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ROLE OF FRACTAL ANALYSIS IN FORENSIC ODONTOLOGY

Oral Medicine & Radiology

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ABSTRACT

Introduction- Age and gender determination becomes the first priority in the process of identification of a person by a forensic investigator in the case of mishaps, chemical and nuclear bomb explosions, natural disasters, crime investigations, and ethnic studies. Fractal analysis has been used in various bone and mucosal lesions but it is seldom used in gender determination and age estimation. **Aims And Objectives-** To assess the role of fractal analysis to evaluate age and gender in digital panoramic radiograph. **Material And Method-** A retrospective radiographic study was planned for fractal analysis, for evaluation of age and gender. This study included a total of 100 panoramic radiographs retrieved from archives of Department of Oral Medicine and Radiology, Government Dental College and Hospital, Mumbai, which were taken for various dental procedures using Planmeca ProMax orthopantogram unit. Images with any pathology, fractures, and artifacts pertaining to the region of interest were excluded. For all analysis, the examiner was blinded to the individual's sex and chronological age. A trained calibrated examiner measured the fractal dimension (FD) of the mandibular condyle and mandibular angle. Linear regression and multiple logistic discriminant analysis were carried out to explore the accuracy of Fractal analysis. The fractal analysis was carried out using the box-counting method with the help of Image J software. Linear measurement of gonial angle and condylar height were also measured on digital orthopantogram. **Results-**The result of the study showed mean D value(value obtained by fractal box counting method) at angle of mandible 1.42 for male and 1.39 for female. D value at condyle showed 1.44 for male and 1.43 for female. The linear measurement mean value for height of condyle was 20.86 mm for male and 20.31mm for female. The mean value for gonial angle for male was 243.65 degree and for female it was 236.02 degree. The data showed statistically significant difference for the values between the groups ($p < 0.01$) for gonial angle with higher values in Male and $p < 0.05$ for height of condyle. **Conclusion-** Our study is one of the few studies which tried exploring fractal analysis in forensic odontology. We found that age and gender determination was promising but it was not evident statistically.

KEYWORDS

Forensic odontology, Fractal analysis , Age and Gender evaluation

INTRODUCTION

Forensic odontology can be defined as a branch of dentistry, which deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of dental findings in the interest of the justice.[1] Sex and age determination is a subdivision of forensic odontology, and it is important especially when information relating to the deceased is not available. Age estimation is of wider importance in forensic medicine, not only for the purpose of identifying deceased victims, but also in connection with crimes and accidents. Age and gender determination becomes the first priority in the process of identification of a person by a forensic investigator in the case of mishaps, bomb explosions, natural disasters, crime investigations, and ethnic studies. Various methods are employed to determine age and gender in forensics such as cheiloscopy, human bites, rugoscopy, and the application of biomolecular methods for analyzing DNA from dental pulp tissue[2,3] and many more are yet in the process of establishment in determination of age and gender.

Digital radiography because of its obvious advantage offers its usefulness in forensics as well. Age estimation in adults is challenging as there are few methods which have been used for the same. In adults, human identification relies on alterations in dental, bone, and oral structures. [4] In this context, digital image processing allows the assessment of morphologic features of the trabecular bone pattern with minimally-invasive techniques, such as fractal analysis (FA) .[5]The word fractal originates from the word “fractus” meaning “broken” or “fractured” .[6]This mathematical method was first described in 1897 and has since improved to encompass irregular and complex body regions.[7] Fractal geometry is a quantitative approach to characterize complex self-similar shapes using the fractal dimension (FD).[6] Fractal dimensions (FD) are metrics useful in characterizing the geometry of sets too irregular to be described in more classical ways that nevertheless exhibit sufficient fractal regularity [7],with $D = \log n / \log \varepsilon$, where N is the total of parts and ε is the specified scale.[8]Fractal analysis has been used in in various bone and soft tissue lesions but it is seldom used in gender determination and age estimation. So, an attempt is made to evaluate the role of fractal analysis in forensic odontology.

