Cerrahpaşa Med J 2022; 46(3): 194-200 ORIGINAL ARTICLE

How Do the Osteoporotic Changes Affect the Maxillary Bone Structure in Women Over 40 Years?

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Cite this article as: Yücesoy T, Şeker ED, Özsoy Z. How do the osteoporotic changes affect the maxillary bone structure in women over 40 years? *Cerrahpaşa Med J.* 2022;46(3):194-200.

Abstract

Objective: This study aimed to evaluate how osteoporosis affects the morphological and structural features of the maxillary bone in osteopenic and osteoporotic patients.

Methods: This study included 72 women over 40 years and were divided into 3 groups as osteoporosis group, osteopenia group, and normal group. In the midsagittal sections of conical beam computerized tomographies, several lengths and angles were measured, whereas Hounsfield unit values were measured in 5 regions of the maxilla in the axial sections.

Results: The outcomes of the 3 groups were analyzed, and no significant difference was found except for the RPL angle that revealed statistically wider scores for the normal group than for the osteoporosis and osteopenia groups ($P = .01$ and $P = .03$, respectively). Moreover, the Hounsfield unit values were also analyzed, and no significant difference was detected between groups except for the outcomes of the left maxillary region. The Hounsfield unit value of this area was statistically lower in osteoporosis patients than in the normal group ($P = .03$).

Conclusion: Left maxillary regions in the patients scored statistically lower Hounsfield unit values with which it could be concluded that these regions would reveal lower bone density in osteoporotic patients. Further studies must be carried out with more samples for early diagnosis of bony changes or additional parameters such as chewing side preferences and status of partial or total edentulous dentition should be evaluated.

Keywords: Osteoporosis, osteoporosis management, maxilla, osteopenia, dentistry

Introduction

Osteoporosis is defined as a common and progressive disease that increases the risk of fragility and fracture in the bone due to decreased mineral density and changes in the bone microstructure. It is a silent disease until a fracture occurs, and this disease occurs when there is an increase in resorption and decrease in formation together or only one.[1-3]

Bone mass is a dynamic structure, it takes shape and grows from birth to adolescence, and it is constantly resorbed and reconstructed for the maintenance of bone health. In our daily life, continuous micro traumas and micro fractures occur that are not noticed in the bone; therefore, the construction and destruction cycle of the bone continues throughout life.[4-6] On the other hand, micro fractures cause macro fractures if not repaired. The fractures occur frequently, especially in the elderly, and can occur with minimal trauma or sometimes without trauma. One of the most important clinical consequences of osteoporosis is fragility fractures.[7,8] Patients experiencing hip fracture after low-impact trauma is at considerable risk for subsequent osteoporotic fractures and premature death, and it was shown that the hip fracture is associated with excess mortality during the first year after fracture ranging from 8.4% to 36%.[9] However, with an early diagnosis of osteoporosis before fractures occur and by assessing the bone mineral density (BMD) and with early treatment, this disease can be prevented.[10] On the other hand, it was estimated that the orofacial bones were not compromised by osteoporosis as much as the axial/appendicular skeleton. However, a regular dental follow-up of osteoporotic patients was advised, especially in the case of periodontal disease and maxillofacial surgery.[11]

The diagnosis of osteoporosis can be made by methods such as biochemical markers, imaging techniques, and bone biopsy. Various imaging techniques are available in the evaluation of osteoporosis, such as conventional radiography, dual-energy x-ray absorptiometry (DEXA), quantitative computerized tomography, and high-resolution magnetic resonance imaging. The proposed procedure for the examination of osteoporosis is the measurement of the BMD of the hip or lumbar spine using history and physical examination, laboratory tests, and DEXA.[12,13] T and Z scores are measured and used for diagnosis by BMD measurements made with DEXA according to the osteoporosis diagnostic criteria reported by the World Health Organization (WHO). T score should be used for the diagnosis of osteoporosis in men over 50 years old and postmenopausal women[14] (Table 1).

