ความสัมพันธ์ระหว่างค่าความหนาแน่นมวลกระดูกกับดัชนีทางภาพรังสีพานอรามิกของกระดูกขากรรไกรล่าง และจำนวนฟันที่สูญเสีย ในผู้ป่วยทันตกรรมของโรงพยาบาลตติยภูมิแห่งหนึ่ง

จุฬามณี สุขพรหม ท.บ.
โรงพยาบาลราชวิถี แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพมหานคร 10400 ประเทศไทย

Association between Bone Mineral Density, Panoramic Radiographic Indices of the Mandible, and Tooth Loss in Dental Patients at a Tertiary Hospital

Chulamanee Sookprome, D.D.S.
Rajavithi Hospital, Thung Phaya Thai, Ratchathewi, Bangkok, 10400, Thailand
Corresponding Author: Chulamanee Sookprome (E mail: chulamanees@gmail.com)
(Received: 29 September, 2025; Revised: 14 December, 2025; Accepted: 22 January, 2026)

Abstract

Background: Previous studies have shown the association between decreased bone mineral density and changes in mandibular bone structure. This has led to increased interest in investigating the relationship between osteoporosis, panoramic radiographic imaging and tooth loss. Panoramic radiographs which commonly used in dentistry are considered a useful and cost-effective screening tool for identifying patients at risk for osteoporosis. **Objective:** To examine the association between bone mineral density (BMD), tooth loss and three panoramic radiographic indices of mandible (panoramic mandibular index-PMI, mental index-MI, and mandibular cortical index-MCI) in dental patients. **Methods:** This cross-sectional study included 125 patients who had an oral examination and were treated at Rajavithi Hospital during the period from January 2024 to August 2025. Inclusion criteria were the patients with no history of fractures and no prior use of osteoporosis. All participants had undergone bone mineral density (BMD) assessment and digital panoramic radiographic imaging. BMD T-score and parameters such as PMI, MI, MCI, and tooth loss were measured. The independent t-test, One-Way ANOVA and Pearson correlation were analyzed. **Results:** A total 125 dental patients in this research were 13 males (10.4%) and 112 female (89.6%), age from 50 to 89 years. This study found a significant association between BMD T-score and panoramic radiographic indices of mandible (MI, MCI) and tooth loss (p-value < .05). However, BMD T-score was not significantly associated with PMI. **Conclusions:** These findings of this study suggest that in patients' panoramic radiographic indices (MI, MCI indices) and tooth loss may be a useful index for screening osteoporosis. Bone mineral density (BMD) measurement by dual-energy X-ray absorptiometry (DEXA) remains the method for screening osteoporosis.

Keywords: Bone mineral density, Panoramic radiographic indices, Tooth loss

บทคัดย่อ

ภูมิหลัง: การศึกษาที่ผ่านมาแสดงให้เห็นถึงความสัมพันธ์ของความหนาแน่นของมวลกระดูกกับการเปลี่ยนแปลงโครงสร้างของกระดูกขากรรไกรล่าง การใช้ภาพถ่ายรังสีพาโนรามิกซึ่งใช้ในทันตกรรมอย่างแพร่หลาย อาจเป็นเครื่องมือที่มีประโยชน์และคุ้มค่าในการคัดกรองผู้ป่วยที่มีความเสี่ยงต่อโรคกระดูกพรุน **วัตถุประสงค์:** ศึกษาความสัมพันธ์ของค่าความหนาแน่นของมวลกระดูก (BMD) กับตัวแปรได้แก่ จำนวนซี่ฟันที่สูญเสีย, ดัชนีจากภาพถ่ายรังสีพานอรามิกของกระดูกขากรรไกรล่าง 3 ดัชนี (ดัชนีพานอรามิกแมนิบูลล่าอินเด็กซ์-PMI,