AIMS AND OBJECTIVES-

To assess the role of fractal analysis of mandibular morphometric measurements using a panoramic radiograph in age and gender determination.

MATERIAL AND METHOD-

A retrospective radiographic study was done for fractal analysis, for age and gender determination . This study included a total of 100 panoramic radiographs retrieved from archives of Department of Oral Medicine and Radiology, Government Dental College and Hospital, Mumbai, which were taken for various dental procedures using Planmeca ProMax orthopantogram unit. For all analysis, the examiners ,blinded to the individuals, sex and chronological age. A trained calibrated examiner measured the fractal dimension (FD) of the mandibular condyle and mandibular angle. The principle investigator also measured linear digital parameter of gonial angle and condylar height. Linear regression and multiple logistic discriminant analysis was carried out to explore the accuracy of Fractal analysis. The investigator carried out fractal analysis using the box-counting method [1] with the help of ImageJ software.

Inclusion Criteria-

- Panoramic image of patients more than 15 years of age as most of the skeletal development completes by 15 years.
- Panoramic image of either gender.

Exclusion Criteria-

- Images with any pathology, fractures, and artifacts pertaining to the region of interest.
- Poor quality panoramic images.

METHOD-

For digital image processing, two Region of interest measuring 64 x 64 pixels were selected within the trabecular bone (Kato et al, 2019). ROI1 and ROI2 were specified-mandibular angle and condyle, respectively (Figure 1).The fractal analysis was carried out using the box-counting method (White & Rudolph, 1999). For the measurement of fractal dimension (FD), the examiner performed the following steps: (A) selection of ROIs (64x64 pixels) (B) duplication of ROIs (C) use of Gaussian or gray filter (sigma: 35 pixels) (D) subtraction of blurred image from original (E) addition of greyscale value of 128 (F) binary image (G) erosion of image(H) dilation of image (I) inversion of image and (J) skeletonization of image to assess FD using fractal box-counting method dividing image into box sizes of 2, 3, 4, 6, 8, 12, 16, 32 and 64 pixels.(Figure 2).

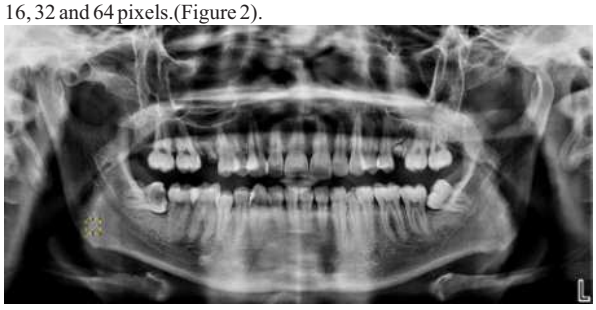

Figure 1- Region Of Interest For Fractal Analysis-angle Of Mandible

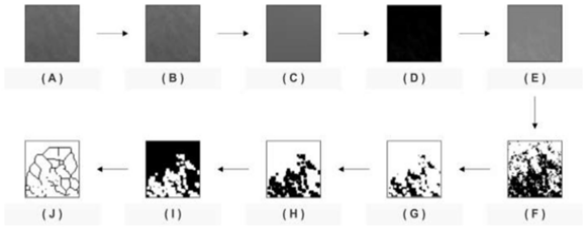

Figure 2- Step Wise Sequence Showing Fractal Box Counting Method

Conventionally, linear measurement of the digital radiograph was done for evaluation of age and gender. As this method showed a promising result, in our study we have tried to compare the conventional method with the fractal box counting method. For this purpose, linear parameter measurement of condylar height and gonial age was measured using measurement tool in the romexis software. For angle of mandible, the angle was obtained by drawing a tangent to the lower border of mandible and a tangent to the distal border of the ramus and condyle.The condylar height was measured as the distance from the line drawn on the superior portion of the condyle to the line drawn on the most inferior portion of the sigmoid notch (Figure 3).

Figure 3- Linear Measurement On Orthopantogram

For age estimation, the association between Fractal dimension and linear measurements and age was investigated using linear regression. Based on the results, a formula was devised for testing accuracy by assessing differences between predicted and actual age. Multiple logistic discriminant analysis was employed for sex estimation.

