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Differences in Fractal Analysis Values for Batak Tribe based on Age Groups in terms of Panoramic Radiograph

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ABSTRACT

Mandibular growth and development are often used as indicators of age. Dentists perform fractal analysis using panoramic radiographs to assess mandibular bone density during its growth and development. Therefore, this study aimed to determine the differences in the mean of fractal analysis values of individuals from the Batak Tribe using a panoramic radiograph. The method used was a cross-sectional design comprising 120 panoramic radiographs. Based on age category, the radiographs were divided equally into Groups 1 (ages 6-12 years), 2 (13-18 years), 3 (19-24 years), 4 (25-35 years), 5 (36-45 years) and 6 (45-60 years). ImageJ software was used to measure density, and data analysis was performed using one-way ANOVA and LSD statistical tests. The highest to lowest mean of right and left fractal analysis values were observed in groups 4, 5, 3, 6, 2, and 1, respectively. The results showed significant differences in fractal analysis value across age groups within the Batak Tribe based on panoramic radiograph assessments.

Keywords: Fractal Analysis Values, Panoramic Radiograph, Age.

ABSTRAK

Pertumbuhan dan perkembangan mandibula seringkali digunakan sebagai indikator usia seseorang. Radiograf panoramik sering digunakan oleh dokter gigi untuk menilai densitas tulang mandibula seiring dengan tumbuh kembang, yang dapat digunakan dengan analisis fraktal. Penelitian ini bertujuan untuk mengetahui perbedaan rerata dari nilai analisis fraktal tulang mandibula Suku Batak ditinjau dari radiograf panoramik, dengan jenis penelitian *cross-sectional*. Jumlah sampel yang digunakan 120 radiograf panoramik, terbagi atas enam kelompok usia, masing-masing terdiri dari 20 sampel. Kelompok 1 (usia dari 6-12 tahun), 2 (13-18 tahun), 3 (19-24 tahun), 4 (25-35 tahun), 5 (36-45 tahun) dan 6 (45-60 tahun). *Software ImageJ* digunakan untuk mengukur densitas secara komputerisasi dan analisis data dilakukan dengan uji statistik *one-way* ANOVA dan LSD. Rerata dari nilai analisis fraktal tulang mandibula sebelah kanan dari yang tertinggi ke yang terendah adalah pada kelompok 4, kelompok 5, kelompok 3, kelompok 6, kelompok 2, dan kelompok 1. Nilai analisis fraktal tulang mandibula Suku Batak ditinjau dari radiograf panoramik berbeda secara signifikan dari setiap kelompok usia.

Kata kunci: Nilai Analisis Fraktal, Radiograf Panoramik, Usia

1. Introduction

The mandible is the hardest and most easily recognized bone of the skull. Its growth, development, and age-related changes have been widely studied. [1] Variations in shape and size due to growth, aging, and disease are well documented, particularly in the ramus, mandibular base, teeth, and temporomandibular joint. Based on observation, several factors influence mandibular growth and development. [1-3] This includes hormones associated with aging, which are believed to affect the metabolism and mineralization of the mandibular bone. [4,5]

Total bone mineral density (BMD) will be maintained during remodeling where old bone is removed and new bone is produced. [6] The mandible, rich in cancellous bone, shows metabolic consistency similar to the cervical spine. Consequently, mandibular bone density is widely used to assess systemic bone density changes. Age is one of the factors that can affect bone density changes. A decline in mandibular bone density reduces facial volume and weakens bone support for soft tissues. [4-8]. As age increases, bone density decline is considered an important indicator in assessing quality, leading to a higher risk of fracture. Ogura et al. reported a decrease in cortical bone density among older women compared to young individuals. [9] Similarly, Guo et al. stated that mandibular mineral density peaked in individuals aged 40-49 years before declining at 50 years. [10]