ดัชนีเมนตัล-MI และ ดัชนีแมนิบูลล่า คอร์ติคอล-MCI) ในผู้ป่วยทันตกรรม **วิธีการ:** ศึกษาแบบภาคตัดขวางในภาพถ่ายรังสีพานอรามิกกระดูกขากรรไกรของผู้ป่วยเข้ารับการตรวจและรักษาทางช่องปากที่โรงพยาบาลราชวิถี ในช่วงระหว่างเดือนมกราคม พ.ศ. 2567 ถึง สิงหาคม พ.ศ. 2568 จำนวน 125 ราย เกณฑ์การคัดเลือก ได้แก่ ผู้ป่วยที่ไม่มีประวัติกระดูกหัก และไม่ได้รับยารักษาโรคกระดูกพรุนมาก่อน ผู้ป่วยทุกคนได้รับการตรวจค่าความหนาแน่นของมวลกระดูก (BMD) และการถ่ายภาพรังสีพาโนรามิกแบบดิจิทัล บันทึกค่า T-score ความหนาแน่นของมวลกระดูกรวมทั้งดัชนี PMI, MI, MCI และจำนวนฟันที่สูญเสีย วิเคราะห์ข้อมูลด้วยสถิติ independent t-test, one-way ANOVA และการวิเคราะห์สหสัมพันธ์แบบเพียร์สัน (Pearson correlation) **ผล:** ผู้ป่วยทั้งหมด 125 คน ประกอบด้วยเพศชาย 13 ราย (10.4%) และเพศหญิง 112 ราย (89.6%) อายุระหว่าง 50 ถึง 89 ปี พบความสัมพันธ์อย่างมีนัยสำคัญทางสถิติระหว่างค่า T-score ความหนาแน่นของมวลกระดูกกับดัชนีทางภาพรังสีพาโนรามิกของกระดูกขากรรไกรล่าง คือ ดัชนีเมนตัล ดัชนีแมนิบูลล่า คอร์ติคอล และจำนวนฟันที่สูญเสีย อย่างไรก็ตามพบว่าค่า T-score ความหนาแน่นของมวลกระดูกไม่มีความสัมพันธ์กับดัชนีพานอรามิกแมนิบูลล่าอินเด็กซ์ **สรุป:** ผลการศึกษานี้ชี้ให้เห็นว่า ดัชนีทางภาพรังสีพาโนรามิกของกระดูกขากรรไกรล่าง ได้แก่ ดัชนีเมนตัล ดัชนีแมนิบูลล่า คอร์ติคอล และจำนวนฟันที่สูญเสีย อาจเป็นตัวชี้วัดที่มีประโยชน์ในการคัดกรองผู้ป่วยที่มีความเสี่ยงต่อโรคกระดูกพรุนได้ ทั้งนี้ การวัดความหนาแน่นของมวลกระดูกด้วยเครื่องดูดซับรังสีเอกซ์แบบสองพลังงาน (DEXA) ยังคงเป็นวิธีมาตรฐานในการคัดกรองโรคกระดูกพรุนที่ใช้กันอยู่

คำสำคัญ: ค่าความหนาแน่นมวลกระดูก, ดัชนีทางภาพรังสีพานอรามิกของกระดูกขากรรไกรล่าง, จำนวนฟันที่สูญเสีย

Introduction

According to the 2024 survey by the National Statistical Office, Thailand is facing a rapidly aging population. 14 million people aged 60 and older, representing approximately 20% of the total population.[1] As the proportion of older adults increases, osteoporosis has become a significant public health concern, leading to higher morbidity and mortality rate.[2]

The standard technique for bone mineral density (BMD) evaluation is dual energy X-ray absorptiometry (DEXA). The BMD T-score is used to define the diagnosis of osteoporosis and reflects how much a patient's bone density differs from that of a young, healthy adult.[2] Because osteoporosis is a generalized skeletal disease, it has been proved that low bone density may lead to accelerated resorption of alveolar bone. The destruction of alveolar bone can result in tooth mobility and eventual tooth loss.[3] Tooth loss may also be with periodontal disease or periodontal attachment loss. Several studies have shown that osteoporosis a potential risk factor for alveolar bone loss and tooth loss.[4-6]

Panoramic radiographs are widely used in dentistry for diagnosis and treatment planning. Numerous studies have investigated the association between panoramic radiographic indices and BMD T-score. Benson first described the use of the Panoramic Mandibular Index (PMI) as a radiographic indicator for detecting osteoporosis and osteopenia.[7] Another radiographic index, the Mandibular Cortical Index (MCI) was first described by Klemetti et al.[8] Many studies have shown that the PMI, Mental Index (MI), and MCI may serve as useful markers for detecting osteoporosis on panoramic radiographs.[9-12] In Thailand, Pornsathapant[13] reported that MCI can be used to screen osteoporotic patients, whereas PMI and MI cannot used for this purpose. Another Thai study by Pornchai[14] recommended using both the MI and MCI as screening tools for osteoporosis. A study of correlation panoramic mandibular index and BMD in women also reported a significant difference in MCI and MI.[15] However, whether osteoporosis is truly associated with MI, PMI, MCI, or tooth loss remains unclear.

