual dimorphism, and should be used for this purpose when accessible (Dudar et al., 1993). The mandible is considered a significant tool in age determination, because it is a strong bone that is difficult to break and disintegrate, and also because of the changes in the size and shape of the jaw bones that occur during adult life.

Radiology is critical in determining a person's age. Radiological images were utilised in the process of estimating age, which is among the most important tools in forensic science (Franklin et al., 2008). Panoramic imaging is a widely implemented technology in routine dental exams. It is a practical method for surveying dental problems, as it provides all of the necessary information on a single panoramic film. As a result, the parameters in this investigation were measured using panoramic radiography (Sairam et al., 2018).

This study assessed, correlated, and evaluated one angular (gonial angle) and four linear (condylar length, ramus length, cortical bone thickness, and ramal notch width) mandibular measurements as seen on digital panoramic radiographs in order to determine their utility in determining the age.

Gonial angle

In our present study, there was no significant difference in gonial angle between any of the

age groups, which was found to be statistically not significant with p > 0.05. This statement is in agreement with the studies conducted by Okşayan et al. (2014), Ceylan et al. (1998), Raustia and Salonen (1997), Fish (1979), Xie and Ainamo (2004), who also found non-significant difference in the gonial angle between the different age groups. In contrast, the study performed by Ohm and Silness (1999) found that the gonial angle increases with age and advancing edentulism. As our study did not include edentulous subjects, this could be one of the reasons for the difference observed in the increased gonial angle found by Ohm and Silness. However, on considering the dentate subjects, this study was found to be correlated with our study. Overall, this parameter (gonial angle) did not show a promising parameter for age determination.

In our study, we discovered a significant difference in the gonial angle between both sides of the jaw, which might be due to developmental variations. The above statement is in correlation with the findings by Chol et al. (2013), who also discovered a significant difference in the gonial angle between the right and left sides of the jaw, with the left side showing a greater value and p < 0.05. However, in our study, the gonial angle was significantly greater on the right side of the mandible and was found to be statically significant when pairing right and left gonial angles with a p value < 0.05. Another study performed by Larheim and Svanaes (1986) observed no significant difference between the right and left gonial angles. All these disagreements might be due to a disparity in sample size and the age group (14-28 years) of their study population.

Condylar length

When comparing different age groups, a study performed by Huumonen et al. (2010) revealed a significant difference in condylar length, in which the condylar length was found to be smaller in the older age group than in the younger age group. In our study, the condylar length was found to be comparatively greater in the older age group than in the younger age group. In contrast, Okşayan et al. (2014), Joo et al. (2013), Raustia and Salonen (1997), Sairam et al. (2018) and Merrot et al. (2005) revealed no significant differences in condylar length when comparing different age groups. This disagreement in the studies might be due to disparities in ethnicity, sample size, and age group. The studies that are in disagreement included edentulous subjects. Our study did not include edentulous subjects, as loss of tooth or edentulism will be associated with changes in mandibular morphology. Overall, this parameter (condylar length) appears to be a promising factor for age determination.

In addition, our study did not show a statistically significant difference in condylar length when comparing both sides of the mandible and found to be statistically insignificant with p > 0.05.

Ramus length

In our study, a significant difference in ramus length was observed between all age groups, which might be due to developmental variations. This statement is in agreement with the other study by Okşayan et al. (2014), who also noted significant differences in ramus length values between all age groups. However, this is not in agreement with the findings of Joo *et al.* (2013), Raustia *and* Salonen (1997) and Merrot *et al.* (2005), who reported no significant difference in the ramus length with ageing. This disagreement in the studies might be due to differences in ethnicity, sample size, and age group. The findings that were found in our study, as well as those of Sairam et al. (2018), show that ramus length increases with age. In contrast, studies by Okşayan et al. (2014) and Huumonen *et al.* (2010) observe that ramus length decreases as age increases. This disagreement might be due to the fact that our study did not include edentulous subjects, as loss of tooth or edentulism will be associated with changes in mandibular morphology. Overall, this parameter (ramus length) can be used for age determination.