Panoramic radiography, widely used in dental practice, is essential for diagnosis and patient care. By analyzing the trabecular bone pattern, it effectively assesses mandibular bone density. Detecting small density changes aids in early diagnosis. Various techniques are available to measure bone mass, mineral content, and density in the mandible. [6-8, 11-14] Fractal analysis is a quantitative method used to assess the complexity of trabecular bone microarchitecture. In radiographic images, grayscale manipulation enhances the visibility of bone trabeculae, facilitating fractal analysis. ImageJ is software that is considered ideal for use in biological and medical research, equipped with spatial calibration in more realistic measurements in millimeters, including grayscale or density. Panoramic radiographs were analyzed using ImageJ software. This technique has been widely applied in studies examining bone changes in various diseases that affect skeletal structure. [15,16]

This study was conducted to assess the density of the mandibular bone through fractal analysis reviewed from panoramic radiography. The results of this study are expected to be information about changes in jaw bone conditions that can be influenced by age, and doctors/dentists in carrying out treatment, especially on the jaw bone, can evaluate bone conditions before and after treatment, which can be done using panoramic radiography examination. Previous studies have been conducted with age groups from children to adults (from the age range of 5-35 years and other studies from the age range of 13-59 years) but were not listed in a particular tribe [16,17] and not specifically to analyze the value of fractal analysis of a particular racial group in the age group from children to the elderly with inclusion and exclusion criteria, as was done in this study. This study adopted ImageJ software with fractal analysis to determine the trabecular bone pattern of mandibular bone in various age groups in the Batak Tribe in Medan City, using panoramic radiography.

2. Materials and Methods

The analytical research adopted a cross-sectional design and was conducted at the Dental Radiology Installation of the Dental and Oral Hospital of North Sumatra University in June 2022. The population consisted of panoramic radiographs of Batak patients for 3 successive generations in Medan City. A total of 6 age groups were included, with each containing 20 radiographs. Ethical approval was obtained from the Health Research Ethics Commission of Universitas Sumatera Utara based on a letter with number 105/KEPK/USU/2023.

Samples were obtained using the purposive sampling method, leading to 120 panoramic radiographs of individuals from the Batak Tribe. The age groups were categorized into Group 1 (at the age of 6-12 years), 2 (13-18 years), 3 (19-24 years), 4 (25-35 years), 5 (36-45 years), and 6 (45-60 years). [16-18] Participants in each group met specific criteria, including the presence of complete teeth (20 primary teeth in the deciduous dentition and 28 permanent teeth, excluding third molars). In children with mixed dentition, premature loss of deciduous or permanent teeth was absent. There was no history of jaw surgery, odontectomy, mandibular fracture, micrognathia, mandibular pathological conditions, persistent teeth, systemic disease, and orthodontic treatment.

The inclusion criteria required high-quality panoramic radiographs of patients who met the outlined conditions, ensuring appropriate contrast and density, particularly in the mental foramen region of both mandibles. Radiographs with poor quality or unclear visibility in the measurement area, especially the mental foramen, were excluded. Data collection included a questionnaire, such as date of birth, age, ethnicity, history of illness/medical treatment that is currently/has been undertaken, followed by panoramic radiographs of eligible patients. The trabecular bone pattern was assessed using ImageJ software, with each radiograph cropped to a 4×4 mm region of interest (ROI) at the distal edge of the mental foramen [Figure 1]. [16]

Figure 1. ROI area capture on panoramic radiograph at the distal edge of the mandibular mental foramen and mean density value on the sample (personal documentation)