At Rajavithi Hospital, patients at high risk for osteoporosis routinely undergo BMD testing. Medication-related osteonecrosis of the jaw (MRONJ)

is more likely to develop in areas affected by local dental infections.[16-17] Therefore, before starting treatment with anti-resorptive agents, patients are typically referred to a dentist to eliminate potential sources of infection or extract teeth with poor prognosis in order to reduce the risk of developing MRONJ.

The aim of this study was to evaluate the association between BMD T-score, Mental Index (MI), Panoramic Mandibular Index (PMI), Mandibular Cortical Index (MCI) and the number of missing teeth in dental patients who have undergone bone mineral density (BMD) measurement.

Materials and Methods

This cross-sectional study in 125 dental patients. The sample size was calculated using the formula for estimating the correlation coefficient.[18] The expected correlation coefficient (r) = 0.3 was calculated from previous study[15] with significance level (α) of .05. the calculated samples were 113. The total sample size was 125 patients to account for data loss.

This study was approved by the Human Research Ethics Committee of Rajavithi Hospital (No.144/2568). All patients examined and treated at Rajavithi Hospital from January 2024 to August 2025 were reviewed.

A total of 125 patients with no history of fractures and who had not received any osteoporosis medication were included. All patients had undergone bone mineral density (BMD) testing and digital radiography. If multiple panoramic radiographs were available, the radiograph taken closest to the date of the BMD assessment was selected for analysis. Patients were excluded if a panoramic radiograph was unavailable or if the mental foramen could not be identified. Patients with a history of radiation therapy or surgery in the head and neck region were also excluded. The observer was blinded to patients' BMD T-scores when evaluating tooth loss and panoramic radiographic indices.

The most common bone mineral density test was central dual-energy x-ray absorptiometry (DEXA). Patients BMD T-score were categorized as normal (T-score > −1.0), osteopenia (T-score = −1.0 to −2.5), or osteoporosis (T-score <−2.5), based on the World Health Organization (WHO) criteria. All digital panoramic radiographs were obtained at dental department in Rajavithi hospital using Sirona Orthophos XG5 (Sirona Dental Systems GmbH, Bensheim, Germany). Exposure parameters were 10 mA-seconds (mAs), 15 seconds, at 80 kVp. Tooth loss and the three panoramic indices (PMI, MI, MCI) were measured using Sidexis software (Sirona Dental Systems GmbH, Bensheim, Germany).

The panoramic mandibular index (PMI)[7], was calculated as the ratio of vertical distance from the lower border of the mental foramen to the inferior border of the mandibular cortex to the cortical thickness directly below the mental foramen (Fig.1). A significant association between low PMI values and osteoporosis progression has been reported. PMI is often used to identify individuals who may be at risk of osteoporosis.[7]

The Mental Index (MI) was defined as the cortical width of mandibular bone at the level of the mental foramen A perpendicular line intersecting the inferior border of the mental foramen was drawn, along which the mandibular cortical width was measured.[12] In the present study the MI used for statistical analysis was the average of the left and right sides. (Fig.1)

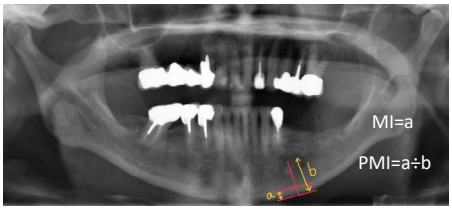

Figure 1. The Mental Index (MI) = a, The Panoramic Mandibular Index (PMI) = a÷b

The mandibular Cortical Index (MCI) was measured by identifying the inferior mandibular cortex on both sides at the distal edge of mental foramen. This index reflects the degree of cortical erosion and is classified into three groups according to the Klemetti index introduced in 1994.[8] C1: Normal cortex. The endosteal margin of the cortex is even and sharp on both sides. C2: Mildly to moderate eroded cortex: semilunar defects (lacunar resorption) and/or appears to form endosteal cortical residues on endosteal margin one or both sides. C3: Severely eroded cortex: The cortical layer forms strong endosteal cortical residues and is clearly porous (Fig.2).

