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"Evaluation of Radiomorphometric Indices and Fractal Dimension of Mandible Using Cone Beam Computed Tomography among Tobacco Habitudes - A Case Control Study"

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KEYWORDS

Evaluation of Radiomorphometric

ABSTRACT:

Purpose: The purpose of the study was to assess how smoking and smokeless tobacco affected the mandibular bone structure using a variety of radiomorphometric indices and fractal dimension (FD) analysis.

Material and methods: 189 patients—63 smokers and 63 patients using smokeless tobacco and 63 healty controls, were included in this study. In the trabecular bone of the mandible, eight areas of interest of 30x30 pixels were chosen, and fractal dimension analysis was carried out. All digital panoramic radiographs were used to measure the mandibular index and mandibular cortical thickness. All values were compared between groups. Utilizing the Kruskall Wallis ANOVA followed by pair wise comparison using Mann Whitney U test data were evaluated.

Results: A total of 189 patients between the ages of 20 and 55 were evaluated. Fractal dimension values showed statistically significant difference between the groups. Similarly, statistically significant differences between groups were seen for MCI and MCT measures ($p>0.05$).

INTRODUCTION:

Osteoporosis, a condition characterized by decreased bone density and fragility, affects millions globally and poses significant public health challenges due to fractures and their associated costs.[1] While non-modifiable risk factors like age and gender exist, behavioural factors, such as tobacco use, contribute significantly to osteoporosis risk.[2,3] Smokeless tobacco, prevalent in India, is a major concern, as tobacco use impairs bone health by reducing bone mineral density and impeding bone healing.[2,4] Tobacco smoke contains over 4800 harmful chemicals, contributing to increased oxidative stress and inflammation, which affect bone metabolism, including vitamin D absorption.[1,5]

To assess osteoporosis, conventional 2D X-rays are commonly used, but Cone Beam Computed Tomography (CBCT) offers improved resolution, 3D imaging, and low radiation, making it valuable for bone density analysis.[3,6,7] Fractal analysis (FA) applied to CBCT scans quantitatively measures trabecular bone structure, offering insights into bone strength and osteoporotic changes.[8] FA is particularly useful in identifying bone mineral loss, as it correlates with bone health and density.

Additionally, mandibular cortical thickness (MCT)

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and mandibular cortical index (MCI) are reliable indicators of osteoporosis, aiding in early detection.[9,10,11] These methods, when used in routine dental exams, can help screen for osteoporosis, especially in the elderly, who are at higher risk.[7,13,14]

AIM:

The aim of this study is to assess the radiomorphometric indices and fractal dimension of mandible in tobacco habitudes using cone-beam computed tomography (CBCT).

OBJECTIVE:

Objectives of the study are as follows-

To evaluate the mandibular cortical index (MCI) and mandibular cortical thickness (MCT) on CBCT as qualitative and quantitative measure of bone density respectively.

To assess fractal dimension of the mandible on CBCT (Axial and Sagittal sections) as a measure of bone density.

PATIENT SELECTION-

This cross-sectional study was conducted in the Department of Oral Medicine and Radiology on 189 patients with the approval of the Institutional Ethical Committee.

The guidelines of the Helsinki Declaration were followed in this study. Sample size was determined using the estimates of mean and standard deviation values from literature add ref of your master article in Vancouver format here using the formula

$n \text{ (per group)} = 2 \times [z(1- \alpha /2) + z(1- \beta)]^2$

Δ^2

$n = 62.72$

Rounded to the nearest value n=63

Patients were divided into 3 study groups with equal number of patients in each group. Groups were as follows:

A) Smokers

B) Smokeless tobacco consumers

C) Healthy Control

INCLUSION CRITERIA-

63, Smokeless tobacco users (SLTs) and smokers(S) each, aged between 20-55years, both with a habit duration of more than a year were included. Healthy controls were also included with no tobacco habits, who voluntarily consented to participate.

EXCLUSION CRITERIA-

Subjects with a previous history of-

Jaw fracture, Reconstructive surgery, Orthodontic treatment, Edentulism, History of pathological lesions of the jaws/ surgery, Periapical lesions in the region of interest (ROI), Para-functional habits like clenching and bruxism, Patients who were previously diagnosed with other metabolic bone diseases or had taken any drugs affecting the bone metabolism were excluded.

MANDIBULAR CORTICAL INDEX (MCI)-

MCI was classified based on the Erosions in the mandibular cortical bone from the mental foramen to the third molar region on CBCT using 5mm (Fig 2A), 10mm (Fig 2B), and 15mm (Fig 2C) thickness.

C1- The inner surface of homogenous mandibular cortical bone exhibiting a sharp and even margin without erosion

C2- Mild erosions and porosity

C3- Numerous erosions with more severe porosity.

MANDIBULAR CORTICAL THICKNESS (MCT)-

For MCT measurement a tangent line parallel to the lower nerve of the mandibular cortex was drawn at the level of the mental foramen in the premolar area on the panoramic reconstruction of CBCT in 15.0mm slice thickness. A line was stretched vertically from the mental foramen to the second parallel line, which was drawn along the superior nerve of the mandibular cortex. On this vertical line, the mandibular cortical width was calculated as the distance between two parallel lines.

