Original Article

Radiographic Findings of Bisphosphonate-Related Osteonecrosis of the Jaws: Comparison with Cone-Beam Computed Tomography and Panoramic Radiography

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Abstract

Objective: The aim of this study is to assess radiographic findings of bisphosphonate-related osteonecrosis of the jaws (BRONJ) and to evaluate the efficiency of cone-beam computed tomography (CBCT) and panoramic radiography (PR) by comparing with each other. **Materials and Methods:** The data of 46 patients treated with bisphosphonates for at least 1 to 10 years were retrospectively examined. 27 patients were selected for study group. The first inclusion criteria was an available CBCT or PR. The patients had at least one clinical symptom of exposed bone, intraoral or extraoral swelling and purulent secretion or fistula formation. In accordance with the position papers of the American Association of Oral and Maxillofacial Surgeons, the patients were classified into stages. CBCT and PR images were evaluated by dividing the jaws in 6 segments. Presence of bone sclerosis, cortex irregularity, persistent sockets, periosteal response, sequestration, and osteolysis were recorded. **Results:** The radiographic findings of BRONJ were mostly determined at posterior mandible with Stage 2 predominancy. Fifteen patients (55.6%) had previous tooth extraction. 9 of them had exposed bone at the same time. Seven patients had exposed bone without extraction. CBCT findings ($P < 0.01$) except persistent socket ($P = 0.157$) were found statistically significant by comparison with PR. Extraction socket finding was detected the same in segments with a percentage of 90.9%. **Conclusion:** This study showed that CBCT findings except extraction socket were significantly higher than PR. CBCT combined with clinical examination can be used effectively to determine the borders of effected areas especially at advanced cases.

Keywords: *Bisphosphonate-related osteonecrosis of the jaws, cone-beam computed tomography, panoramic radiography*

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Introduction

It is known that bisphosphonates are potent by suppressing the osteoclastic activity. As antiresorptive medications, bisphosphonates are prescribed to reduce bone pain, improve life quality, and prevent the skeletal complications for the patients treated for lytic bony changes such as multiple myeloma, hypercalcemia related to malignancy, bone metastasis from primer tumors such as breast cancer, prostate cancer, and lung cancer, osteoporosis and less commonly Paget's disease, osteogenesis imperfecta, and fibrous dysplasia.[1-4] In 2003, Marx[5] first described avascular necrosis of the jaws associated with bisphosphonates. Since 2003, a growing number of reports have been published on necrosis of the jaws associated with bisphosphonate treatment, known as bisphosphonate-related osteonecrosis of the jaws (BRONJ).[1]

The incidence of BRONJ depends on strongly the route of administration, duration of therapy, and type of bisphosphonate.[2,3] It is reported that intravenous application increase the risk of complications while the risk of oral bisphosphonates is rare.[2,6] As pathogenesis of BRONJ loss of blood supply, suppression of bone turnover, dentoalveolar trauma, and infection are major

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hypotheses.[1,2] The recent approach is that the disease may be multifactorial.[1]

The diagnostic criteria for BRONJ was proposed as persistent exposed jaw bone for more than 8 weeks by the 2009 American Association of Oral and Maxillofacial Surgeons (AAOMS) Position Paper.[7] Then the name of BRONJ is changed as MRONJ because of growing number of osteonecrosis cases associated with other antiresorptive and antiangiogenic therapies. In addition, the diagnostic criteria is modified as exposed bone or bone that can be probed through a fistula persisted for more than 8 weeks by the 2014 update of AAOMS Position Paper.[1] As a term of BRONJ was preferred for this study, all patients under investigation have been treated only with bisphosphonates.

Many studies revealed diagnostic criteria, risk factors, and the recommendations about prevention and treatment protocols.[1,4,5,7-12] Still imaging is considered as an essential part of the clinical assessment of BRONJ patients and might be an additional tool for tracking the progression of the disease. Hence, some other studies tried to explain the imaging findings of BRONJ with plain films,[6,13-15] computed tomography (CT) and/or magnetic resonance imaging (MRI),[13,15-19] and cone-beam CT (CBCT).[3,20,21] At a pictorial review study of Morag *et al*.,[2] the radiologic imaging characteristics of BRONJ described as osteolysis, sclerosis, narrowing bone marrow, inferior alveolar canal involvement, and fractures. Besides all these characteristics, persistent socket, cortex irregularity, periosteal response, and sequestrum formation were investigated as to whether specific for BRONJ.[6,13-21] However, the radiographic findings of BRONJ is variable and mostly nonspecific. The panoramic radiography (PR) is the most common imaging technique in BRONJ cases as well as in routine dentistry. Whereas CT and MRI were also reported adequate in evaluating bone involvement, in addition to offering the advantage of a high resolution destructive processes.[13,15-19] The higher detectability of MRI as well as CT were reported for BRONJ cases than PR by far.[14] As our knowledge, the comparison of PR and CBCT in detectability of radiographic findings of BRONJ has not been investigated yet. Then the aim of this study is to assess radiographic findings of BRONJ and to compare two imaging modalities which are popular in routine dental practice: PR versus CBCT.