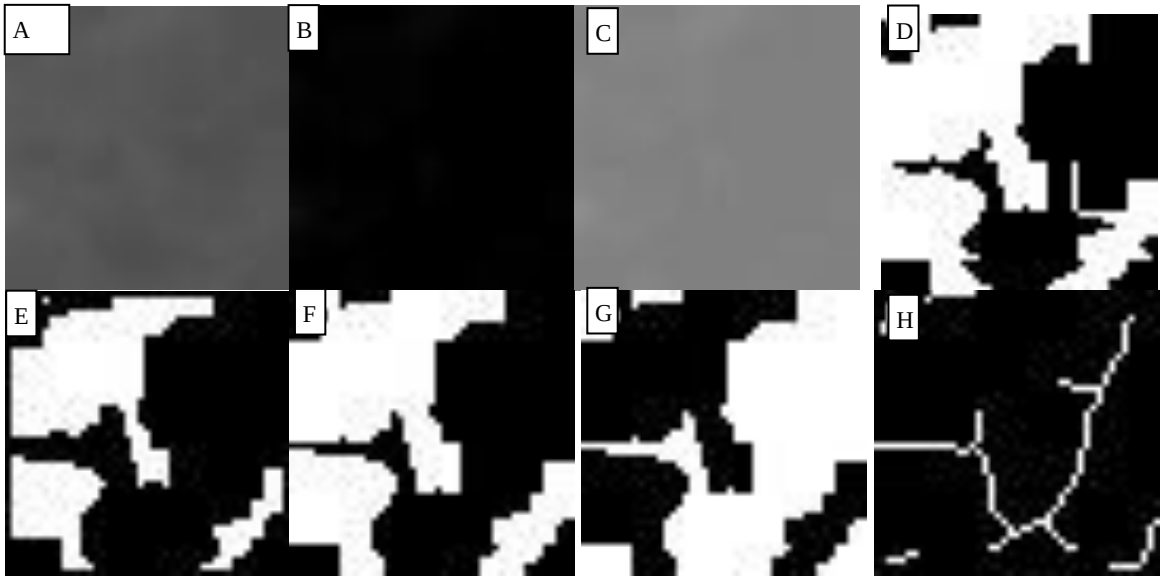

Figure 2. ROI on panoramic radiographs for analysis of panoramic radiograph A. Blurred image of the cropped and duplicated region of interest, B. Blurred image substracted from the original image, C. Addition of 128 grayscale value to each piel location D. Conversion of image to black and white, E. Erosion, F. Dilation, G. Inversion, and H. Skeletonization. [13]

The cropped panoramic radiograph, ROI defined and duplicated, was filtered with Gaussian blur on the duplicated image, with details blurred to visualize only areas with significant density variations [Figure 2A]. The resulting image was then subtracted from the original image [Figure 2B]. The bone marrow and trabecular spaces were distinguished from each other by adding grayscale values at each pixel location [Figure 2C]. Using the "Make Threshold" option, the image was converted to a 2-color format, namely black and white [Figure 2D]. The "Erode" option stage was performed to reduce noise in the image [Figure 2E] and the "Dilate" option stage, the existing areas were enlarged and made more visible [Figure 2F]. In the "Invert" option stage, the white areas of the image were converted to black and the black areas were converted to white to reveal the outlines of the trabecular bone [Figure 2G]. In the "Skeletonize" option stage, the outlines of the trabecular structures were skeletally defined with lines, making them ready for fractal analysis [Figure 2H]. [13]

Data collection and analysis were conducted by computerization. One-way ANOVA test was conducted to obtain the mean difference of the fractal analysis values obtained, by analyzing the calculated data with $p < 0.05$.

3. Results

The results of the normality test using a one-sample Kolmogorov-Smirnov Test showed that the variables were normally distributed ($p > 0.05$). Table 1 shows the mean values of fractal analysis performed on panoramic radiographs (right and left sides of patients) from age groups 1-6. On the right and left sides, the highest mean values were in age group 4, and the lowest in age group 1. Tables 2 and 3 provide details of the significant differences (LSD Multiple Comparison Test Results) in the trabecular bone pattern on each right and left side across six age groups ($p < 0.05$). The mean of fractal analysis values of trabe*cular* bone pattern of the right and left mandible, from highest to lowest, were recorded in groups 4, 5, 3, 6, 2, and 1, respectively.

Table 1. The Mean of Fractal Analysis Values of Trabecular Bone Pattern of Batak Tribe Based on Age Groups in terms of Panoramic Radiography

Age Groups	n	Right Mandible	Left Mandible
		Mean ± SD (*gray value*)	Mean ± SD (*gray value*)
1	20	103.87 ± 7.63	105.13 ± 7.35
2	20	115.68 ± 2.78	116.63 ± 2.40
3	20	124.76 ± 2.96	126.33 ± 3.01
4	20	131.55 ± 1.87	133.30 ± 1.69
5	20	126.98 ± 2.23	128.28 ± 2.16
6	20	124.44 ± 1.86	125.81 ± 1.68