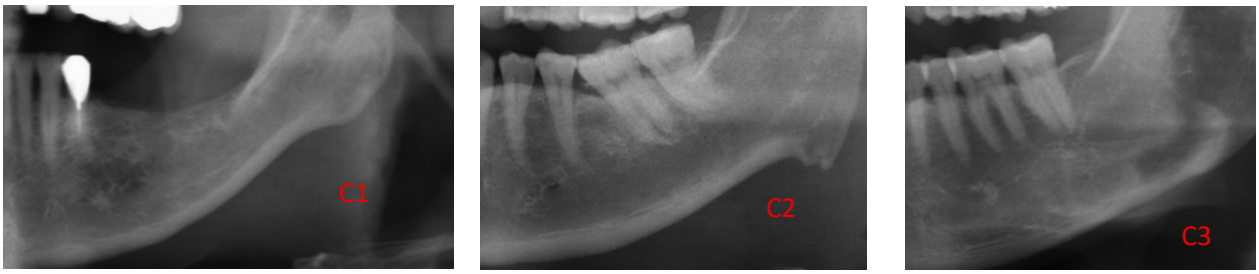

Figure 2. The mandibular cortical index (MCI): classification of Klemetti[8]

Tooth loss was assessed by manually counting the missing teeth on each panoramic radiograph. Wisdom teeth, implant and retained root were excluded.[19]

Demographic variables such as age and gender were analyzed using descriptive statistics and presented as frequencies, percentage, means, and standard deviations. The correlation among Mental Index (MI), Panoramic Mandibular Index (PMI), tooth loss and BMD will be analyzed using the Pearson correlation. The comparison between the BMD and MCI, the BMD and gender were analyzed using one-way ANOVA and the Independent t-test, respectively. All statistical analysis was conducted with SPSS statistical software (version 22.0), with a significance level of $p < .05$.

Result

In this study 125 patients age from 50 to 89 years were included. These patients included 112 females (89.6%) and 13 males (10.4%), yielding a female-to-male ratio of 8.6:1. The mean patient age was 71.58 years (SD = 8.43), with similar mean ages for females and males (females 71.69±8.27, males 70.62±10.04). According to WHO criteria, BMD T-score classification showed the total number of normal, 4 (3.2%); osteopenia, 47 (37.6%); osteoporosis, 74 (59.2%).

This result showed a negative correlation between age and BMD in the femoral neck ($r = -0.339$, $p < .001$) and total femur ($r = –0.272$, $p = .002$), suggesting that increased age may result in a decreased tendency toward osteoporosis. This study also showed a negative correlation between tooth loss and BMD in the femoral neck ($r = –0.241$, $p = .007$) and total femur ($r = –0.242$, $p = .006$). An increase in tooth loss may result in a decreased tendency toward osteoporosis. There was a positive correlation between MI and BMD in the spine ($r = .189$, $p = .034$) and total femur ($r = .348$, $p < .001$). But PMI was not significantly correlated with BMD. (Table 1)

Table 1 Correlation between BMD T-score and factors

BMD		Age	Tooth Loss	MI (mm)	PMI
Spine (L1-L4)	r	0.040	0.103	0.189	0.002
	p	.659	.253	.034*	.978
Femoral Neck	r	−0.339	−0.241	0.166	−0.061
	p	<.001*	.007*	.064	.498
Total Femur	r	−0.272	−0.242	0.348	-0.005
	p	.002*	.006*	<.001*	.960

* significant at p < .05, MI=Mandibular Index, PMI=Panoramic Mandibular Index, BMD=bone mineral density

Table 2 showed a significant association between MCI and BMD in the Femoral Neck (p = .029) and Total Femur (p = .032). These results suggest an inverse relationship; BMD decreases as MCI increases.

Table 2 Comparison between BMD T-score and MCI

BMD	MCI			Eta	p-value
	C1 (n=37)	C2 (n=60)	C3 (n=28)		
Spine (L1-L4)	−1.83±1.61	−2.43±1.13	−2.45±1.23	0.210	.064
Femoral Neck	−1.97±1.00	−2.20±0.76	−2.54±0.76	0.237	.029^{A}*
Total Femur	−1.71±1.14	−2.05±1.01	−2.39±0.86	0.234	.032^{A}*

* significant at p < .05, A = p-value from One-way ANOVA Test

When analyses were stratified by sex (male and female), no significant correlation between the BMD and gender were observed. Gender was not found to have an effect on BMD. (Table 3)

Table 3 Comparison between BMD T-score and Gender

BMD	Gender		Eta	p-value
	Male (n=13)	Female (n=112)		
Spine	−2.07±1.48	−2.28±1.31	0.048	.598
Femoral Neck	−2.16±0.46	−2.21±0.89	0.018	.846
Total Femur	−1.61±0.62	−2.07±1.07	0.138	.126