METHOD FOR CALCULATING FRACTAL DIMENSION:

The Region of interest (ROI) selection started by creating a panoramic reconstruction image of the mandible. The ROI of 30 X 30 was selected bilaterally

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equidistant from midline on the sagittal (Fig4B) and the axial (Fig4A) planes and was chosen to avoid anatomical interference from structures such as teeth, foramina, and the inferior alveolar canal.

FD was analysed using ImageJ public domain software (Fig 4) and the procedures were conducted using White and Rudolph method through box counting method. Image processing included selection and cutout of ROI with duplication and application of gaussian filter (35 pixels), subtraction from original image, addition of 128 gray value, binarization, erosion, dilation, inversion and skeletonization. After this the resultant image was used to calculate FD with "Box counting" algorithmic tool available in ImageJ.

The mean FD of the right and left sides of both axial and sagittal sections was calculated. The overall FD value of trabecular bone was also calculated as the mean FD values of 4 ROIs.

STATISTICAL ANALYSIS-

Data obtained was compiled on a MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States), and was subjected to statistical analysis using Statistical package for social sciences (SPSS v 26.0, IBM).

Inter group comparison (>2 groups) was done using Kruskall Wallis ANOVA followed by pair wise comparison using Mann Whitney U test.

Comparison of frequencies of categories of variables with groups /time was done using chi square test.

For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

* = statistically significant difference ($p<0.05$)

** = statistically highly significant difference ($p<0.01$)
# = non- significant difference ($p>0.05$)

RESULTS

This study included CBCT scans of 189 patients, from which 63 scans each belonged to the patients who consumed smokeless tobacco, smokers and control group. The patients included were aged between 20 – 55 years. The mean age of patients in control group was 37.8±8.2 years, and was 37.8±8.4 and 35.2±6.4 years in the SLTs and smoker groups, respectively. Among the scans taken for smokeless tobacco patients, 73% (n=46) were of males and 17 % (n=24) from females, the smoker group consisted of males only and the control group comprised 92% (n=58) males and 8% (n=5) females. The duration of smokeless tobacco usage was 1–25 years, with an average of

7.8 years, with frequency of 2–8 times daily. The frequency of smoking was 2–24 times, with an average of 10 times daily and the duration of smoking was 1–30 years, with an average of 9.1 years.

The measurements were taken from panoramic reconstruction of CBCT from both axial and sagittal sections bilaterally from all scans. The mean FD of the right and left sides of both axial and sagittal sections was calculated. The overall FD value of trabecular bone was also calculated as the mean FD values of 4 ROIs.

Kruskal Wallis test was performed to calculate average fractal dimension values of all the four sites that is right and left of both axial and sagittal sections which are the highest i.e 1.08722 with mean deviation of .169976 in group 3 that is in the control group, the FD value was 0.83153 with mean deviation of .064036 in Group 1 and the FD value was least i.e 0.70308 with mean deviation of .119055 in group 2. Similarly, the average MCT value was the highest in Group 3 which is 4.65556 with mean deviation of .339130, the MCT value in group 1 was 3.79524 with mean deviation of 0.428022 and was the least in group 2 i.e 2.91746 with mean deviation of .338659. There was a statistically highly significant difference seen for the values between the groups ($p<0.01$)

Mann- Whitney test was performed to calculate the Intra group average fractal dimension values between group 1 and group 2, i.e smokers and smokeless tobacco consumers, group 1 and group 3

i.e smokers and control group and group 2 and group 3 i.e smokeless tobacco consumers and control group in all the four sites that is right and left of both axial and sagittal sections as well as to calculate average MCT. And the results were statistically significant.

Chi- square test was performed to calculate the MCI wherein the maximum patients the quality of bone was C2 followed by C1 and the least was C3. MCI

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was majorly C1 in Group 3, C2 was maximum in group 1 and C3 was found to be maximum in Group 2

There was a statistically highly significant difference seen for the frequencies between the groups ($p<0.01$) with higher frequency for C2 with group 1

DISCUSSION

Osteoporosis is an age-related disease marked by reduced bone mineral density (BMD) and deteriorating microstructure, increasing fracture risk, especially in the elderly and postmenopausal women.[15,16,17] It poses a growing health and economic burden due to fragility fractures. Key risk factors include low BMI, aging, hormonal changes, poor nutrition, smoking, inactivity, and female gender.[10,18] Bone loss occurs through rapid osteoclastic destruction and slow osteoblastic depletion. Fracture risk depends on peak bone mass and age-related loss, with smoking cessation as a key modifiable factor.[10,16,19,20, 21] Beyond BMD, bone quality—assessed through trabecular structure via radiographs—is crucial in determining bone strength.[22, 23, 24]

Existing studies in the medical literature on smoking and osteoporosis risk have reported that smoking increases the incidence of fractures by decreasing bone density.[25, 26] Male smokers were shown to have lower forearm BMD than non-smokers. In the study of **Hijazi et al**.[27] in which they evaluated the incidence of osteoporosis, it was shown that smoking and non-smokers had different incidences. The possible mechanism by which smoking can affect bone health by increased hepatic metabolisms of vitamin D metabolites and impaired calcium absorption. Decreased serum calcium due to the interference of parathormone action with renal tubules in smokers has also been noted.