Table 2. Post test LSD The Mean of Fractal Analysis Values of Trabecular Bone Pattern of Right Mandible

Dependent Variable	(I) Age Groups	(J) Age Groups	Mean Difference (I-J)	Standard Error	Sig.
The Mean of Fractal Analysis Values of Trabecular Bone Pattern (Right Mndible)	1	2	-11.80525*	1.20174	.000
		3	-20.88860*	1.20174	.000
		4	-27.67545*	1.20174	.000
		5	-23.10855*	1.20174	.000
		6	-20.57210*	1.20174	.000
	2	1	11.80525*	1.20174	.000
		3	-9.08335*	1.20174	.000
		4	-15.87020*	1.20174	.000
		5	-11.30330*	1.20174	.000
		6	-8.76685*	1.20174	.000
	3	1	20.88860*	1.20174	.000
		2	9.08335*	1.20174	.000
		4	-6.78685*	1.20174	.000
		5	-2.21995	1.20174	.067
		6	.31650	1.20174	.793
	4	1	27.67545*	1.20174	.000
		2	15.87020*	1.20174	.000
		3	6.78685*	1.20174	.000

		5	4.56690*	1.20174	.000
		6	7.10335*	1.20174	.000
	5	1	23.10855*	1.20174	.000
		2	11.30330*	1.20174	.000
		3	2.21995	1.20174	.067
		4	-4.56690*	1.20174	.000
		6	2.53645*	1.20174	.037
	6	1	20.57210*	1.20174	.000
		2	8.76685*	1.20174	.000
		3	-.31650	1.20174	.793
		4	-7.10335*	1.20174	.000
		5	-2.53645*	1.20174	.037

*. The mean difference is significant at the 0.05 level.

Table 3. Post test LSD The Mean of Fractal Analysis Values of Trabecular Bone Pattern of Left Mandible

Dependent Variable	(II)Age Groups	(J) Age Groups	Mean Difference (I-J)	Standard Error	Sig.
The Mean of Fractal Analysis Values of Trabecular Bone Pattern (Left Mndible)	1	2	-11.50565*	1.15008	.000
		3	-21.20645*	1.15008	.000
		4	-28.17175*	1.15008	.000
		5	-23.14635*	1.15008	.000
		6	-20.68040*	1.15008	.000
	2	1	11.50565*	1.15008	.000
		3	-9.70080*	1.15008	.000
		4	-16.66610*	1.15008	.000
		5	-11.64070*	1.15008	.000
		6	-9.17475*	1.15008	.000
	3	1	21.20645*	1.15008	.000
		2	9.70080*	1.15008	.000
		4	-6.96530*	1.15008	.000
		5	-1.93990	1.15008	.094
		6	.52605	1.15008	.648
	4	1	28.17175*	1.15008	.000
		2	16.66610*	1.15008	.000
		3	6.96530*	1.15008	.000
		5	5.02540*	1.15008	.000
		6	7.49135*	1.15008	.000
	5	1	23.14635*	1.15008	.000
		2	11.64070*	1.15008	.000
		3	1.93990	1.15008	.094
		4	-5.02540*	1.15008	.000
		6	2.46595*	1.15008	.034
	6	1	20.68040*	1.15008	.000
		2	9.17475*	1.15008	.000
		3	-.52605	1.15008	.648
		4	-7.49135*	1.15008	.000
		5	-2.46595*	1.15008	.034

*. The mean difference is significant at the 0.05 level.

4. Discussion

Bone mineral density (BMD) represents the amount of mineral material per unit volume of bone, accounting for approximately 60% of overall bone strength [19]. Its measurement is widely used to detect osteoporosis in the early stages, assess fracture risk, and monitor bone changes during treatment. Panoramic radiography, an extraoral imaging technique, has been extensively applied in BMD assessment for osteoporosis prediction. Radiographic image formation depends on the interaction between X-rays and matter, influenced by tissue composition, atomic structure, density, and geometric properties. Tissues with higher calcium content, greater thickness, and increased density absorb more radiation. [6,17,19-21]