For analysis, the sample was expressed as frequencies, percentages, mean, and median and depicted using box plots by sex. The investigator employed Student's t-test and the Mann-Whitney U-test for FD values for sex.

RESULTS-

In the present study, the sample comprised of 51 females and 49 males, respectively. Intergroup comparison of variables between gender was done which showed mean FD values 1.42 for male and 1.39 for female for mandibular angle and 1.44 for male and 1.43 for female at mandibular condyle, respectively. The mean value for height of condyle was 20.86 mm for male and 20.31mm for female, respectively. The mean value for gonial angle for male was 243.65 degree and for female it was 236.02 degree, respectively. The data showed statistically highly significant difference for the values between the groups ($p<0.01$) for gonial angle with higher values in Male and $p<0.05$ for height of condyle with higher values in Male. There was a statistically non significant difference seen for the values between the groups ($p>0.05$) for D value (angle of mandible) and D value (condyle). Table 1 shows the data.

Table 1- Inter Group Comparison Of Variables Between Gender

D value (angle of mandible)	M	49	1.4202 0	.090015	.012859	965.000	-1.962	0.050#
	F	51	1.3941 2	.084642	.011852			
D value (condyle)	M	49	1.4400 2	.047832	.006833	1140.00 0	-0.755	0.450#
	F	51	1.4318 8	.051230	.007174			
height of condyle	M	49	20.865	2.5348	.3621	955.500	-2.030	0.042*
	F	51	20.311	2.6092	.3654			
gonial angle	M	49	243.65 1	8.3611	1.1944	597.500	-4.498	0.000**
	F	51	236.00 2	8.1146	1.1363			

Multiple regression analysis was done to derive a formula for age estimation. Since only gonial angle had a p value which was statistically significant (table no. 2), a formula was derived as , Age = -4.991 + .124 x gonial angle. The respective derived formula was applied to the study sample size and comparison was done for actual and predicted age which showed a statistically ,non significant difference for the values between the actual vs predicted age ($p>0.05$). Table no. 3 provides the data.

Table 2- Coefficients For Regression Analysis

Model	Unstandardized Coefficients		Standardized Coefficients		95.0% Confidence Interval for B	
	B	Std. Error	Beta	p value	Upper Bound	Upper Bound
(Constant)	-12.026	19.619	-.613	.541	-50.974	26.923
D value (angle of mandible)	1.482	6.071	.244	.808	-10.571	13.535
D value (condyle)	4.087	10.690	.382	.703	-17.135	25.309
height of condyle	-.011	.203	-.052	.959	-.413	.392
gonial angle	.121	.056	2.142	.035	.009	.233

a. Dependent Variable: Age

Age = -4.991 + .124 x gonial angle

Table 3- Comparison Of Actual Vs Predicted Age

		N	Mean	Std. Deviation	Std. Error Mean	T value	p value of t test
Age	Actual	100	24.72	5.063	.506	.037	.970#
	PA	100	24.70	1.151	.115		

DISCUSSION

As literature is sparse in role of fractal analysis in forensic odontology for age and gender determination. In our study we have pioneered using this simple, mathematical calculations in evaluation of age and gender. Therefore, our study tries to present the role of fractal analysis for age and gender estimation using digital orthopantogram radiographs.

In the present study, the mean linear measurement value for height of condyle was 20.86 mm for male and 20.31mm for female, respectively.

The mean value of gonial angle for male was 243.65 degree and for female it was 236.02 degree, respectively. The values showed statistically significant data which showed higher value in male for condylar height and gonial angle which was in agreement with the study done by Ashima Bali Behl et al[9] in which 400 orthopantograms were studied (200 male and 200 female) of north Indian population between 10 and 40 years of age. Linear measurement of ramus breadth(1.74±0.26), condylar (3.01±0.31) and coronoid ramus height (2.93±0.41) for males were higher than the females, which was 1.67±0.35 for ramus, 2.79±0.32 for condylar height and 2.73±0.36 for coronoid height ,respectively. Female have higher gonial angle (120.45±8.33) as compared to males (117.87±9.04) and the angle decreases with age which was contrary to the present study. Most probably due to more number of sample size.

