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FRACTAL DIMENSION AND RADIOMORPHOMETRY OF THE MANDIBLE ON PANORAMIC RADIOGRAPHS AS PREDICTORS OF OSTEOPOROSIS IN TOBACCO USERS: A DXA-BASED PROSPECTIVE CROSS-SECTIONAL STUDY

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Keywords:

Osteoporosis, Fractal dimension, radiomorphometric indices, Panoramic radiography, Bone mineral density, DXA scan

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ABSTRACT: Introduction: Osteoporosis is a systemic skeletal disorder marked by reduced bone strength and increased fracture risk, often due to alterations in trabecular bone microarchitecture. Tobacco use both smoked and smokeless has emerged as a modifiable risk factor influencing bone health. Panoramic radiography (PR), a common dental imaging modality, offers potential for early detection of osteoporosis through analysis of fractal dimension (FD) and radiomorphometric indices (RMIs). **Materials and Methods:** This study conducted a comparative evaluation of mandibular bone quality using digital panoramic radiographs and dual-energy X-ray absorptiometry (DXA) scans in tobacco users and non-users aged 20–40 years. Fractal dimension and radiomorphometric parameters including MI, MCI, and PMI were analysed using Image J software. BMD values were obtained using DXA, and statistical analysis was performed to evaluate correlations. **Results:** Tobacco users demonstrated significantly lower FD values and altered radiomorphometric indices compared to controls, indicating compromised bone quality. A positive correlation was observed between FD/RMIs and DXA-derived BMD values, suggesting their diagnostic utility in early osteoporosis screening. **Conclusion:** Fractal geometry and radiomorphometric analysis on digital panoramic radiographs may serve as non-invasive, cost-effective indicators of early osteoporotic changes in the mandible, especially in tobacco users. These tools can assist dental practitioners in identifying at-risk individuals for timely medical referral and intervention.

INTRODUCTION: Osteoporosis is a widespread skeletal disorder characterized by diminished bone strength, increasing the likelihood of fractures due to alterations in bone microarchitecture [1]. The use of tobacco whether smoked or chewed is a significant and preventable risk factor that contributes to deteriorating bone health [2-4].

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Panoramic radiography (PR) is a commonly used imaging technique in dentistry that offers potential for identifying early signs of osteoporosis by evaluating mandibular bone structure [5-8]. Parameters such as fractal dimension (FD) and radiomorphometric indices (RMIs) can reflect early bone quality changes even before clinical fractures occur [6, 9-12].

Although dual-energy X-ray absorptiometry (DXA) remains the definitive method for assessing bone mineral density (BMD), its limited accessibility emphasizes the importance of alternative screening tools [5, 7, 13]. Analyzing FD and RMIs from PR images and comparing them with DXA-derived

BMD values may offer a simple, non-invasive method for early osteoporosis screening, especially in individuals with tobacco habits [3, 14-16]. The aim of the study is to evaluate fractal dimension and radiomorphometric indices on panoramic radiographs as potential indicators of early bone quality changes in tobacco users, in correlation with DXA-derived bone mineral density.

MATERIALS AND METHODS:

Study Design and Setting: This was a prospective, cross-sectional, observational study conducted in the Department of Oral Medicine and Radiology, CSMSS dental college and hospital from the time period of August 2025 to November 2025. The study protocol was approved by institutional ethical committee numbered as - CSMSS/DCH/EC/SS/2025 and was adhered to ethical guidelines and informed consent was obtained from all participants prior to enrollment.

Study Population: Total sample size comprised of completely dentulous 60 patients aged 20–40 years with 15 in each group were included. Participants were categorized equally into four groups (figure 1): Group A: Smokeless tobacco users, Group B: Smoking tobacco users, Group C: Users of both forms, Group D: Control group with no tobacco habits. The sample size was calculated based on detecting a significant difference between two independent group means with a power of 80% and a significance level of 5%. Although the final study included four groups (n = 60; 15 per group), the sample size was considered sufficient to detect clinically meaningful differences for primary outcomes such as fractal dimension and bone mineral density. The sample size estimation was aligned with the primary objective of evaluating fractal dimension and its correlation with bone mineral density, while additional analyses involving radiomorphometric indices were considered exploratory.