Fractal analysis is a quantitative method used to assess the complex ity of trabecular bone microarchitecture, such as bone trabecular patterns, using ImageJ software.[15,16] Many studies have been conducted to evaluate mandibular bone density through trabecular bone patterns using fractal analysis on panoramic radiographs, but none have been specifically conducted on the Batak tribe. The Batak tribe is one of the tribes found in Medan City. Postnatal changes in the mandible are thought to be influenced by the age of the patient. Mandibular bone growth from infancy to childhood is the period of the fastest growth rate until adulthood between 30-35 years is the peak of the growth stage and after that the growth rate will decrease. [16-18]

The mandible, part of the axial skeleton along with the spine and hips, provides valuable information in the early stages of disease progression. Physiologically, it undergoes continuous remodeling, with bone mass changing throughout life. Table 1 shows the lowest average value of the fractal analysis of trabecular bone patterns in group 1 (right mandible = 103.87 ± 7.63; left mandible = 105.13 ± 7.35), while the highest value was observed in group 4 (right mandible = 131.55 ± 1.87; left mandible = 133.30 ± 1.69), with variations caused by many factors. Bone growth and development begin in the embryonic stage and continue through young adulthood. By age 18 in females and 20 in males, approximately 85–90% of peak adult bone mass is attained, remaining stable until around age 30 before gradually declining, with a more pronounced reduction after age 45. [17,19]

Several factors influences bone density, including heredity, growth hormones, nutrition, systemic diseases, culture, gender, and age. [22-24] Muscle mass is dependent on androgen hormones, and greater muscle mass can exert greater mechanical action on bone, resulting in increased bone size and bone mass. [17] Bone mass develops from childhood through adolescence, reaching peak mineral levels in adulthood. Achieving optimal peak bone mass is essential for reducing the risk of osteoporosis and fractures. [25] Based on observation, hormones play a crucial role in bone growth [2,19]. Sex hormones, including estrogen and androgens such as testosterone, enhance osteoblast activity and bone extracellular matrix synthesis, as well as accelerate growth during adolescence. [17] Puberty is a key phase in skeletal development, marked by increased levels of growth hormone (GH) and insulin-like growth factor 1 (IGF-1). GH stimulates prechondrocytes in the growth plate, leading to clonal expansion and osteoblast activation. IGF-1, the most abundant growth factor stored in bones, is produced by osteoblasts and plays a vital role in bone remodeling [17].

Peak bone mass is typically reached by age 25, influenced by genetic and environmental factors such as physical activity, muscle mass, calcium and vitamin D intake, fat levels, gender, and ethnicity, but varies among individuals [16,26]. Table 1 presents the results of the study showing that the highest mean value of 131.55 ± 1.87 on the right side and 133.30 ± 1.69 on the left side was in group 4, which is the peak bone mass. These results are in line with the investigation conducted by Su et al on Chinese women and men, which assessed bone density using DXA (dual-energy X-ray Absorptiometry) and identified peak bone mass at age 25. [26] Tables 2 and 3 show that the mean value of mandibular bone density on the left side was greater when compared to the right side. This contrasts with the report by Amri et al., where the mandibular alveolar bone resorption index (MM ratio) in the right mandible was greater when compared to the left. [17]

Table 1 shows that the mean value of fractal analysis of trabecular bone pattern in age group 4 (right mandible = 131.55 ± 1.87; left mandible = 133.30 ± 1.69) was higher than in groups 5 (right mandible = 126.98 ± 2.23; left mandible = 128.28 ± 2.16) and 6 (right mandible = 124.44 ± 1.86; left mandible = 125.810±1.68). Bone mass decreases significantly at age 50 due to a decrease in body's estrogen levels, especially when a woman reaches menopause. Bone density will decrease by 40-50% of bone mass during the first 5-8 years after menopause in women, while in men bone mass decreases by 1% each year after age 50. [17]

Tables 2 and 3 present Post Test LSD of the mean value of fractal analysis for both the right and left sides. The order from highest to lowest values was observed in Group 4, followed by Groups 5, 3, 6, 2, and 1. A similar trend was reported by Rahmi et al., who analyzed female patients using 16 panoramic radiographs per group. The results showed a significant increase in the mean value of fractal analysis of trabecular bone pattern across the age groups 5–11, 12–16, 17–25, and 26–35 years. [16] In the study by Amri et al., who examined bone quality using panoramic radiography and reported a decrease between the 30–44 and 45–59 year age groups. [17] In this study, significant differences were detected in the mean value of fractal analysis of trabecular bone pattern of Group 1 compared to the other groups on both sides.