Decreased vitamin D levels, increased free radicals, and oxidative stress in smokers are associated with bone resorption. Various studies have provided evidence that smoking affects the balance of the naturally occurring processes of bone resorption and bone formation, resulting in low bone mineral density. It has also been reported that cigarette smoke extract inhibits in vitro differentiation of osteoprogenitor cells to osteoblast like cells.

There is evidence supporting the adverse effect of second hand smoke on bone health. Laboratory studies in rats, mouse models, and cell culture demonstrate direct negative effects of passive smoke on osteoblast and osteoclast activities. Two cross-sectional studies reported that subjects exposed to second hand smoke had significantly lower phalangeal BMD ($p < 0.01$) and higher risk for femoral neck osteoporosis than unexposed subjects. Few studies have investigated the effect of smoking cessation on bone health. In study conducted **by J. Cornuz et al**.[25] an intermediate risk of fracture was found in ex-smokers. And in study conducted by **P. Gerdhem et al**.[26] found the effect of smoking on bone density was reversible, and the bone density of ex-smokers improved in less than 10 years. Interestingly, other studies reported that the effects of smoking cessation in postmenopausal women produced improvement in gonadal hormones, level of bone formation, and resorption markers in 6 weeks and improvement in the bone density after 1 year of cessation/reduction.[28]

While the effects of cigarette smoking on bone mineral density (BMD) and osteoporosis are well-documented, the impact of smokeless tobacco (SLT) has not been thoroughly studied. SLT affects bone remodeling by lowering vitamin D levels, increasing oxidative stress, reducing serum parathormone (PTH), and inhibiting calcium reabsorption, all of which impair bone health. It also decreases estrogen and testosterone levels, contributing to lower BMD.[14] SLT products, which may contain areca nut, impact osteoblastic metabolism and promote osteoclast activity, leading to bone resorption. Additionally, nicotine in SLT induces vasoconstriction and tissue ischemia, further damaging bone health. Studies show a strong correlation between mandibular and skeletal bone densities, highlighting the mandible's sensitivity to changes in bone mass.

The World Health Organization defines osteoporosis as a bone mineral density (BMD) greater than

2.5 standard deviations below the young adult mean BMD. Hence, it is very important to identify low-BMD individuals, especially those who are at a higher risk of fractures. Many patients with normal BMD or osteopenia, suffer from fragility fractures. Therefore, auxiliary methods are necessary to identify

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microstructural bony changes. The data presented supports the hypothesis that patients with tobacco habits have an altered trabecular pattern in the jaws compared with control individuals. Which results in osteoporosis which means reduction of bone mineral density of the mandible.

This study examined the potential use of different radiomorphometric indices and fractal dimension in CBCT examinations of the mandible for evaluation of BMD. Panoramic radiography has been indicated as a predictive tool for osteoporosis in several studies. A change in the cortical morphology of maxillofacial bones makes it possible to screen patients by this method. We decided to use CBCT as an evaluation tool because it has several uses in dentistry and in the field of maxillofacial imaging. It provides three-dimensional images of high resolution. It also allows the qualitative and quantitative evaluation of osseous structures. It has improved image quality; has reduced distortions, overlaps, and extensions which helps us to analyse anatomical features. Its three-dimensional perspective, is widely used to evaluate patients' bone structure in dentistry and associated subspecialties.

Fractal analysis provide the clinician with box counting values, a subjective method of evaluating bone density using CBCT scans. **Geraets and van der Stelt**[15] stated that all stages in the "analytic chain" of FA have an influence in the assessment of bone due to the wide variations of analysing methods. In the present study a specific methodology has been followed using the ImageJ software to ensure that the ROIs were exactly similar on the scans taken.

Link et al,[18] investigated the trabecular structure of human vertebral and femoral bone. They used high-resolution magnetic resonance and computed tomography images combined with texture analysis using morphometric measures and box-counting FD and compared these techniques with bone mineral density. It was concluded that texture analysis using FD might provide additional information to analyse bone strength and quality. Various studies have been carried out to differentiate subjects with and without osteoporosis using fractal analysis on dental radiographs. **Doyle et al,**[20] suggested the possibility of detecting osteoporosis with fractal analysis of dental radiographs. They reported a preliminary study where FD of mandibular radiographs of postmenopausal women was higher than that of premenopausal women. **Southard et al,**[21] in an in vitro study examined radiographic FD changes in a decalcified human alveolar bone process. They found that the average FD value decreased in simulated osteoporosis in the maxilla under ideal conditions and stated that the radiographic FD holds promise for detecting osteoporosis. The results of the present study are consistent with these results.

Kiel et al,[22]reported an independent association between smoking during adulthood and bone mineral density, suggesting the possibility of peak bone mass reduction due to smoking. It has been reported that bone is influenced by dose (frequency) and the duration of smoking, and increased smoking exposure can lead to a more significant loss in bone mineral density.