Discussion

The demographic data in this study indicated a mean patient age of 71.58±8.43 years, confirming that osteoporosis primarily occurs later in older adults. Approximately 89.6% of participants were female; 59.8% of females were in the osteoporosis group. This aligns with global findings that osteoporosis is more prevalent in women. A prevalent meta-analysis reported worldwide prevalence rates of 23.1% in women and 11.7% in men, with the higher female prevalence attributed mainly to menopause-related hormonal changes that accelerate bone loss.[20]

Previous studies have investigated whether panoramic indices could help detect individuals at high risk of osteoporosis. The present study found that PMI were not associated with BMD T-scores. These results are similar to a Thai study reported by Pornsupaporn,[13] which found no relationship between PMI, MI, and BMD, although MCI was significantly associated with BMD at the total femur and spine, but not total body BMD. Other studies have found weak correlation between PMI and BMD, but found significant association between MCI classification and DEXA-measured BMD.[8-9]

This study used the MCI because Klemetti et al.[8] reported significant correlation between MCI classification and BMD. Many researchers have supported using MCI on panoramic radiographs as a screening tool for osteoporosis.[12,21-23] A previous study in Thai women reported significant differences in MI and MCI across BMD categories and recommended both indices as screening tools for postmenopausal women.[14] The present study found significant association between MCI and BMD T-scores in the femoral neck ($p = .029$) and total femur ($p = .032$). Lower MCI values were associated with more severe reductions in bone mineral density. This result suggests that MCI may be a useful indicator of osteoporosis risk specifically in patients. Osteoporosis happens when bone resorption rate is more than bone formation rate. The gender, hormonal status, and physical activity are the factors that determine peak bone mass (PBM). When women were menopause and progressing, age causes a discrepancy between resorption and formation rate of bone. During menopause, the decrease in estrogen levels leads to osteoclast activation, causing an increase in bone resorption.[24] In the present study, the association between gender and BMD was not clearly demonstrated, due to the relatively small number of male participants. Further studies with larger sample sizes may increase statistical power and confirm these findings.

Tooth loss was also examined in this study. Osteoporosis reduces bone mineral density in the jawbone, which may impair alveolar bone support and increase tooth loss³. Xu et al.[5] reported that osteoporosis is associated with increased risk of periodontitis and tooth loss. Similarly, Darcey et al.[6] found significant differences in molar count between women with osteoporosis and normal bone density, though the correlation was weak. Conversely, Klemetti et al.[25] reported no correlation between tooth count and BMD in postmenopausal women. In the present study, a correlation between tooth loss and BMD was found in femoral neck and total femur. The patients with osteopenia or osteoporosis appeared to have more tooth loss than those with normal BMD.

Dual-energy X-ray absorptiometry (DEXA) is the gold standard for diagnosing osteoporosis. BMD was measured at three preferred anatomical sites: the lumbar spine, femoral neck, and total femur to ensure accurate classification.

This study had several limitations. First, although both male and female patients were included, the number of male participants was small, limiting sex-based comparisons. Second,

the number of participants with normal BMD was very low (only 4), reducing the reliability of comparisons involving this group. Third, careful selection of cases and controls is essential to represent results and to minimize potential biases. Further studies with large sample size particularly among men and individuals with normal BMD are recommended, including case–control designs to strengthen diagnostic comparisons.

Conclusion

This study found an association between MI, MCI, tooth loss, and BMD in the overall sample. The results suggest that the MI, MCI index and tooth loss may be a useful indicator for screening or diagnosing whereas PMI does not appear to be suitable for this purpose.

Acknowledgments

This study was supported by the Research Fund of Rajavithi Hospital, and I would like to thank to Ms. Sirinat Treesinchai of the Department of Research and Technology Assessment, Rajavithi Hospital for her assistance with data analysis.

เอกสารอ้างอิง (References)