In our study, a difference in ramus length was found between the right and left sides of the mandible and was found to be statistically significant, with the right side showing a higher value (p = <0.05).

Cortical bone thickness

In our present study, a statistically significant difference in the thickness of cortical bone was observed between all age groups of dentate subjects and was shown to be in accordance with a few other studies carried out by Joo et al. (2013) and Schwartz-Dabney and Dechow (2002). The cortical bone thickness found in our study was statistically lower in younger age groups and increased in older age groups. Our study did not include completely edentulous individuals. Hence, this factor cannot be compared with the findings involving edentulous subjects in previous studies. Overall, this parameter (cortical bone thickness) can be strongly used for age determination.

In our study, though a difference in the cortical bone thickness was found between right and left sides of the mandible, the right side showed a greater value than the left side and was found to be statistically insignificant with $p > 0.05$.

Ramal Notch width

The study by Okşayan et al. (2014), observed that ramal notch width increases with age but showed no statistically significant differences when compared with different age groups. In our study, ramal notch width was found to be statistically significant, being lower in younger age groups and increasing in older age groups. This factor is not correlated with the study conducted by Okşayan et al. (2014), who did not find any significant differences in ramus notch width when comparing different age groups. This disagreement in the study might be due to the fact that it involved only the older age group subjects (60-69 years) as well as edentulous subjects, and also due to variations in ethnicity and sample size. Our study included four different age groups, of 12 to 60 years-and-above subjects, and no edentulous subjects were included. Overall, this parameter (Ramal notch width) was found to be a promising factor for age determination.

In our study, when comparing the right and left sides, the ramal notch width was greater on left side than on right. However, this was statistically not significant with $p > 0.05$.

As this was a time-bound study, a statistically qualified minimum sample size was assessed. In the future, further studies are recommended to validate our hypothesis with the larger sample size, including various ethnicity and socioeconomic groups for age determination.

From overall results obtained in our present study, it was revealed that all parameters can be used as a tool for age estimation, as the condyle length, ramus length, cortical bone thickness and ramal notch width (all except the gonial angle) show anatomical variations between different age groups and are found to be statistically significant. Therefore, it is concluded that all linear measurements, except the angular measurement on digital panoramic images, with significant differences among different age groups, can be used in forensic anthropology as valuable tools for the estimation of age. Because linear measurements vary depending on population ethnicity, age, and dental state, there is a need to define harmonised standards for diverse populations in terms of age group and dental status. Hence, these measurements are advocated varyingly for providing evidence in forensics, especially when other bones of the skeleton are unavailable.

REFERENCES

CEYLAN G, YANÍKOGLU N, YÍLMAZ AB, CEYLAN Y (1998) Changes in the mandibular angle in the dentulous and edentulous states. *J Prosthet Dentist,* 80(6): 680-684.

CHOLE R, PATIL R, BALSARAF CHOLE S, GONDIVKAR S, GADBAIL A, YUWANATI M (2013) Association of mandible anatomy with age, gender, and dental status: a radiographic study. *ISRN Radiology,* 2013: 453763.

DUDAR JC, PFEIFFER S, SAUNDERS SR (1993) Evaluation of morphological and histological adult skeletal age-at-death estimation techniques using ribs. *J Forensic Sci*, 38: 677-685.

FRANCIS FISH S (1979) Change in the gonial angle. *J Oral Rehabil,* 6(3): 219-227.

FRANKLIN D, CARDINI A, HIGGINS PO, OXNARD CE, DADOUR I (2008) Mandibular morphology as an indicator of human subadult age: geometric morphometric approaches. *J Forensic Sci,* 4: 91-99.

GHOSH S, VENGAL M, PAI KM, ABHISHEK K (2010) Remodelling of the antegonial angle region in the human mandible: A panoramic radiographic cross-sectional study. *Med Oral Patol Oral Cir Bucal,* 15: e802–7.