Likewise, group 2 and group 4, respectively, where there was a significant difference for the other groups on both sides.

This study used panoramic radiograph samples from patients who did not experience tooth loss and other requirements that met the criteria and questionnaires. In the chewing process, mechanical stimulation will occur on the teeth that receive chewing loads, namely tension, on the bones adjacent to the teeth. The chewing load on the teeth, the work of the masticatory muscles, and the reaction force on the temporomandibular joint will result in a bending moment on the mandible. This bending moment will also cause tension on the bones around the teeth. Steady-state conditions are assumed to occur, which means that the amount of this strain will represent the strain stimulus required to maintain bone mass. In addition, if the alveolar bone in the jaw experiences continuous atrophy after tooth extraction and the use of complete dentures. [17]

5. Conclusion

In conclusion, the mean of fractal analysis values of mandible varied across age groups in the Batak Tribe, as reviewed using a panoramic radiograph. The highest density was observed in group 4 (age 25-35 years), while the lowest was in group 1 (age 6-12 years). The results suggested that age influenced the mean of trabecular bone pattern value.

6. Acknowledgments

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7. Conflict of Interest

The authors declare that there are no conflicts of interest related to this study.

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Appendix

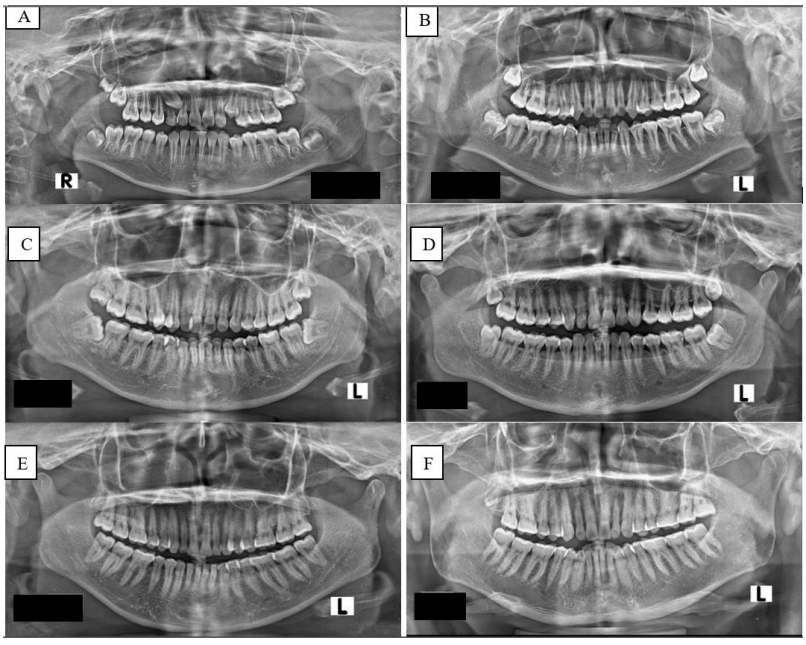


Figure 1. Panoramic radiographs of patients according to age groups (personal documentation). A. Group 1 (ages 6-12 years), B. Group 2 (13-18 years), C. Group 3 (19-24 years), D. Group 4 (25-35 years), E. Group 5 (36-45 years) and F. Group 6 (45-60 years)