1. National Statistical Office. The 2024 report: survey of the older persons in Thailand [Internet]. Bangkok: Ministry of Digital Economy and Society; 2024 [cited 2025 Jan 9]. Report No.: ISSN 1906-2869. Available from: https://www.nso.go.th/nsoweb/nso/survey_detail/iM?set_lang=en
2. Kanis JA. An update on the diagnosis of osteoporosis. Curr Rheumatol Rep 2000;2(1):62-6.
3. Jeffcoat M. The association between osteoporosis and oral bone loss. J Periodontol 2005;76(11 Suppl):2125-32.
4. Erdem RZ, Erdem M, Kıranatlı M, Karakaya K. Relationship between bone mineral density and oral health: a cross sectional observational study. BMC Oral Health 2025;25(1):250.
5. Xu S, Zhang G, Guo JF, Tan YH. Associations between osteoporosis and risk of periodontitis: A pooled analysis of observational studies. Oral Dis 2021;27(2):357-69.
6. Darcey J, Horner K, Walsh T, Southern H, Marjanovic EJ, Devlin H. Tooth loss and osteoporosis: to assess the association between osteoporosis status and tooth number. Br Dent J 2013;214(4):E10.
7. Benson BW, Prihoda TJ, Glass BJ. Variations in adult cortical bone mass as measured by a panoramic mandibular index. Oral Surg Oral Med Oral Pathol 1991;71(3):349-56.
8. Klemetti E, Kolmakov S, Kröger H. Pantomography in assessment of the osteoporosis risk group. Scand J Dent Res 1994;102(1):68-72.
9. Kinalski MA, Boscato N, Damian MF. The accuracy of panoramic radiography as a screening of bone mineral density in women: a systematic review. Dentomaxillofac Radiol 2020;49(2):20190149.
10. Alam T, AlShahrani I, Assiri KI, Almoammar S, Togoo RA, Luqman M. Evaluation of Clinical and Radiographic Parameters as Dental Indicators for Postmenopausal Osteoporosis. Oral Health Prev Dent 2020;18(3): 499-504.
11. Kiswanjaya B, Priaminiarti M, Bachtiar-Iskandar HH. Three panoramic indices for identification of healthy older people at a high risk of osteoporosis. The Saudi Dental Journal 2022;34(6):503-8.

เอกสารอ้างอิง (References)

12. Taguchi A, Suei Y, Ohtsuka M, Otani K, Tanimoto K, Ohtaki M. Usefulness of panoramic radiography in the diagnosis of postmenopausal osteoporosis in women. Width and morphology of inferior cortex of the mandible. Dentomaxillofac Radiol 1996;25(5):263-7.
13. Pornsathapant D. Relationship between osteoporosis and indices of mandible from panoramic radiograph. J DMS 2019;44(6):106–11.
14. Chongruangsri N, Jansisyanont P, Chuenchompoonut V, Amphansap T, Stitkitti N. Digital panoramic radiographic indices correlated with BMD status. J Dent Assoc Thai 2021;71(3):194–204.
15. Marandi S, Bagherpour A, Imanimoghaddam M, Hatef M, Haghighi A. Panoramic-based mandibular indices and bone mineral density of femoral neck and lumbar vertebrae in women. J Dent (Tehran) 2010;7(2): 98-106.
16. Nakamura N, Otsuru M, Miyoshi T, Suyama K, Omori K, Morishita K, et al. Risk factors for the development of medication-related osteonecrosis of the jaw and effects of tooth extraction with local infection. J Dent Sci 2024;19(3):1770-82.
17. Lorenzo-Pouso AI, Pérez-Sayáns M, Chamorro-Petronacci C, Gándara-Vila P, López-Jornet P, Carballo J, et al. Association between periodontitis and medication-related osteonecrosis of the jaw: A systematic review and meta-analysis. J Oral Pathol Med 2020;49(3):190-200.
18. Sokal RR, Rohlf FJ. Introduction to biostatistics. 2nd ed. New York: Dover Publications; 2009.
19. Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH, et al. Periodontitis: Consensus report of workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Periodontol 2018;89 Suppl 1:S173-82.
20. Salari N, Ghasemi H, Mohammadi L, Behzadi MH, Rabieenia E, Shohaimi S, et al. The global prevalence of osteoporosis in the world: a comprehensive systematic review and meta-analysis. J Orthop Surg Res 2021;16(1):609.
21. Horner K, Devlin H, Harvey L. Detecting patients with low skeletal bone mass. J Dent 2002;30(4):171-5.
22. Taguchi A, Suei Y, Sanada M, Ohtsuka M, Nakamoto T, Sumida H, et al. Validation of dental panoramic radiography measures for identifying postmenopausal women with spinal osteoporosis. AJR Am J Roentgenol 2004;183(6):1755-60.
23. Damanaki A, Habel ML, Deschner J. Association of Osteoporosis with Tooth Loss and Dental Radiomorphometric Indices. Biomedicines 2024;12(12):2886.
24. Sözen T, Özışık L, Başaran N. An overview and management of osteoporosis. Eur J Rheumatol 2017;4(1): 46-56.
25. Klemetti E, Collin HL, Forss H, Markkanen H, Lassila V. Mineral status of skeleton and advanced periodontal disease. J Clin Periodontol 1994; 21(3):184-8.