In the present study, we included 189 patients. The patient sample consisted of the age groups between 20-55 years. The differences in the distribution of study participants according to age was not significant (p-value= 0.99) due to inclusion of approximately equal number of participants in each age group. The distribution of study participants according to gender was significant as there was a huge difference between male and female participants in the groups and this was in in accordance with the study conducted by **Rolf Jorde et al**,[29] and **Duygu Azman et al,**[9] Among these, 46 males and 24 females used smokeless tobacco. In comparison, the study by **Suman Basavarajappa et al**, reported 66 male and 9 female users of smokeless tobacco, indicating a higher prevalence among males in both studies. Notably, in both studies, smoking was exclusively reported among males.

Regarding the control groups, our study included 58 males and 5 females, while the control group in **Suman Basavarajappa et al**,[1] study consisted of 71 males and 4 females. Both studies thus showed a predominance of males in the control groups as well, reflecting similar trends across both studies.

In the present study, we correlated FD between Smokers, tobacco consumers and control group, using CBCT in both axial and sagittal section bilaterally. The overall mean FD of left and right of both axial

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and sagittal sections was 1.08722 in the control group which was the highest amongst all three groups, followed by the FD in smokers that is 0.83153, and was least in the group where patients consumed smokeless tobacco which is 0.70308. The results are in accordance with **Suman Basavarajappa et al,** [1] where the FD values are 0.84, 0.97 and 1.20 for smokeless, smokers and control group respectively. In the study conducted by **Duygu Azman et al,** [9] the FD values for smokers and nonsmokers group were 1.09 and 1.42 respectively, and in the study by **Berrin Çelik et al,** [27] the FD values for smokers and control group were 0.92 and 1.50 respectively, this concludes that the bone loss is maximum in the patients consuming smokeless tobacco products, followed by patients who smoke and the bone loss is the least in the control group.

These studies however compared FD values only at the sagittal section, as against our study that included sagittal as well as the axial section giving us a 3-dimensional value. The results were significant in between all the three groups (p value < 0.01).

Similarly, the average MCT value was the highest in the control group i.e 4.65 followed by patients who smoke which is 3.79 and is the least is in patients consuming smokeless tobacco which is 2.91, the results were statistically significant with P value < 0.001, while lower values (4.40 mm) were obtained in smokeless tobacco users, the results were not found to be less than 3 mm, which is consistent with the other studies. The results obtained by **Berrin Çelik et al**, [27] where the MCT values were 3.40 and 4.46 in smokers and non- smokers respectively and **A. C. Alman et al**, where the values were 4.45 and 5.01 in smokers and non-smokers respectively

The MCI has somewhat variable results where C3 quality of bone is found to be maximum in smokeless tobacco consumers, C2 is found to the highest amongst all the 3 patterns and is found more in smokers and C1 quality of bone is seen in least of the patients and is found maximum in the control group. However, in the study performed by **Berrin Çelik et al**, Mandibular index did not show any statistically significant differences between the groups as C2 was found to be maximum in both smokers and non-smokers, and there were only a few number of patients with C1 and C3 quality of bone, which is not in accordance with present study.

CONCLUSION

We conclude that, assessing jaw bone density is essential before performing invasive dental procedures on patients who use tobacco. Tobacco use can negatively impact vitamin D metabolism in the liver leading to lower circulating levels of active vitamin D and decreased ability of the body to absorb calcium. Low mineral density of the bone results in complications or failure of certain dental procedures. Screening of the jaw bone using FD, MCT, and MCI can detect early changes in bone structure and density before significant clinical symptoms or fractures occur. Combining quantitative analysis (FD and MCT) with qualitative analysis (MCI) provides a comprehensive view of bone

health. While FD and MCT offer detailed numerical data, MCI provides contextual insights into bone quality. These methods together facilitate a thorough evaluation of bone density and quality, enabling early detection of bone loss and timely, effective intervention. Regular use of these tools can significantly enhance the management of osteoporosis and other bone-related conditions.

REFRENCES

1. Spangler JG, Quandt S, Bell RA. Smokeless tobacco and osteoporosis: a new relationship?. Medical hypotheses. 2001 May 1;56(5):553-7.
2. Basavarajappa S, Ramachandra VK, Kumar S. Fractal dimension and lacunarity analysis of mandibular bone on digital panoramic radiographs of tobacco users. Journal of Dental Research, Dental Clinics, Dental Prospects. 2021;15(2):140.
3. Çelik B, Arslan ZB. Fractal analysis and radiomorphometric indices: comparison of mandibular bone structure changes on digital panoramic radiographs of smokers. Pamukkale Medical Journal. 2024 Jan 1;17(1):117-28.
4. Chauhan R, Singh AK, Singh M, Shree R, Anand S, Singh AK, Verma S. Correlation of serum cornitine levels with bone mineral density among Indian male tobacco users. Bioinformation. 2022;18(6):543

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(2), 107-119 | ISSN:2251-6727