Sample size Calculation: The sample size for this prospective cross-sectional study was derived based on the difference in fractal dimension (FD) reported between tobacco users and non-users in prior studies (Basavarajappa *et al.*, 2021 [30], Yasar & Akgünlü, 2005 [6]. Using the formula for comparing means across multiple groups in ANOVA:

Sample Size Formula: $n = 2(Z\alpha/2+Z\beta)^2\sigma^2/\Delta^2$

Where, $Z\alpha/2 = 1.96$ (at 95% confidence), $Z\beta = 0.84$ (for 80% power), σ = pooled SD of FD from previous studies ≈ 0.05, Δ = minimum clinically significant difference in FD ≈ 0.05.

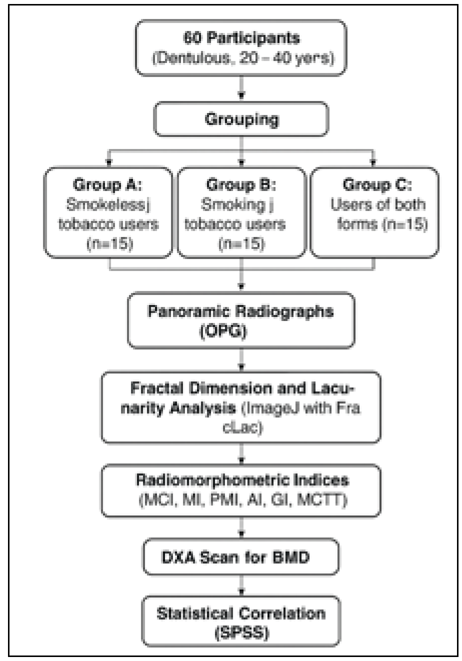

FIG. 1: STUDY FLOW DIAGRAM SHOWING PARTICIPANT SELECTION, GROUPING, AND WORKFLOW OF ANALYSIS

Inclusion Criteria: Patients included in the study were sampled from daily OPD of the department with habitual tobacco use for over one year (Groups A–C) with consumption for more than twice a day in form of chewing tobacco(smokeless) & Cigarettes/Bidi(smoked), dentulous individuals aged 20–40 years, no pathological, traumatic, or surgical conditions affecting the mandibular region were included in the study, Participants were screened to exclude significant periodontal disease and alveolar bone loss, and only those with clinically healthy or minimal periodontal changes without radiographic bone loss were included to avoid confounding of trabecular measurements and the study was conducted accordingly.

Exclusion Criteria: Patient with systemic diseases like metabolic bone diseases, endocrine disorders, chronic kidney disease, malabsorption syndromes, and long-term use of bone-affecting drugs, missing teeth, mandibular fractures, radiotherapy, pregnancy/lactation, implants or metal artifacts, parafunctional habits, or periapical lesions in the region of interest were excluded. These criteria were strictly applied during participant selection to maintain the internal validity of the study.

Image Acquisition and Analysis: Digital panoramic radiographs (OPG) were obtained using a Vatech PCH-2500 scanner operated within range of 50-90kVp & 4-10mA. Exposure parameters were typically adjusted based on patients gender &age. Images were exported in JPEG format via DICOM software. Bone mineral density was analysed using a DXA scan (SONOST 2000 Advance DXA system), with measurements obtained at the calcaneus (heel) and expressed in terms of T-scores. Fractal dimension (FD) and lacunarity were analysed using Image J 1.44 with the FracLac plug-in, focusing on four predefined regions of interest (ROIs) in the mandible **Fig. 2.**

ROI 1: Subcortical area of the right condyle subjacent to the superior pole.

ROI 2: Supracortical area superior to the right angle of the mandible.

ROI 3: Alveolar bone mesial to the left mental foramen.

ROI 4: Alveolar bone between the root of the left second premolar and the mesial root of the mandibular first molar in the periapical area.