For more than 70 years, researchers have been exploring the effectiveness of techniques such as subtraction radiography, radiometric classifications based on grayscale histograms, microdensitometer, pixel density, grayscale analysis, cortical bone thickness, and fractal size analysis using dental radiographs.[15,16] Conical beam computerized tomography (CBCT) systems provide 3-dimensional volumetric data with a very low radiation dose. Conical beam computerized tomography facilitates the evaluation

Received: April 8, 2022 **Accepted:** July 18, 2022 **Publication Date:** October 4, 2022
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DOI: 10.5152/cjm.2022.22025

Table 1. Evaluation of T-Score According to the World Health Organization (WHO)

Normal	**(T-score≥−1.0)**
Osteopenia (low bone mass)	(−1 > T-score >−2.5)
Osteoporosis	(T-score≤−2.5)
Severe osteoporosis (established osteoporosis)	(T-score≤−2.5) the presence of one or more osteoporotic fractures

of bone and anatomical structures because they produce high-resolution images.[17,18] Improvements in the image quality of CBCT are indicative of the applicability of structural analysis methods, which are often used in micro computerized tomography and histology, and allow the viewing of trabecular bone forms.[19] Conical beam computerized tomography is generally used for the detailed examination of important anatomical structures such as maxillary sinus, incisive canal, mandibular canal, mental foramen, as well as preoperative localization of impacted and supernumerary teeth or broken roots and important anatomical structures, trauma patients, dentoalveolar fractures and condyle fractures, evaluation of the bone component of the temporomandibular joint, and evaluation of pathologies such as cysts and tumors in the jawbones.[20,21]

One of the objective evaluation criteria of bone density in CBCT is scoring with Hounsfield unit values. The numerical data determined in this scoring are called the Hounsfield unit (HU), and the property of the material to absorb x-rays determines the density of the structure. For example, bone calcification gives high HU values (80-100 HU), while water gives medium (0 HU) and air gives values below the scale (-1000 HU). The increased HU value indicates the denser bone.[22,23] It is known that the quantitative CBCT indices would help dentists to screen for women with low spinal and femoral BMD so that they could refer postmenopausal women for bone densitometry.[24]

Various radiographic imaging methods on the mandible are used to determine the BMD by evaluating alveolar and cortical bone.[15,25-28] In one of the study, Bollen et al[28] revealed that a markedly eroded or porous mandibular cortex on the panoramic radiograph in elderly patients was strongly associated with osteoporotic fractures. These fractures were 2-fold to 8-fold greater in subjects with a moderately or severely eroded mandibular cortex below the mental foramen.

As the hypothesis of the study, the patients with early findings of osteoporosis would be detected by dental volumetric tomography examinations on the maxilla, so early diagnosis and treatment of osteoporosis could be provided by referring the patients to the relevant departments for further investigations. Therefore, this study aims to evaluate whether the measurement analysis and examinations affect morphological features of the maxillary bone and determine the differences in normal, osteopenic, and osteoporotic patients.

Methods

Ethical Statement

All procedures performed in this study involving human participants followed the ethical standards of the institutional and/or national research committee with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was given by the Bezmialem Vakif University Ethic Committee (Approval No: 2011-KAEK-42-2774).

Study Plan

The data were collected from the patients who applied to both medicine and dentistry faculties of Bezmialem Vakif University between 2014 and 2018. Patients with DEXA measurements and CBCT imaging of dental structures obtained within 1 year and women over 40 years were included in the study. Male gender and those who are in the active treatment of bisphosphonates were excluded from the study. Moreover, CBCT imaging of the maxilla must include all the crucial anatomic landmarks, such as anterior nasal spine (ANS), posterior nasal spine (PNS), and both maxillary tuberosities to allow for 3-dimensional measurements of density, lengths, and angles. Another evaluation was performed on the DEXA scores of the patients and the study groups were divided into osteoporosis (OS) group with the patients whose scores were lower than -2.5 and osteopenia (OP) group with scores between -o1 and - 2.5. The patients whose DEXA scores were higher than -1 were regarded as normal (N) group.

Totally 128 patients matched the first criteria of the study whose DEXA measurements and dental topographies were taken in Bezmialem Vakif University. However, 27 of all patients lacked ANS points in CBCT images, which did not allow the measuring of exact distances or angles, and were excluded from the present study. Furthermore, 29 of the 101 patients' CBCT images were not taken within 1 year so these patients were also not eligible according to the inclusion criteria. Eventually, 72 patients who were diagnosed with osteoporosis or with a suspicion of osteoporosis were included in the present study and were randomly selected for the OP and N groups. The mean age of the patients was 59.37 ± 9.64.