In the present study, statistical significant correlation was present between age and gonial angle which was contrary to the study done by Noha Saleh Abu-Taleb et al[10] in which they studied a total number of 191 panoramic images (105 males and 86 females).No statistically significant correlation between age and gonial angle was found. Males showed statistically significant higher mean linear ramus measurements (8.3±0.8)) and lower mean gonial angle (122.2 ±4.8)) values than females in which the mean ramus measurement was 7.2 ±0.7 and gonial angle was 125.1 ± 4.3 .Condylar height (8.4 ± 0.8) and coronoid height (7.8 ± 0.7) were the most significant predictors for sex and age respectively.

In the present study, the value was statistically significant for condylar height for male as compared to female which is similar to the study done by Aditi Ramesh et al[11] in which 150 digital panoramic radiograph were assessed. The values of condylar height for male was 59.03 height of and 54.15 for female, the data showed statistically significant higher mean value for male than female for condylar and coronoid height. The present study was in agreement with Saini et al. [12] study on mandibles of Northern Indian population (92 males, 24 females, mean age 37.4 years) who found that all the ramus metric parameters were higher in males than females (coronoid height: 61.68 ± 5.45) and 54.89 ± 3.54, projective height: 53.89 ± 6.93 and 47.45 ± 4.63, condylar height: 60.67 ± 5.32 and 54.46 ± 4.97, maximum breadth: 42.81 ± 3.59 and 40.34 ± 3.76 and minimum breadth: 31.29 ± 2.99 and 29.65 ± 1.96 in males and females respectively) and showed significant sexual dimorphism. Similarly, Indira et al. [13] found that all linear ramus dimensions measured on orthopantomographs (50 males, 50 females aging 20-50 years) were significantly higher for Bangalore males compared to females (coronoid height: 119.70 ± 10.87 mm and 111.15 ± 9.51, projective ramus height: 129.05 ± 9.51 and 120.82 ± 7.85, condylar height: 131.30 ± 9.26) and 123.27 ± 7.36), maximum breadth: 74.20 ± 6.34 and 68.98 ± 5.75 and minimum breadth: 51.35 ± 4.43, 46.96 ± 3.83 in males and females respectively).

In the present study, the mean fractal value for male was greater than female which was 1.44 and 1.43 in the condylar region for male and female ,respectively. At the mandibular angle region the mean value were 1.42 for male and 1.39 for female, respectively which was similar to the study done by Fabrício dos et al[14] in which 120 lateral cephalogram were studied and fractal analysis using box count method was done in Brazilian population at mandibular ramus and mandibular angle. The mean age group was 38.5 years. The average FD values was higher for males (1.50) than females (1.48). The FA was more accurate for identifying males than females in the mandibular ramus and mandibular angle for which the mean value was 1.49±0.10 for mandibular ramus and 1.48±0.09 for mandibular angle, respectively. However, the data in the present study was found to be statistically non significant which can be due to differences in type of radiograph taken for study, region of interest selected for fractal analysis and variation in the population subtype. Although, the FD value was statistically non significant still the use of fractal analysis in orthopantogram radiographs constitute a low-cost, non-destructive minimally-invasive technique for human identification services which needs to be assessed more for further accurate results.

CONCLUSION

Thus it can be concluded from this study that FA values of the mandibular condyle and mandibular angle are slightly higher in males. The linear measurements of the height of condyle and gonial angle are significantly higher in males and are reliable in gender identification. Using regression analysis, the following formula was derived for estimation of age using gonial angle. Age = -4.991 + 0.124 x gonial angle. In the present study, Linear measurement were found to be more accurate and relevant in evaluation of age and gender than the fractal analysis. The results showed that the mean FA value in the mandibular condyle and mandibular angle provided acceptable sexual differences.

Conflict Of Interest
None Reported.

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