FIG. 2: PANORAMIC RADIOGRAPH SHOWING SELECTED REGIONS OF INTEREST (ROIS) IN THE MANDIBULAR TRABECULAR BONE FOR FRACTAL DIMENSION AND LACUNARITY ANALYSIS

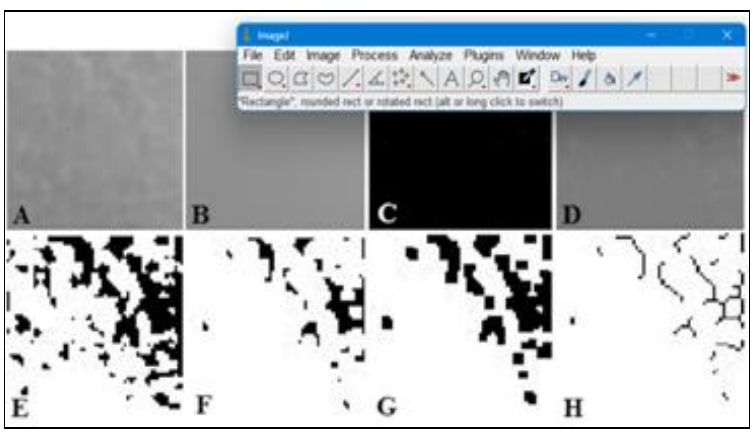

FIG. 3: IMAGE SHOWING FRACTAL DIMENSION (FD) AND LACUNARITY ANALYSIS USING IMAGE J 1.44 SOFTWARE

Calculations of Fractal Dimensions: The region of interest (ROI) was opened in Image J 1.44 software and subjected to Gaussian blurring. The blurred image was subtracted from the original image, and a constant gray value of 128 was added to each pixel. The image was then converted into a binary format using a threshold of 128, followed by erosion and dilation to reduce noise. Subsequently, the image was skeletonized, and the fractal dimension (FD) values were calculated using the box-counting method described by White and Rudolph **Fig. 3.**

Radiomorphometric Indices (RMIs) & Bone Mineral Density Assessment: The following indices were measured: Mandibular Cortical Index (MCI), Mental Index (MI), Panoramic Mandibular Index (PMI), Antegonial Index (AI), Gonial Index (GI), Mandibular Cortical Thickness (MCT) for the evaluation of mandibular jaw bone. Mandibular radiomorphometric indices were evaluated bilaterally and averaged for analysis. The following indices were measured:

Mandibular Cortical Index (MCI): Classified according to cortical morphology as C1 (normal cortex with sharp endosteal margin), C2 (presence of semilunar defects or cortical residues), or C3 (porous cortex with heavy endosteal residues).

Mental Index (MI): Cortical thickness measured on a line perpendicular to the inferior border of the mandible at the midpoint of the mental foramen (normal value > 3.1 mm).

Panoramic Mandibular Index (PMI): Ratio of mandibular cortical thickness to the distance between the superior margin of the mental foramen and the inferior border of the mandible (normal value > 0.3).

Antegonial Index (AI): Cortical thickness measured at the intersection of the tangent to the anterior border of the ramus and the inferior mandibular cortex (normal value > 3.2 mm).

Gonial Index (GI): Cortical thickness measured at the bisector of the angle formed by the tangent to the posterior border of the ramus and the inferior border of the mandible (normal value > 1.2 mm). And bone mineral density was assessed using dual-energy X-ray absorptiometry (DXA), which served as the reference standard for comparison.

Statistical Analysis: Data were analysed using SPSS version 21. Descriptive statistics were expressed as mean ± standard deviation. Normality was tested using the Shapiro–Wilk test. Intergroup comparisons among the four groups were performed using one-way analysis of variance (ANOVA) for normally distributed data, followed by Tukey's post hoc test. For non-normally distributed data, the Kruskal–Wallis test with appropriate post hoc analysis was applied. A 5% level of significance ($p<0.05$) and 95% confidence interval were used. Correlation between radiographic variables (FD, λ, RMIs) and DXA-derived BMD was assessed using the Pearson correlation coefficient (r). Intra- and inter-observer reliability for continuous variables (FD, lacunarity, and RMIs) were assessed using the intraclass correlation coefficient (ICC), while agreement for the categorical variable (MCI) was evaluated using Cohen's kappa (κ).To account for multiple comparisons across outcome variables, Bonferroni correction was applied, and an adjusted significance level of $p < 0.00625$ was considered statistically significant.