Measurements in Midsagittal Cone-Beam Computed Tomography Section of the Maxilla

In the middle sagittal section of the maxillary CBCT, the section that fully centered the incisors and the incisive canal was determined and measurements were made on this section. During the CBCT shots, the Frankfurt horizontal (FH) plane of the patients was made parallel to the ground. All the points were selected on the midsagittal images of maxillary CBCT as shown in Figure 1.

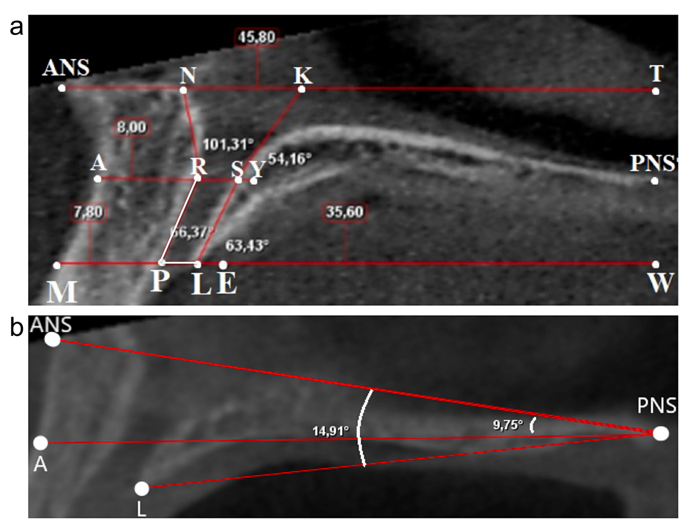

Figure 1. CBCT measurements of 3 different angles between specific points in midsagittal section of maxilla. (a). Note the white-colored RPL angle (RPL angle revealed a significant difference in osteoporotic patients) (b). Three different angles between PNS and the specific points. CBCT, cone-beam computed tomography; PNS, posterior nasal spine.

Point A is the deepest point on the middle sagittal plane of the bone concave between the base of the maxilla and the alveolar protrusion. Anterior nasal spine is the most advanced point of the anterior nasal protrusion in the sagittal plane. Posterior nasal spine is the intersection point of the nasal floor with the continuation of the anterior wall of the pterygopalatine fossa (Figure 1a).

A line parallel to FH Line was drawn from the ANS point. A line perpendicular to FH was drawn from the PNS point, and the point where this line intersects with the line passing through ANS is called the T point. Anterior nasal spine-T length was noted. Anterior nasal spine-T length is the point where the pre-maxillary cut the post-maxillary was called the N point, and the point where the posterior maxillary cut the anterior border was called the K point. A line was drawn parallel to FH passing through point A. The point where this line intersects the pre-maxilla posteriorly is called the R point, and the point where the posterior maxillary crosses the anterior border is called the S point. A-R length was noted and ANS-T length and A-R length were measured and noted (Figure 1b).

The inferior point of the anterior border of the posterior maxilla was called the L-point. A line parallel to FH passing through the L point was drawn, the point where this line intersects the anterior of the pre-maxilla, the point M, the point where the pre-maxillary intersects the posterior, the point where the plot drawn from PNS to FH intersects this line. LW line and MP line lengths were measured. ANS-PNS-L and ANS-PNS-A angle was measured (Figure 1b). On the line drawn from point A to FH, a random Y point was chosen on the posterior of the S point. NRS and KSY angles were measured. Line E was chosen at the posterior of the