5. Gupta D, Vashi PG, Trukova K, Lis CG, Lammersfeld CA. Prevalence of serum vitamin D deficiency and insufficiency in cancer: Review of the epidemiological literature. Experimental and therapeutic medicine. 2011 Mar 1;2(2):181-93.
6. Santos IG, de Faria FR, da Silva Campos MJ, de Barros BÁ, Rabelo GD, Devito KL. Fractal dimension, lacunarity, and cortical thickness in the mandible: Analyzing differences between healthy men and women with cone-beam computed tomography. Imaging Science in Dentistry. 2023 Jun;53(2):153.
7. Carvalho BF, de Castro JG, de Melo NS, de Souza Figueiredo PT, Moreira-Mesquita CR, de Paula AP, Sindeaux R, Leite AF. Fractal dimension analysis on CBCT scans for detecting low bone mineral density in postmenopausal women. Imaging Science in Dentistry. 2022 Mar;52(1):53.
8. Germec-Cakan D, Tozlu M, Ozdemir F. Cortical bone thickness of the adult alveolar process-a retrospective CBCT study. Australasian Orthodontic Journal. 2014 May 1;30(1):54-60.
9. Azman D, Tassoker M. Determination of Trabecular Bone Changes in Smokers Using Fractal Analysis: A Case-Control Study.
10. White SC, Rudolph DJ. Alterations of the trabecular pattern of the jaws in patients with osteoporosis. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 1999 Nov 1;88(5):628-35.
11. Al-Bashaireh AM, Haddad LG, Weaver M, Chengguo X, Kelly DL, Yoon S. The effect of tobacco smoking on bone mass: an overview of pathophysiologic mechanisms. Journal of osteoporosis. 2018;2018(1):1206235.
12. Suman B, Redhu A. Relationship of bone mineral density with panoramic radiomorphometric indices in tobacco users in India. Journal of Indian Academy of Oral Medicine and Radiology. 2020 Apr 1;32(2):119-26.
13. Hastar E, Yilmaz HH, Orhan H. Evaluation of mental index, mandibular cortical index and panoramic mandibular index on dental panoramic radiographs in the elderly. European journal of dentistry. 2011 Jan;5(01):060-7.
14. Zeytinoğlu M, İlhan B, Dündar N, Boyacioğlu H. Fractal analysis for the assessment of trabecular peri-implant alveolar bone using panoramic radiographs. Clinical oral investigations. 2015 Mar;19:519-24.
15. Barra SG, Gomes IP, Amaral TM, Brasileiro CB, Abreu LG, Mesquita RA. New mandibular indices in cone beam computed tomography to identify low bone mineral density in postmenopausal women. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. 2021 Mar 1;131(3):347-55.
16. Nursari EM, Kiswanjaya B, Priaminiarti M, Bachtiar-Iskandar HH. Osteoporosis detection using radiomorphometric examination and fractal dimensions through cone- beam computed tomography. Majalah Kedokteran Gigi Indonesia.;8(2):84-97.
17. Alman AC, Johnson LR, Calverley DC, Grunwald GK, Lezotte DC, Hokanson JE.Diagnostic capabilities of fractal dimension and mandibular cortical width to identify men and women with decreased bone mineral density. Osteoporosis International. 2012 May;23:1631-6.
18. Arsan B, Köse TE, Çene E, Özcan İ. Assessment of the trabecular structure of mandibular condyles in patients with temporomandibular disorders using fractal analysis. Oral surgery, oral medicine, oral pathology and oral radiology. 2017 Mar 1;123(3):382-91.
19. Yeşiltepe S, Yılmaz AB, Kurtuldu E, Sarıca İ. Fractal analysis of temporomandibular joint trabecular bone structure in patients with rheumatoid arthritis on cone beam computed tomography images. Meandros Medical and Dental Journal. 2018 Dec 1;19(4):345.
20. Santos IG, de Faria FR, da Silva Campos MJ, de Barros BÁ, Rabelo GD, Devito KL. Fractal dimension, lacunarity, and cortical thickness in the mandible: Analyzing differences between healthy men and women with cone-beam computed tomography. Imaging Science in Dentistry. 2023

Jun;53(2):153.

21. Hayek E, Aoun G, Geha H, Nasseh I. Image-based bone density classification using fractal dimensions and histological analysis of implant recipient site. Acta Informatica Medica. 2020 Dec;28(4):272.

22. Gumussoy I, Duman SB. Alternative cone-beam CT method for the analysis of mandibular condylar bone in patients with degenerative joint disease. Oral radiology. 2020 Apr;36:177- 82.

23. Bachtler R, Walter C, Schulze RK. Fractal dimension in CBCT images as predictor for MRONJ: a retrospective cohort study. Clinical oral investigations. 2021 Apr;25:2113-8.

24. Secgin CK, Gulsahi A, Yavuz Y, Kamburoglu K. Comparison of mandibular index values determined from standard panoramic versus cone beam computed tomography reconstructed images. Oral surgery, oral medicine, oral pathology and oral radiology. 2019 Mar 1;127(3):257-64.

25. Kato CN, Tavares NP, Barra SG, Amaral TM, Brasileiro CB, Abreu LG, Mesquita RA. Digital panoramic radiography and cone-beam CT as ancillary tools to detect low bone mineral density in post-menopausal women. Dentomaxillofacial Radiology. 2019 Feb 1;48(2):20180254.

26. Munhoz L, Morita L, Nagai AY, Moreira J, Arita ES. Mandibular cortical index in the screening of postmenopausal at low mineral density risk: a systematic review. Dentomaxillofacial Radiology. 2021 May 1;50(4):20200514.