$$\text{Bonferroni correction: } \alpha = 0.05 / 8 = 0.00625$$

RESULTS: A total of 60 participants were included in the study and divided equally into four groups: Group A – smokeless tobacco users, Group B – smoking tobacco users, Group C – combined tobacco users, and Group D – controls with no tobacco habits. The mean age of participants was comparable across all groups ($p > 0.05$). A total of 60 participants were included and equally distributed into four groups (n = 15 each). The mean age was comparable across groups, with no significant difference observed. Tobacco user groups showed a male predominance, whereas the control group had a relatively balanced sex distribution. Smokeless tobacco users reported a frequency of 3–7 times per day, while smokers consumed 4–20 cigarettes per day. Combined users exhibited both forms of exposure with variable intensity. Overall, the groups were comparable in terms of age, although differences in sex distribution and exposure patterns should be considered when interpreting the results.

TABLE 1: BASELINE CHARACTERISTICS OF STUDY PARTICIPANTS

Parameter	Smokeless (n=15)	Smoking (n=15)	Combined (n=15)	Control (n=15)
Age (years, mean ± SD)	33.4 ± 4.8	33.7 ± 4.6	32.9 ± 4.9	34.2 ± 5.2
Male, n (%)	11 (73.3%)	12 (80.0%)	11 (73.3%)	7 (46.7%)
Female, n (%)	4 (26.7%)	3 (20.0%)	4 (26.7%)	8 (53.3%)
Tobacco exposure (per day)	3–7 times/day	4–20 cigarettes/day	Mixed exposure	Nil

Fractal Dimension (FD): The mean fractal dimension values were lowest among tobacco users compared to controls, indicating reduced trabecular bone complexity. Values were as: Group A (smokeless tobacco): 1.175 ± 0.04, Group B (smokers): 1.169 ± 0.05, Group C (combined users): 1.161 ± 0.03, Group D (controls): 1.208 ± 0.04.Intergroup comparison revealed a statistically significant reduction in FD among all tobacco user groups compared to controls ($p < 0.001$). The lowest FD was observed in combined tobacco users **Fig. 4.**

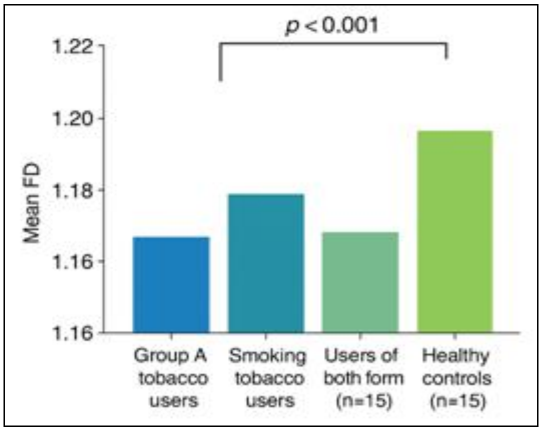

FIG. 4: COMPARISON OF MEAN FRACTAL DIMENSION (FD) AMONG STUDY GROUPS. TOBACCO USERS EXHIBITED SIGNIFICANTLY LOWER FD VALUES THAN CONTROLS (P<0.001)

Lacunarity (λ): Mean lacunarity values were Group A: 0.455 ± 0.07, Group B: 0.463 ± 0.06, Group C: 0.478 ± 0.08, Group D: 0.415 ± 0.05 showing higher values in tobacco users, suggesting a more heterogeneous and porous trabecular pattern. The difference in lacunarity between groups was statistically significant ($p < 0.05$), with the highest heterogeneity observed in Group C **Fig. 5.**