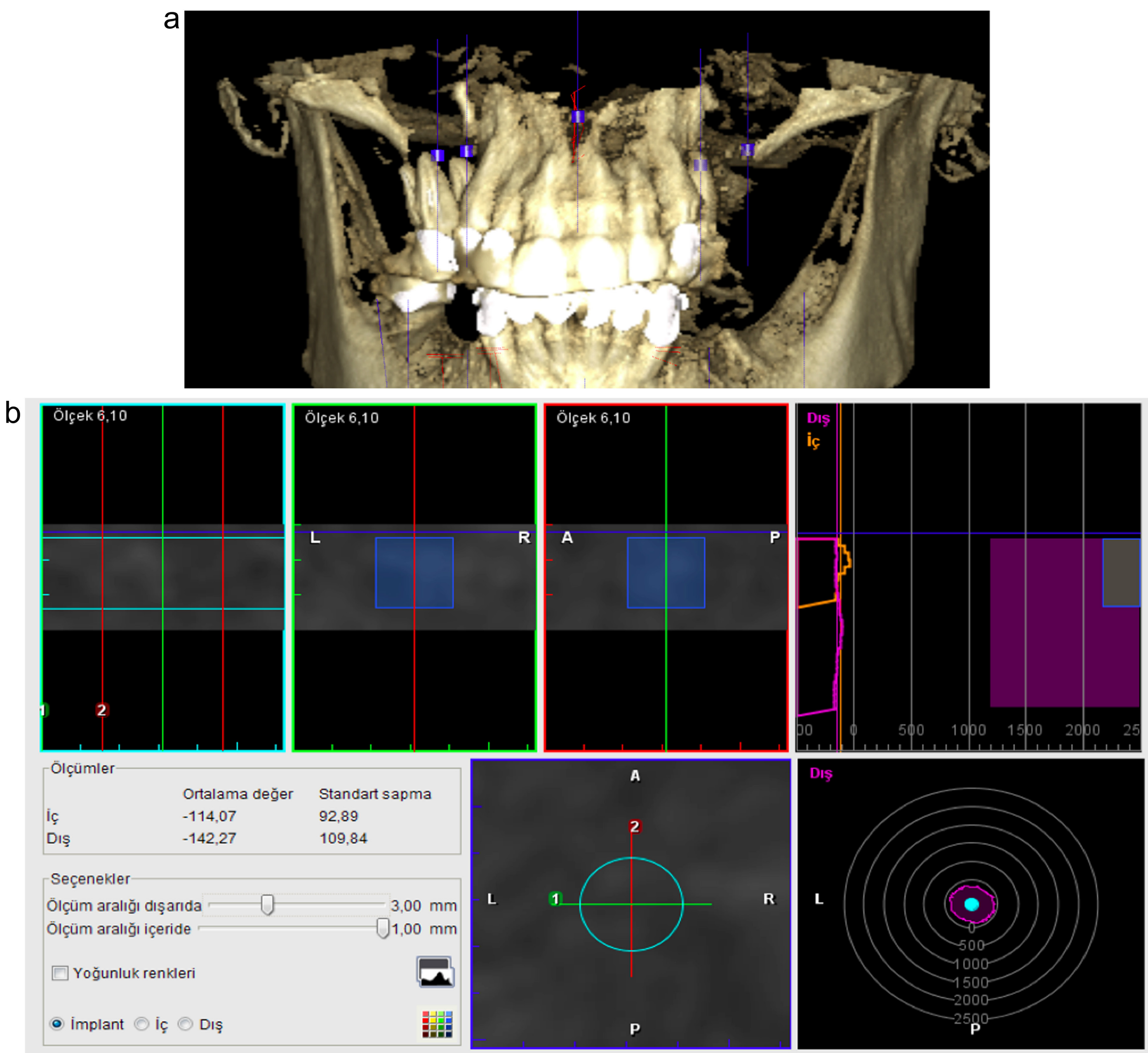

Figure 2. (a) Five regions selected in maxilla are 2 × 2 mm isometric voxels selected on lines drawn in blue. (b) HU measurements were performed from the outside of the 2 mm isometric voxel. HU, Hounsfield unit.