GLUCKMAN PD, LOW FM, BUKLIJAS T, HANSON MA, BEEDLE AS (2011) How evolutionary principles improve the understanding of human health and disease. *Evol Appl*, 4(2): 249-263.

HUUMONEN S, SIPILÄ K, HAIKOLA B, TAPIO M, SÖDERHOLM AL, REMES-LYLY T, OIKARINEN K, RAUSTIA AM (2010) Influence of edentulousness on gonial angle, ramus and condylar height. *J Oral Rehabil,* 37(1): 34-38.

JOO JK, LIM YJ, KWON HB, AHN SJ (2013) Panoramic radiographic evaluation of the mandibular morphological changes in elderly dentate and edentulous subjects. *Acta Odontol Scand,* 71: 357-362.

KONIGSBERG LW, HERRMANN NP, WESCOTT DJ, KIMMERLE EH (2008) Estimation and evidence in forensic anthropology: age-at-death. *J Forensic Sci,* 53(3): 541-557.

LARHEIM TA, SVANAES DB (1986) Reproducibility of rotational panoramic radiography: mandibular linear dimensions and angles. *Am J Orthod Dentofacial Orthop*, 90(1): 45-51.

MAAT GJ, MAES A, AARENTS MJ, NAGELKERKE NJ (2006) Histological age prediction from the femur in a contemporary Dutch sample. The decrease of nonremodeled bone in the anterior cortex. *J Forensic Sci*, 51: 230-237.

MALOTH AK, DORANKULA SP, PASUPULA AP (2016) Lip outline: A new paradigm in forensic sciences. *J Forensic Dent Sci*, 8(3): 178.

MANN RW, UBELAKAR DH (1990) The forensic anthropologist. F.B.I Law enforcement bulletin. *Am J Phys Anthropol*, 81: 17-25.

MERROT O, VACHER C, MERROT S, GODLEWSKI G, FRIGARD B, GOUDOT P (2005) Changes in the edentate mandible in the elderly. *Surg Radiol Anat,* 27: 265-270.

NATIONAL ACADEMY OF SCIENCES (1999) Science and Creationism: A View from the National Academy of Sciences: Second Edition. Washington (DC): National Academies Press (US).

NGUN TC, GHAHRAMANI N, SÁNCHEZ FJ, BOCKLANDT S, VILAIN E (2011) The genetics of sex differences in brain and behavior. *Front Neuroendocrinol,* 32(2): 227-246.

OHM E, SILNESS J (1999) Size of the mandibular jaw angle related to age, tooth retention and gender. *J Oral Rehabil,* 26(11): 883-891.

OKŞAYAN R, ASARKAYA B, PALTA N, ŞIMŞEK İ, SÖKÜCÜ O, İŞMAN E (2014) Effects of edentulism on mandibular morphology: evaluation of panoramic radiographs. *Sci World J*, 2014: 254932.

RAUSTIA AM, SALONEN MA (1997) Gonial angles and condylar and ramus height of the mandible in complete denture wearers- a panoramic radiograph study. *J Oral Rehabil,* 24(7): 512-516.

SAIRAM V, GEETHAMALIKA MV, KUMAR PB, NARESH G, RAJU GP (2016) Determination of sexual dimorphism in humans by measurements of mandible on digital panoramic radiograph. *Contemp Clin Dent*, 7(4): 434-439.

SAIRAM V, POTTURI GR, PRAVEEN B, VIKAS G (2018) Assessment of effect of age, gender, and dentoalveolar changes on mandibular morphology: A digital panoramic study. *Contemp Clin Dent*, 9: 49-54.

SCHWARTZ-DABNEY CL, DECHOW PC (2002) Edentulation alters material properties of cortical bone in the human mandible. *J Dent Res,* 81: 613-617.

WEISBERG YJ, DEYOUNG CG, HIRSH JB (2011) Gender differences in personality across the ten aspects of the big five. *Front Psychol*, 2: 178.

XIE QF, AINAMO A (2004) Correlation of gonial angle size with cortical thickness, height of the mandibular residual body, and duration of edentulism. *J Prosthet Dent,* 91: 477-482.