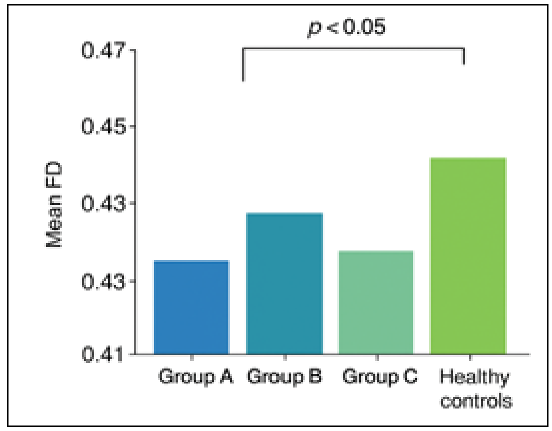

FIG. 5: MEAN LACUNARITY VALUES ACROSS STUDY GROUPS. TOBACCO USERS SHOWED HIGHER LACUNARITY INDICATING INCREASED TRABECULAR BONE HETEROGENEITY

Radiomorphometric Indices: Significant variation was also noted in mandibular cortical and morphometric indices: Mandibular Cortical Index (MCI): The majority of control participants exhibited C1 type (sharp, even cortex), whereas tobacco users more frequently showed C2 or C3 types, indicating cortical porosity. Intra-observer reliability demonstrated excellent agreement, with ICC values ranging from 0.88 to 0.93 and κ = 0.86 for MCI. Inter-observer reliability showed good to excellent agreement, with ICC values ranging from 0.84 to 0.90 and κ = 0.82. These findings indicate high consistency and reproducibility of the measurements. Mental Index (MI) and Panoramic Mandibular Index (PMI) values were reduced in tobacco users compared to controls ($p < 0.05$) **Table 2, Fig. 6, 7, 8.**

TABLE 2: COMPARISON OF MEAN RADIOMORPHOMETRIC INDICES BETWEEN GROUPS

Index	Smokeless Tobacco	Smoking Tobacco	Combined Users	Control Group	p-value
Mandibular Cortical Thickness (mm)	2.56 ± 0.44	2.52 ± 0.42	2.51 ± 0.43	3.51 ± 0.48	< 0.001
Panoramic Mandibular Index (PMI)	0.22 ± 0.05	0.21 ± 0.05	0.20 ± 0.04	0.29 ± 0.04	< 0.001
Mental Index (MI) (mm)	2.71 ± 0.24	2.67 ± 0.22	2.66 ± 0.23	3.23 ± 0.41	< 0.001
Antegonial Index (AI) (mm)	2.56 ± 0.27	2.52 ± 0.25	2.50 ± 0.26	2.87 ± 0.52	< 0.05
Gonial Index (GI) (mm)	0.92 ± 0.20	0.85 ± 0.18	0.82 ± 0.19	1.94 ± 0.65	< 0.001