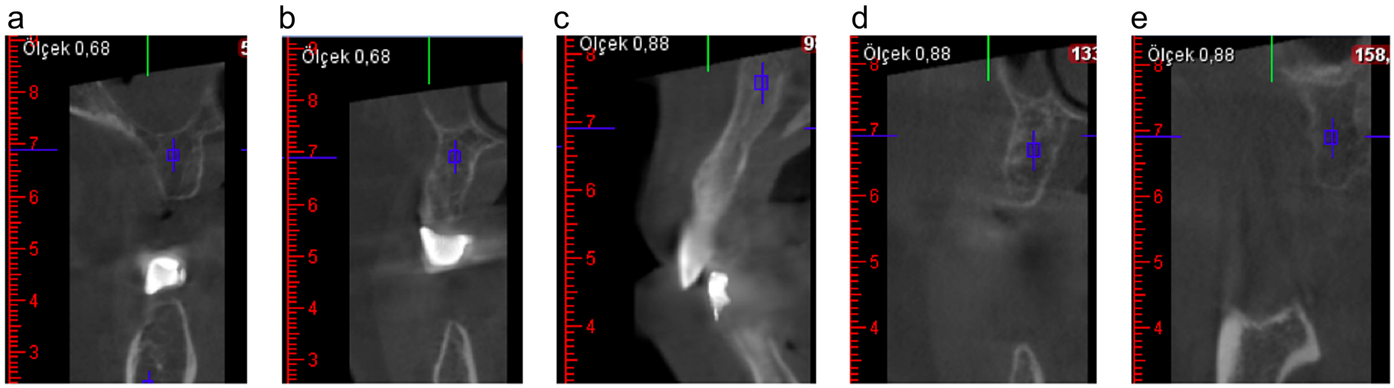

Figure 3. Isotropic voxels selected from the maxilla right posterior molar region (a), right premolar region (b), maxillary midline region (c), left premolar region (d), left posterior molar (e) regions.

L point on the line drawn from the L point parallel to FH. RPL angle (Figure 1c) and SLE angles were measured.

Measurements on Cone-Beam Computed Tomography Cross-Sections in the Maxilla

In the axial sections of the maxilla CBCT image of the patients, a panoramic curve was created and cross-sections were obtained (Figure 2). Through the panoramic curve, 5 regions have been determined to be in the superior position of the alveolar bones in the right posterior molar region, the right premolar region, the maxillary midline region, the left premolar region, and the left posterior molar region (Figure 3). To ensure that the measurements examined in cross-sections are not affected by the presence or absence of teeth, an isometric voxel of 2 × 2 mm was chosen from the spongiosis bone region closest to the sinus (Figure 2a), and the HU value on the outside of the selected region was calculated and noted as a facility of the CBCT program (Planmeca Promax 3D Mid, Helsinki, Finland) (Figure 2b).

Statistical Analysis

Eight patients were randomly selected and measured again 1 month later for error analysis. Error analysis showed that there was no significant difference between the first and second measurements of the angle and length values ($P < .05$). The random errors of the angle and length measurements ranged from 0.8° to 2.03° and 0.0 to 0.41 mm, respectively.

According to G*Power 3.1, it was calculated that a total of 21 individuals for each group would guarantee the power of 80% at the 5% significance level allowing the detection of differences between groups. Therefore, 24 patients were included in each group.

The distribution of the data was evaluated with the Shapiro–Wilk test and it was determined that the data were normally distributed. For this reason, the one-way analysis of variance test was used for comparisons between 3 groups. Tukey (post hoc Tukey HSD test) test was performed for binary comparisons. P values $< .05$ were considered statistically significant.

Results

Measurements in Midsagittal Section of the Maxilla

The measurements were performed in 8 different data: ANS-PNS-L angle, ANS-PNS-A angle, NRS angle, KSY angle, RPL angle, SLE angle, ANS-T length to AR length ratio, and LW length to MP

Table 2. Intergroup Comparison of Angle and Distance Measurements in the Midsagittal CBCT Section of the Maxilla

	Osteoporosis (Group OS)	Osteopenia (Group OP)	Normal (Group N)		
Measurements	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	***P***	
a: ANS-PNS-L (°)	13.27 ± 2.35	13.42 ± 4.51	14.85 ± 3.2	.61	
b: ANS-PNS-A (°)	5.9 ±2.71	5.97 ± 2.43	5.91 ± 2.11	.99	
c: NRS (°)	86.29 ± 15.74	80.9 ± 13.5	89.66 ± 33.29	.74	
d: KSY (°)	67.23 ± 13.9	56.49 ± 19.97	57.5 ± 20.34	.44	
e: RPL (°)	60.9 ± 9.39	62.47 ± 6.53	73.01 ± 8.86	**.017***	**1-3: *P* < .02*** **2-3: *P* < .04***
f: SLE (°)	69.23 ± 18.24	81.78 ± 10.14	84.48 ± 18.83	.15	
g: Ratio of lengths of ANS-T(mm) and A-R(mm)	6.54 ± 1.77	6.48 ± 1.11	7.72 ± 1.55	.2	
h: Ratio of lengths of L-W(mm) and M-P(mm)	6.5 ± 2.4	5.49 ± 0.83	5.98 ± 1.42	.5	

SD, standard deviation; CBCT, cone-beam computed tomography; OS, osteoporosis; OP, osteopenia; PNS, posterior nasal spine; ANS, anterior nasal spine.
*$P < .05$.