27. Seki K, Yoshino T, Ogisawa S, Arai Y, Tonogi M, Iinuma T. Diagnostic study of mandibular cortical index classification using dental cone-beam computed tomography findings: A preliminary cross-sectional study. Reports. 2023 Oct 11;6(4):48.

28. Kim YS, Kim KA, Koh KJ. The relationship between age and the mandibular cortical bone thickness by using panoramic radiograph. Imaging Science in Dentistry. 2010;40(2):83-7.

29. Dutra V, Susin C, da Costa NP, Veeck EB, Bahlis A, Fernandes AD. Measuring cortical thickness on panoramic radiographs: a validation study of the Mental Index. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2007 Nov 1;104(5):686-91.

30. Flanagan D. A comparison of facial and lingual cortical thicknesses in edentulous maxillary and mandibular sites measured on computerized tomograms. Journal of Oral Implantology. 2008 Oct 1;34(5):256-8.

31. Mostafa RA, Arnout EA, Abo el-Fotouh MM. Feasibility of cone beam computed tomography radiomorphometric analysis and fractal dimension in assessment of postmenopausal osteoporosis in correlation with dual X-ray absorptiometry. Dentomaxillofacial radiology. 2016 Sep 1;45(7):20160212.

32. Geraets WG, van der Stelt PF. Fractal properties of bone. Dentomaxillofac Radiol. 2000; 29(3): 144-153.

33. Link TM, Majumdar S, Lin JC, Newitt D, Augat P, Ouyang X, et al. A comparative study of trabecular bone properties in the spine and femur using high resolution MRI and CT. J Bone Miner Res. 1998;13(1):122-32. doi: 10.1359/ jbmr.1998.13.1.122.

34. Ergün S, Saraçoglu A, Güneri P, Ozpinar B. Application of fractal analysis in hyperparathyroidism. Dentomaxillofac Radiol. 2009;38(5):281-8. doi: 10.1259/dmfr/24986192.

35. Doyle MD, Rabin H, Suri JS. Fractal analysis as a means for the quantification of intramandibular trabecular bone loss from dental radiographs. In: Proc. SPIE 1380, Biostereometric Technology and Applications, (1 April 1991). doi: 10.1117/12.25125.

36. Southard TE, Southard KA, Krizan KE, Hillis SL, Haller JW, Keller J, et al. Mandibular bone density and fractal dimension in rabbits with induced osteoporosis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000;89(2):244-9. doi: 10.1067/ moe.2000.102223.

37. Kiel DP, Zhang Y, Hannan MT, Anderson JJ, Baron JA, Felson DT. The effect of smoking at

different life stages on bone mineral density in elderly men and women. Osteoporos Int. 1996;6(3):240-8. doi: 10.1007/bf01622741

38. Yoon V, Maalouf NM, Sakhaee K. The effects of smoking on bone metabolism.Osteoporos Int. 2012;23(8):2081-92. doi: 10.1007/s00198-012-1940-y.

39. Jorde R, Stunes AK, Kubiak J, Grimnes G, Thorsby PM, Syversen U. Smoking and other determinants of bone turnover. PLoS One. 2019 Nov 25;14(11):e0225539.

Figures:

Figure 1 Photograph of Carestream CS 9600 CBCT Unit

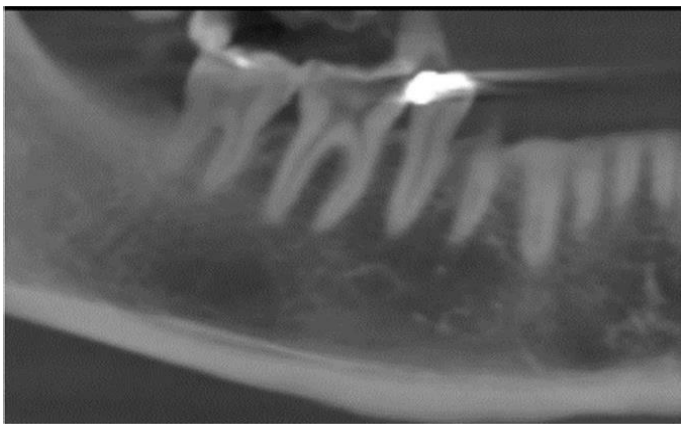

Figure 2(A) MCI observed on Panoramic reconstruction of CBCT image with 5mm thickness

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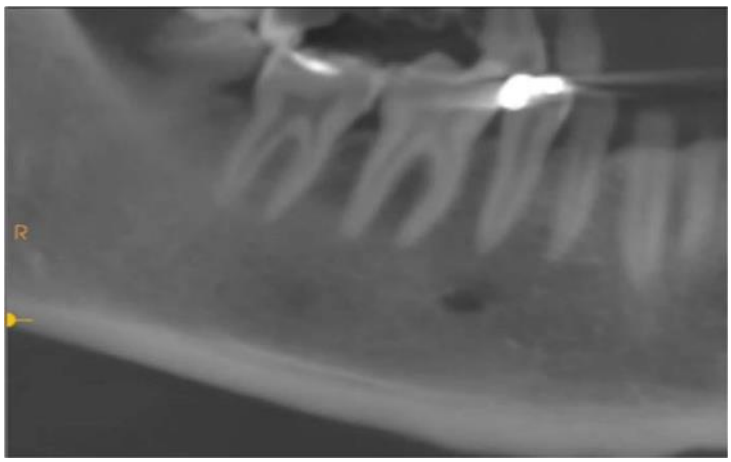