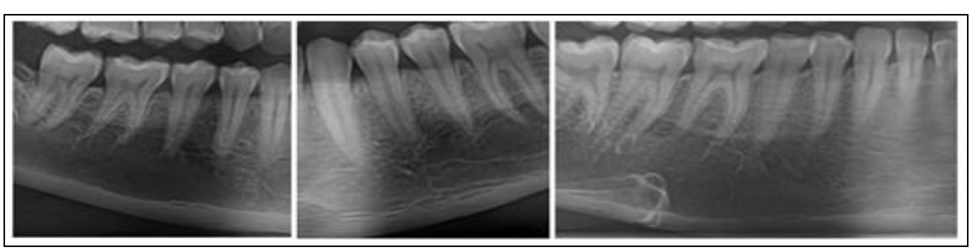

FIG. 6: MANDIBULAR CORTICAL INDEX

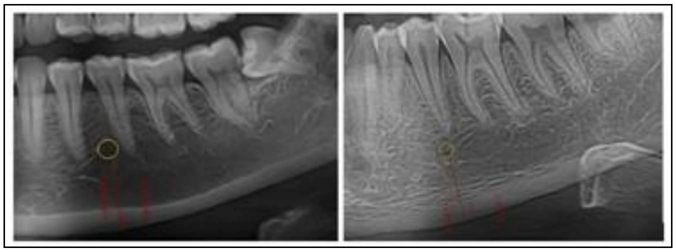

FIG. 7: PANORAMIC MANDIBULAR INDEX

FIG. 8: ANTEGONIAL INDEX AND GONIAL INDEX

Bone Mineral Density (DXA): T-score values were used for bone mineral density assessment as they provide a standardized comparison of an individual's BMD with that of a healthy young adult reference population and are widely accepted for the diagnosis and classification of osteoporosis according to World Health Organization (WHO) criteria. This allows for consistent interpretation, risk stratification, and comparison with existing literature, making T-scores a reliable parameter for correlating radiographic findings with bone status. DXA analysis showed that tobacco users had lower mean BMD values compared to controls: Group A: 0.872 ± 0.03 g/cm², Group B: 0.865 ± 0.04 g/cm², Group C: 0.852 ± 0.05 g/cm², Group D: 0.912 ± 0.04 g/cm². The reduction in BMD among tobacco users was statistically significant ($p < 0.01$), with combined users showing the lowest bone mineral density.

Correlation Analysis: A strong positive correlation was found between FD and DXA-measured BMD ($r = 0.78$, $p < 0.001$) and between RMIs and BMD ($r = 0.71$, $p < 0.01$). Conversely, lacunarity was negatively correlated with BMD ($r = –0.65$, $p < 0.01$) **Fig. 9, 10, Table 3.**

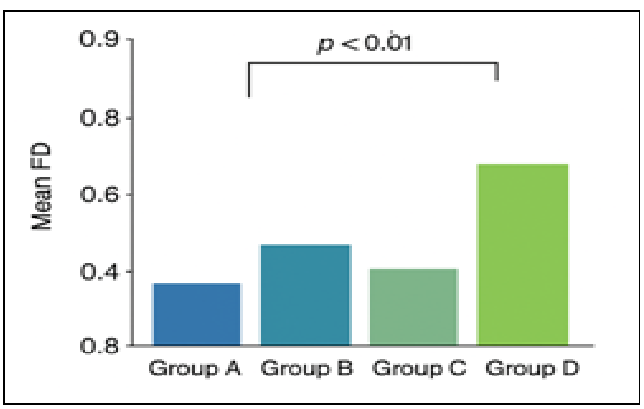

FIG. 9: MEAN BONE MINERAL DENSITY (BMD) VALUES MEASURED BY DXA ACROSS STUDY GROUPS. COMBINED TOBACCO USERS (GROUP C) SHOWED THE LOWEST BMD (P<0.01)

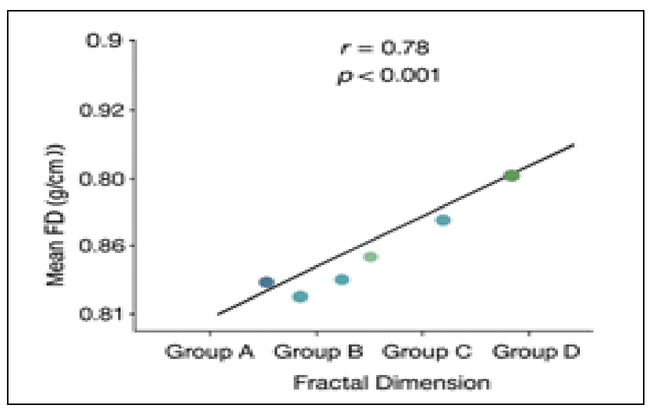

FIG. 10: SCATTER PLOT SHOWING POSITIVE CORRELATION BETWEEN FRACTAL DIMENSION AND DXA-DERIVED BONE MINERAL DENSITY

TABLE 3: SUMMARY OF FRACTAL, RADIOMORPHOMETRIC, AND BONE MINERAL DENSITY PARAMETERS AMONG STUDY GROUPS

Parameter	Group A	Group B	Group C	Group D	Notes
Fractal Dimension (FD)	1.175 ± 0.04	1.169 ± 0.05	1.161 ± 0.03	1.208 ± 0.04	Lower in tobacco users (p<0.001)