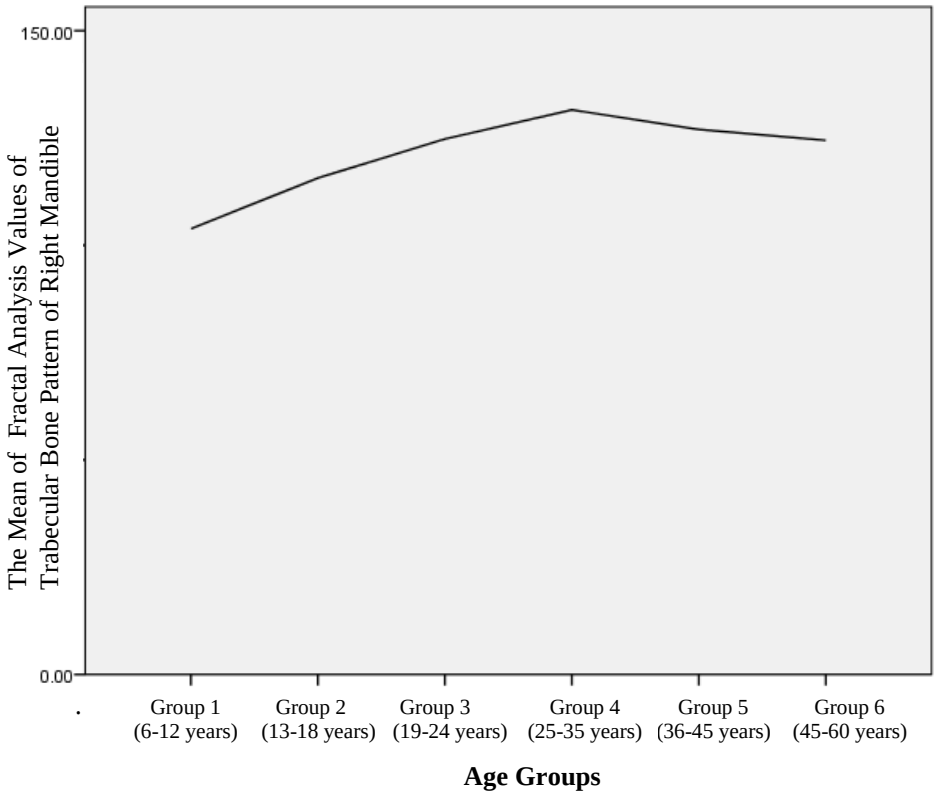
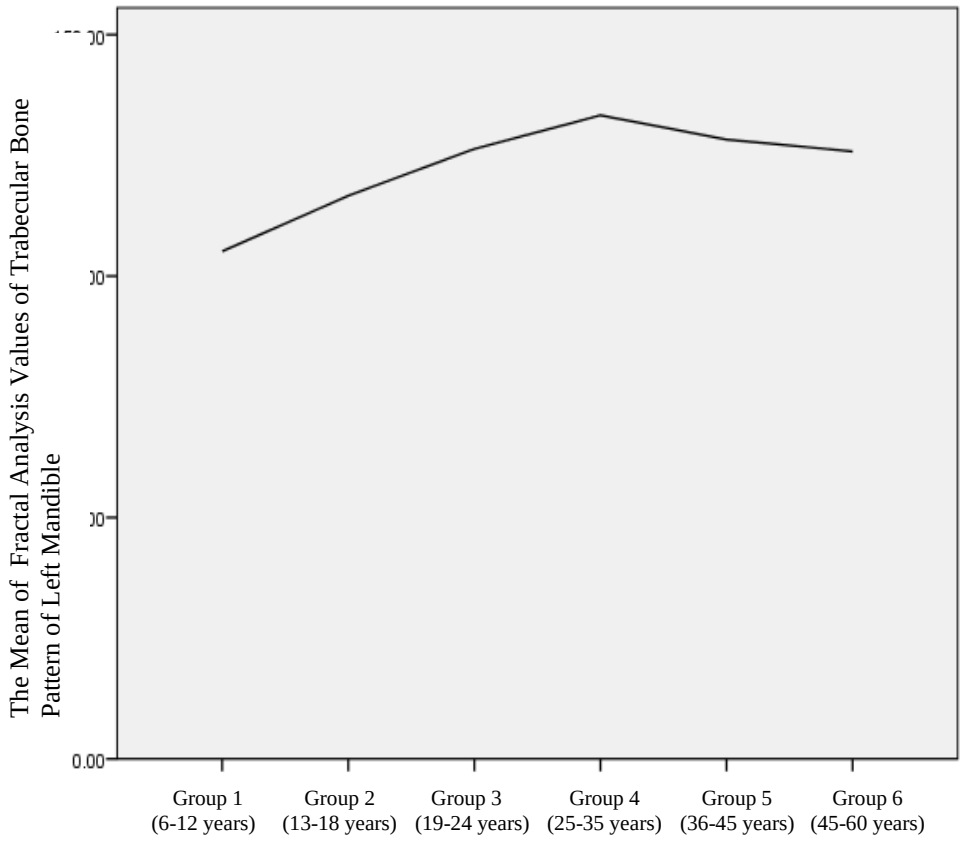