Table 3. Intergroup Comparison of HU Values on CBCT Cross-sections

HU Values of Maxillary Areas	Osteoporosis (Group OS) Mean ± SD	Osteopenia (Group OP) Mean ± SD	Normal (Group N) Mean ± SD	P	
Right maxilla posterior	27.75 ± 193.88	45 ± 177.45	156.87 ± 229.40	.39	
Right maxilla premolar	191.75 ± 144.86	250.37 ± 199.46	275.75 ± 136.67	.57	
Maxillary midline area	341.87 ± 158.65	331 ± 134.37	408.12 ± 171.01	.57	
Left maxilla premolar	103.37 ± 154.03	171 ± 118.62	167.87 ± 154.87	.57	
Left maxilla posterior	−82.5 ± 169.81	−8.5 ± 100.64	120.37 ± 147.82	**.03***	**1-3: *P* < .02***

HU, Hounsfield unit.

length. The outcomes of the 3 groups were analyzed and no significant difference was found except for RPL angles. This angle was statistically narrower in OS and OP groups than in the N group ($P = .01$ and $P = .03$, respectively) (Table 2).

Measurements on Cone-Beam Computed Tomography Cross-Sections in the Maxilla

The measurements were performed in 5 different areas: right maxillary posterior, right maxillary premolar, maxillary anterior, left maxillary premolar, and left maxillary molar regions. These data were also analyzed and no significant difference was detected between groups except for the outcomes of the left maxillary region. The HU value of this area was statistically lower in the OS group than in the N group ($P = .03$) (Table 3).

Discussion

The progression of alveolar bone loss can be seen in patients with low systemic bone density and patients with natural teeth have been suggested to have significantly higher systemic bone density than those without teeth, and osteoporosis weakens the trabecular structure of the alveolar bone, making it more susceptible to destruction.[2,29,30] As one of the diseases that directly affect bone structure and morphology, osteoporosis is generally observed as “silent” unless a spontaneous fracture occurs. Obtaining a careful medical story and examining the patient are very crucial for the early diagnosis of osteoporosis. However, patients are likely to be diagnosed when they have osteoporotic fractures. Osteoporotic fractures can cause many secondary health problems and even fatal consequences.[31] Therefore, in this study, the effects of osteoporosis on the maxillary bone were aimed to be evaluated by measuring the various lengths, angles, and densities.

Although the artifacts are considered as the disadvantage of CBCT, many studies have revealed a linear relationship between HU in CT and Gray scale, and voxel values in CBCT were likely to give an idea of bone density.[16,32,33] Besides, bone density and HU measurements could be performed by following the CBCT imaging protocols.[34] The outcomes of the grayscale in CBCT were parallel to the HU value for hypodense structures, but its accuracy for hyperdense structures has not been established. Moreover, fractal dimension (FD) analysis, which is used to measure the microarchitecture structure of spongiosis with numerical data, is a statistical structural analysis.[35-38] In a study, the FD rates of osteoporotic patients in the left maxilla reported lower scores than normal patients.[16] Compatible with this study, here we report that the left maxilla revealed significantly lower HU scores, whereas no significant difference was observed in the other sections ($P < .05$). (Table 3)

The structure of the bone tissue is adjusted according to the severity of the pressure on it. Bones under heavy load become thicker. The internal structure of the bone fits best against the pressure and strain it would normally encounter. According to Wolff’s Law, the bone can change shape and adapt to new conditions in different functional situations, even though it has a hard, stiff structure. Mechanical forces have a stimulating and even initiating function in bone remodeling. Both tensile and compressive forces cause the thickening of the bone tissue. The bone is reshaped with functional forces, and resorption may occur in forces that exceed physiological limits.[39-41]

When it comes to the oral and maxillofacial region, Newton et al[42] stated that the oral function of older adults was essential and was maintained and a major component of the muscle function for mastication and speech. Elevation of the mandible is primarily due to bilateral, symmetrical activity of the masseter, temporalis, and medial pterygoid muscles, whereas during chewing, the activity of the masseter muscle is asymmetric, with greater activity on the chewing side.[43] As reported by other authors,[44,45] most of the individuals preferred to chew on the right side and it was previously reported as highly significant masticatory preference toward the right side ($P < .001$).[46] Although determining the chewing side preference (CSP) is difficult to be proven completely, it is known that almost 95% of individuals showed left angular gyrus and temporal lobe as dominant and the right-handedness caused by the motor areas for controlling hands is also dominant in the left side of the brain.[47] Considering the relationship between the effects of the chewing side and osteoporosis, the statistically significant differences in HU values of the left maxillary posterior region give insights into this interaction. However, this outcome should not be accepted as a proven conclusion of this study because of the limited numbers in all groups of the present study. It is recommended that future studies should be planned with more numbers of patients in multiple centers.