Lacunarity (λ)	0.455 ± 0.07	0.463 ± 0.06	0.478 ± 0.08	0.415 ± 0.05	Higher in tobacco users (p<0.05)
BMD (g/cm²)	0.872 ± 0.03	0.865 ± 0.04	0.852 ± 0.05	0.912 ± 0.04	Lowest in combined users (p<0.01)
Mental Index (MI)	Reduced	Reduced	Reduced	Higher	p < 0.05
PMI	Reduced	Reduced	Reduced	Higher	p < 0.05
MCI	Few C1, More C2/C3	Few C1, More C2	Very few C1, Many C2/C3	Mostly C1	Trend only
Correlation FD–BMD	r = 0.78				Strong positive (p<0.001)
Correlation RMIs–BMD	r = 0.71				Moderate positive (p<0.01)
Correlation Lacunarity–BMD	r = –0.65				Moderate negative (p<0.01)

One-way ANOVA demonstrated statistically significant differences among the groups for fractal dimension (FD), radiomorphometric indices, and bone mineral density (BMD) ($p < 0.05$). Mean FD was highest in controls (1.208 ± 0.04) and lowest in combined users (1.161±0.03). Tukey's post hoc analysis revealed that combined tobacco users showed significantly lower BMD (0.852 ± 0.05 g/cm²) compared to controls (0.912 ± 0.04 g/cm²). The Kruskal–Wallis test showed significantly higher lacunarity in tobacco users, particularly in combined users (0.478 ± 0.08), compared to controls (0.415±0.05) ($p < 0.05$). Effect size analysis demonstrated clinically meaningful differences between tobacco users and controls. For fractal dimension (FD), large effect sizes were observed for smokeless (d = 0.83), smoking (d = 0.92), and combined users (d = 1.25) compared to controls. Similarly, bone mineral density (BMD) showed moderate to large effect sizes, with the highest effect observed in combined users (d = 0.95). The 95% confidence intervals for these comparisons did not cross zero, indicating consistent and meaningful differences between groups. After Bonferroni correction, FD and selected radiomorphometric indices remained statistically significant, whereas lacunarity, AI, and BMD did not retain statistical significance. These findings suggest that FD and selected radiomorphometric indices are more robust indicators of bone quality changes in tobacco users **Table 4.**

TABLE 4: BONFERRONI CORRECTION

Parameter	Original p-value	After Bonferroni	Interpretation
FD	<0.001	Significant	Remains significant
Lacunarity	<0.05	Not significant	Loses significance
BMD	<0.01	Not significant	Borderline / NS
MI	<0.001	Significant	Remains significant
PMI	<0.001	Significant	Remains significant
MCT	<0.001	Significant	Remains significant
AI	<0.05	Not significant	Not significant
GI	<0.001	Significant	Remains significant

DISCUSSION: The present study evaluated the potential of fractal dimension (FD) and radiomorphometric indices (RMIs) of the mandibular bone on digital panoramic radiographs as predictors of bone mineral density (BMD) determined by DXA scans among tobacco users. The study demonstrated a significant reduction in FD and RMI values and an increase in lacunarity among tobacco users when compared to healthy controls, indicating early microarchitectural deterioration of the mandibular trabecular bone.

Fractal Dimension and Lacunarity Findings: In this study, the mean FD values were significantly lower among all forms of tobacco users compared to controls, consistent with the findings of Basavarajappa *et al.* (2021) [30], who reported that FD values were lower in tobacco users, suggesting a less complex trabecular bone pattern. Similarly, higher lacunarity values in smokeless and combined tobacco users reflected a more heterogeneous and porous bone texture, corroborating Basavarajappa's observation that lacunarity is an indicator of trabecular bone irregularity and disorganization. The reduced FD and increased lacunarity in the tobacco groups could be attributed to nicotine-induced vasoconstriction and oxidative stress, which compromise bone formation and remodelling. Mishra *et al.* (2015) [1] and Wong *et al.* (2007) [4] highlighted that nicotine and tobacco toxins impair osteoblast activity and calcium metabolism, leading to diminished bone quality. Additionally, Yasar and Akgünlü (2005) [6] demonstrated that FD and lacunarity parameters on dental radiographs are sensitive markers of trabecular bone changes, supporting the present findings.