Figure 2. Graph Depicting The Mean of Fractal Analysis Values of Trabecular Bone Pattern of Right Mandible in each age group (where group 4 has the highest mean value)



Age Groups

Figure 3. Graph Depicting The Mean of Fractal Analysis Values of Trabecular Bone Pattern of Left Mandible in each age group (where group 4 has the highest mean value)

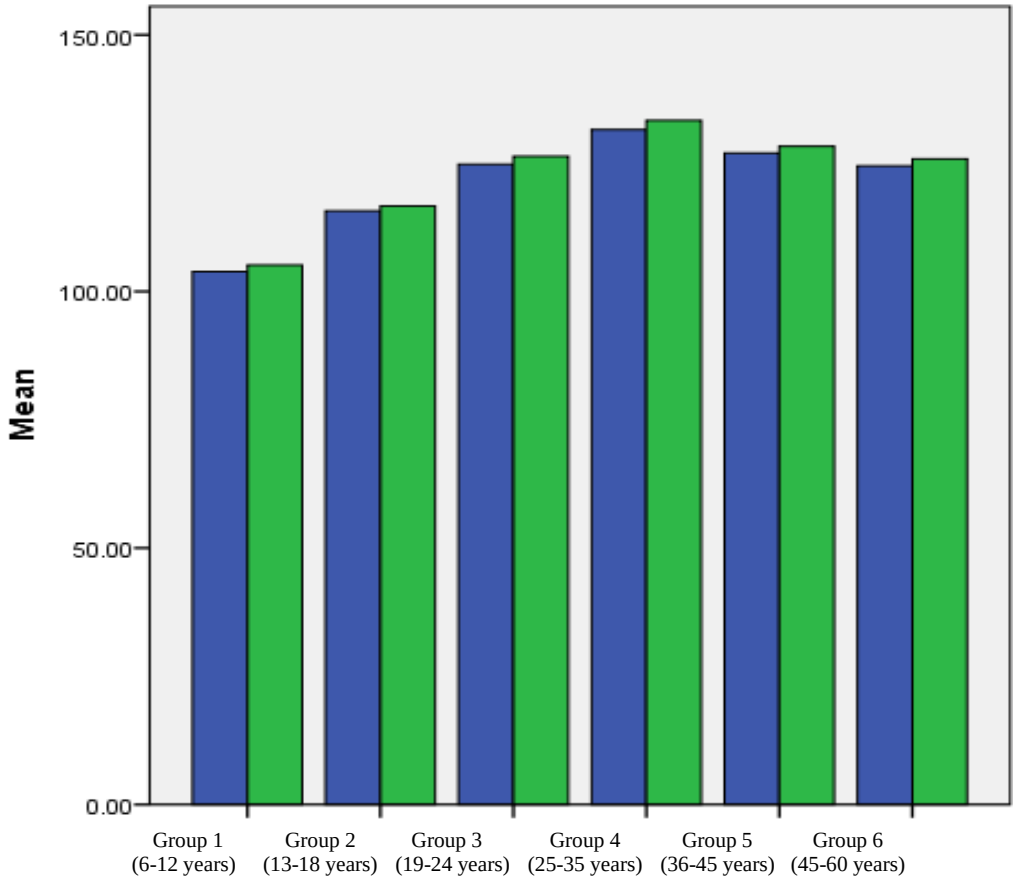


Figure 4. Bar graph depicting The Mean of Fractal Analysis Values of Trabecular Bone Pattern of Right and Left Mandible in each age group (where group 4 has the highest mean value) (where group 4 has the highest mean value)