Figure 2(B) MCI observed on Panoramic reconstruction of CBCT image with 15 mm thickness

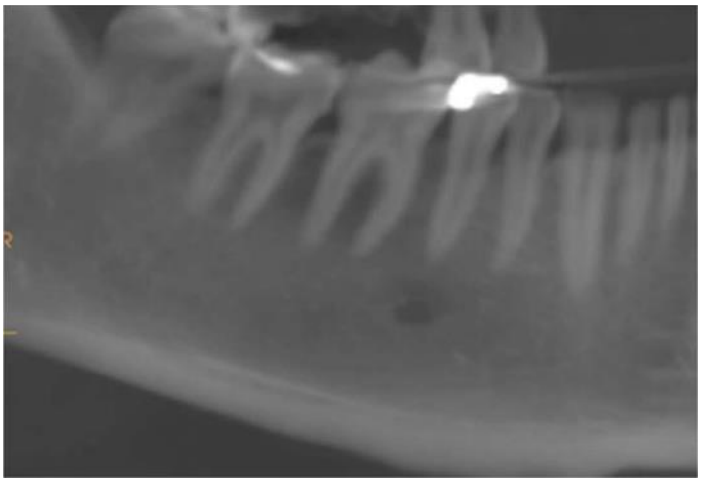

Figure 2(C) MCI observed on Panoramic reconstruction of CBCT image with 25mm thickness.

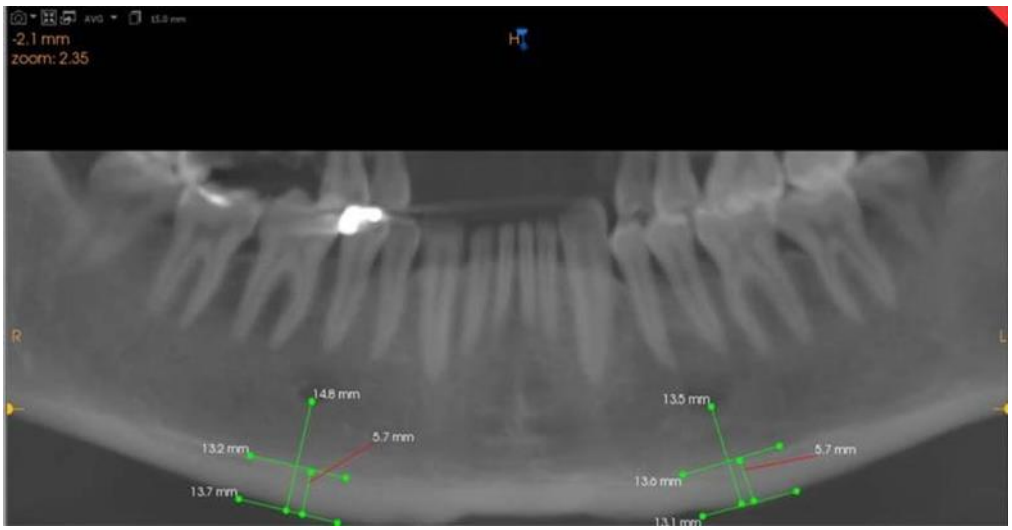

Figure 3- Cropped panoramic reconstruction image of CBCT showing mandibular cortical thickness.

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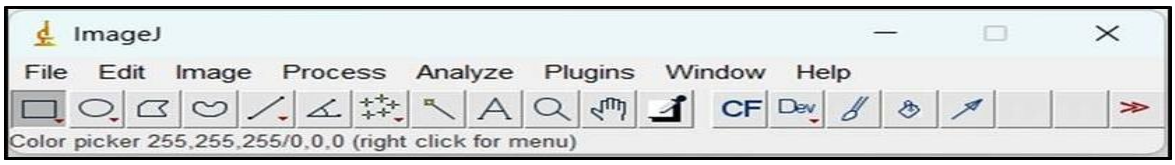
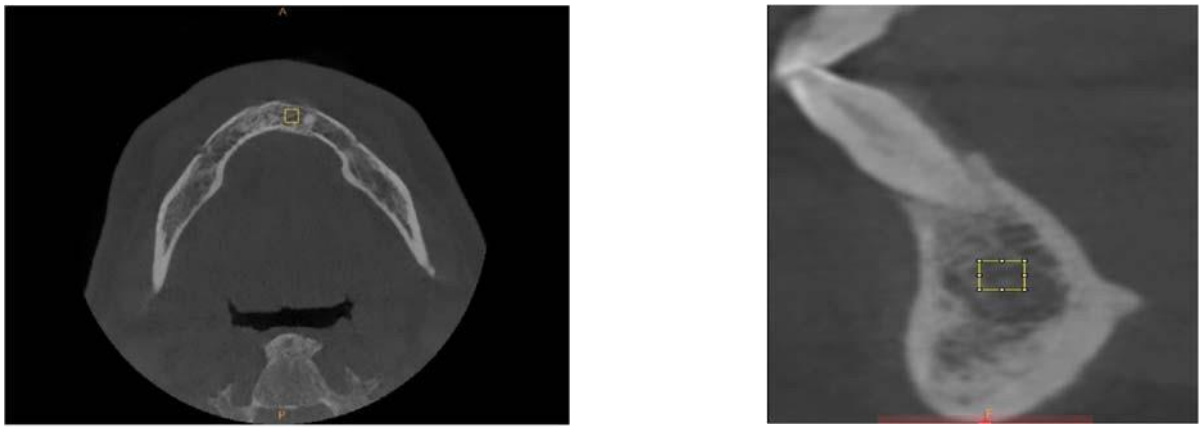