On the other hand, the most important effects of osteoporosis on oral and dental health are periodontitis with a decrease in bone volume and density. It has been suggested that osteoporosis weakens the trabecular structure of the alveolar bone, making it more susceptible to destruction. Although periodontal diseases are observed locally and osteoporosis is a systemic disease, the common feature of periodontal disease and osteoporosis is that they are affected by bone loss and similar risk factors.[2,28,48-50] On et al[51] concluded that the measurement of HU values on CT can be valuable in assessing the bone density of the maxilla and mandible and they suggested that osteoporosis might affect bone density at the osteotomy sites even in orthognathic surgery, and the preoperative measurement of HU values might be useful in predicting unfavorable fracture or the risks involved in such surgery. Compared with the literature, our study reported that the numerical analysis and examinations reflected different results in morphological features of the maxillary bone in patients with osteoporosis, osteopenia, and normal patients. According to our results, a significant difference was found between the 3 patient groups in terms of the RPL angle. These angle measurements were significantly narrower among the groups (Table 3).

Besides, it was observed that the repeatability of the N and K points was determined due to the variations in the anatomical shape of the incision canal during the measurements of the NRS and KSY angles in other angles, and there was no significant difference between the 3 groups in the measurements of the NRS and KSY angles (Table 3).

The main limitation of this study was the limited number of patients in the study groups in which the measurements were repeatedly performed. Moreover, it was a single-center study that may need further prospective studies and the sample numbers should be increased. Also, as another limitation of this study, the periodontal status and patients who underwent oral surgical procedures prior to CBCT imaging might yield lower HU values. The patients should be investigated on extra parameters such as the periodontal status, the number of teeth, status of partial or total edentulous dentition, and dominant chewing side in further studies.

White et al[2] stated that the oral radiographic and clinical findings should be evaluated together in the early diagnosis of osteoporosis and in determining the effects of the disease on the jaws, and standardization is important in data collection and regular dental visits and healthy lifestyle is necessary for strengthening and maintenance of good bone health.[52] Moreover, Tabrizi et al[53] stated that their study did not provide enough evidence to prove any causal relationship between marginal bone loss and osteoporosis. Therefore, we recommend that clinicians should avoid delaying or postponing dental treatment, especially dental implant treatments in the upper jaw bone in osteoporotic patients.

In the literature, it is well known that osteoporosis affected the mandibular structures due to its cortical bone structure. However, the maxilla is very difficult to examine and study in terms of osteoporotic changes.[16] In this study, the literature was examined in detail, and the materials and methods were determined according to the literature. The angle measurements were measured for the first time and an angle was significantly more different in osteoporotic patients, and also left molar region of the maxillary bone revealed statistically less density which was thought to be related to the CSP.

Statistically significant outcomes were reported in the RPL angle measurements in the premaxillary region and HU measurements in the left maxillary molar region in the osteoporosis group. Therefore, it could be concluded that the left molar region of the maxilla would show less density than other parts of the maxilla. This outcome could have been affected by CSP. However, further prospective CSP and CBCT studies are required to be planned with osteopenic and osteoporotic patients to ensure the guidance of dentists in the early diagnosis of osteoporosis and to benefit dentists from imaging methods.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Bezmialem Vakif University (Approval No: 2011-KAEK-42-2774).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – T.Y., Z.Ö.; Design – T.Y., E.D.S.; Supervision – T.Y., E.D.S.; Materials – T.Y., Z.O., E.D.S.; Data Collection and/or Processing – T.Y., E.D.S.; Analysis and/or Interpretation – E.D.S., T.Y.; Literature Review – T.Y., Z.O.; Writing – T.Y., Z.O.; Critical Review – T.Y., E.D.S.

Declaration of Interests: The authors declare that they have no competing interest.

Funding: The authors declared that this study has received no financial support.

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