Radiomorphometric Indices: The mandibular cortical and morphometric indices (MI, PMI, and MCI) were reduced in tobacco users, consistent with increased cortical porosity. The shift from MCI type C1 in controls to C2 and C3 in tobacco users reflects endosteal cortical erosion and thinning, which align with the results of Tavares *et al.* (2016) [4] and Mudda *et al.* (2010) [17], who found that RMIs from panoramic radiographs are reliable indicators of reduced BMD and potential osteoporosis. White and Rudolph (1999 [5] first reported that trabecular changes in the jaws correlate with systemic osteoporosis, while Yasar and Akgunlu (2008) [10] confirmed that cortical indices can be quantitatively assessed to evaluate mandibular bone loss. These findings reinforce the diagnostic potential of panoramic radiographs in identifying individuals at risk of osteoporosis.

Correlation with DXA Bone Mineral Density: The current study found a strong positive correlation between FD/RMIs and DXA-derived BMD, and a negative correlation between lacunarity and BMD. These results are consistent with Sindeaux *et al.* (2014) [1], who demonstrated that both FD and mandibular cortical width are significantly lower in osteoporotic individuals as confirmed by DXA. Tavares *et al.* (2016) [4] also concluded that panoramic radiographic indices can serve as auxiliary tools to predict low BMD and identify at-risk individuals for DXA screening.

The decline in BMD among tobacco users observed here supports findings by Abbas *et al.* (2015) [3] and Quandt *et al.* (2005) [15], who reported a significant association between tobacco consumption and bone density reduction. Yoon *et al.* (2012) [24] further emphasized that smoking affects bone metabolism through hormonal and vascular pathways, leading to decreased calcium absorption and increased bone resorption.

Comparative Interpretation: Among the tobacco user groups, combined users (Group C) showed the greatest reduction in FD and RMI values and the lowest DXA BMD, indicating a cumulative detrimental effect of both smoking and smokeless tobacco on bone health. This trend mirrors the findings of Basavarajappa *et al.* (2021) [30] and Abbas *et al.* (2015) [3], suggesting that dual-form tobacco exposure has a compounded impact on bone microstructure. The use of fractal analysis offers a sensitive, non-invasive method to quantify trabecular bone complexity. As demonstrated by Ruttimann *et al.* (1992) [25] and Doyle *et al.* (1991) [20], FD analysis can reveal subtle variations in bone density patterns that precede clinically detectable bone loss. When combined with radiomorphometric indices, as in the present study, panoramic radiography becomes a valuable adjunct for early osteoporosis screening in routine dental practice.

Clinical Significance: The findings of this study suggest that mandibular bone changes observed on panoramic radiographs can serve as early indicators of osteoporosis, particularly in high-risk groups such as tobacco users. Since panoramic radiographs are commonly used in dental clinics, dentists are well positioned to identify early radiographic signs of decreased bone mass and refer patients for DXA evaluation and preventive care.

Limitations and Future Scope: The study's limitations include a relatively small sample size and the restriction to a 20–40-year age group, which may limit generalizability to older populations more prone to osteoporosis. Certain potential confounding factors, including body mass index (BMI), physical activity, dietary calcium and vitamin D intake, alcohol consumption, sunlight exposure, hormonal status, medication history (e.g., corticosteroids and antiepileptics), systemic illnesses, and family history of osteoporosis, were not assessed in this study, which may have influenced the findings.

The absence of adjustment for key confounders, including age and sex, in the correlation analysis may have introduced residual confounding, thereby limiting the accuracy of the observed associations. The sex distribution across the study groups was not balanced, and no stratified or adjusted analysis was performed; therefore, sex-related differences in bone density may have influenced the results. Future studies with larger, multi-centric samples and longitudinal follow-up using 3D imaging modalities such as CBCT or MRI-based trabecular analysis are recommended to validate the predictive accuracy of FD and RMIs across different populations.

CONCLUSION: Fractal dimension and radiomorphometric analysis of mandibular bone on digital panoramic radiographs demonstrate a strong association with DXA-measured bone mineral density. These parameters can thus be used as non-invasive, cost-effective screening tools for early detection of osteoporotic changes in tobacco users, facilitating timely medical intervention and preventive management.

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CONFLICT OF INTEREST: Nil

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