Figure 4- Image J public domain software



A B

Figure 5- Region of interest for calculating Fractal dimension selected on Axial(A)and Sagittal sections(B)

A B C D E F G

H I

Figure 6- Stages of Fractal Analysis

A- Selection and cutout of ROI

B- Duplication of Image

C- Gaussian filter application

D- Subtraction from original image

E- Addition of gray value

F- Binarization G-Erosion

H-Dilation

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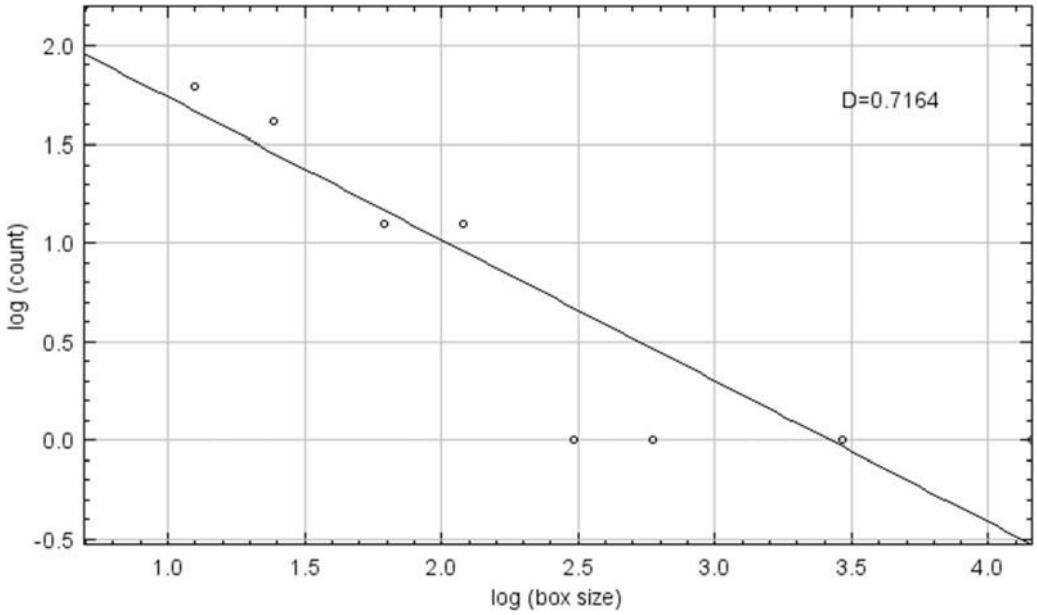
I- Skeletonization



Graph 1- Graph showing D value corresponding to the fractal dimension.

	Group	N	Mean	Std. Deviation	Median	Mean rank	Chi square value	p value of Kruskal-Wallis Test
FD avg	1	63	.83153	.064036	0.834	89.58	120.618	.000**
	2	63	.70308	.119055	0.689	44.46		
	3	63	1.08722	.169976	1.019	150.96		
MCT avg	1	63	3.79524	.428022	3.900	92.74	148.251	.000**
	2	63	2.91746	.338659	2.900	36.96		
	3	63	4.65556	.339130	4.600	155.30		

Table 1-Inter group comparison of Variables using Kruskal-Wallis Test

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	Mann-Whitney U value	Z value	p value of Mann-Whitney U test
FD avg	634.500	-6.601	0.000**
MCT avg	312.500	-8.190	0.000**

Table 2-Intra group Pair wise comparison of Group 1vs2 using Mann-Whitney U test

	Mann-Whitney U value	Z value	p value of Mann- Whitney U test
FD avg	293.000	-8.271	0.000**
MCT avg	170.000	-8.897	0.000**

Table 3-Intra group Pair wise comparison of Group 1vs3 using Mann-Whitney U test

	Mann-Whitney U value	Z value	p value of Mann- Whitney U test
FD avg	150.500	-8.964	0.000**
MCT avg	0.000	-9.711	0.000**

Table 4-Inter group Pair wise comparison of Group 2vs3 using Mann-Whitney U test

		Group					
		1	2	3	Total	Chi-Square value	P value of Chi-Square test
MCI	C1	0	0	48	48	143.076	.000**
	C2	61	50	15	126		
	C3	2	13	0	15		
	Total	63	63	63	189		

Table 5-Inter group comparison of frequencies of MCI Group Crosstabulation