Materials and Methods

The data of 46 patients treated with bisphosphonates for at least 1 to 10 years who referred to the Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Marmara University, from 2009 to 2014 were retrospectively examined, and 27 patients were selected as the samples of this study. The first inclusion criteria was an available CBCT or PR imaging of the patients.

Twenty-three of the 27 patients underwent CBCT examining and 26 of the 27 patients were taken PR while 22 of the selected patients were received both CBCT and PR images. The patients had at least one clinical symptom of exposed bone persistent more than 8 weeks, intraoral swelling or purulent secretion and extraoral swelling or fistula formation. The patients underwent radiation therapy excluded from the study.

At the end, 27 patients (19 females [70.4%], 8 males [29.6%], age between age range 37 and 83 years with mean age 64.14 ± 12.78 years) were retrospectively included to this study. The reasons of clinical symptoms were determined as extraction for 15 patients (55.6%), pulpal-periodontal infection for 5 patients (18.5%), and irritation of prosthesis for 7 patients (25.9%).

The samples were selected from screened images from January 2012 to October 2014 by CBCT and PR devices. All projections were taken with the same radiographic equipment (Planmeca Promax SD Mid CBCT device, Helsinki, Finland, with 90 kVp and 12 mA and Morita Veraviewpocs model 550 panoramic device, Kyoto, Japan, with the maximum KVP of 80, 12 mA). All tomographic and panoramic images were carried out by the same technician. The images were exported and saved as a single frame DICOM files for tomography and as jpeg files for panoramic. The assessment of images was fulfilled directly on monitor screen (N56VZ-S4283H model of Asus Computer with NVIDIA GeForce GT 650M 4GB screen cart and 15.6 inch Full HD LED 1920 × 1080 pixel monitor).

To ensure a professional and efficient evaluation, oral diagnosis and radiology clinician and specialist who had been working in the Department of Oral Diagnosis and Radiology evaluated the clinical images. During meetings for the pilot study, the clinician and radiology specialist trained to evaluate panoramic and tomographic images by specialist who had been working in Oral Diagnosis and Radiology for 15 years or more, and an agreement on the objective criteria for the qualitative evaluation of the images was forged among the evaluators.

CBCT and PR images were evaluated by dividing the jaws in 6 segments [Figure 1]. Segments represent right posterior maxilla, anterior maxilla, left posterior maxilla, right posterior mandible, anterior mandible, and left posterior mandible in numeric order.[6]

Presence of bone sclerosis, cortical surface irregularity, persistent extraction sockets, periosteal response, bone sequestration, and osteolytic changes were recorded as present or absent regardless of number. Extraction sockets were accepted persistent at least 3 months later after tooth extraction and the criteria of Treister *et al*.[6] were considered for radiographic findings of BRONJ.

In accordance with the position papers of AAOMS, the selected patients were classified into Stages 0, 1, 2, and 3 [Table 1].[7] There was no asymptomatic patient so stage 1 of BRONJ was not detected among the included patients. The study protocol numbered as 092015127 was approved by the Local Committee of Research of Ethics of Marmara University.

All data from patients was transferred to Microsoft Excel Program for data processing and the analyses were completed in IBM SPSS Statistics 22.0 (SPSS Inc., Chicago, IL, USA). Besides the descriptive statistics such as mean value, standard deviation, and frequency; Wilcoxon Signed Ranks Test was used to compare quantitative data, and McNemar Test was used to compare qualitative data. Kendall' s W correlation test was used to analyze the agreement of the PR and CBCT findings for same patients. It was accepted statistically significant as $P < 0.05$ for McNemar Test, and $P < 0.01$ for Wilcoxon Signed Ranks Test and Kendall' s W correlation test.

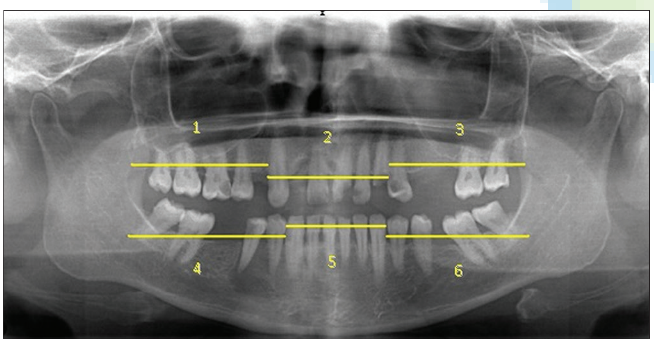

Figure 1: Symbolic representation of maxillary and mandibular segmentation: Segments represent right posterior maxilla, anterior maxilla, left posterior maxilla, right posterior mandible, anterior mandible and left posterior mandible in numeric order

Results

The outlined aspect of medical anamnesis of the 27 patients were summarized in Table 2.

The known underlying disease for bisphosphonate treatment was stated as osteoporosis in 7 patients, breast cancer in 7 patients, prostate cancer in 5 patients, renal cancer in 2 patients, thyroid cancer in 1 patient, and multiple myeloma in 4 patients. Treatment with intravenous bisphosphonates was reported in 20 patients and oral bisphosphonates in 5 patients, whereas 2 patients administration route were unknown. All oral bisphosphonates were prescribed for osteoporosis although 2 osteoporosis patients were treated with intravenous bisphosphonates [Table 2].

Fifteen patients (55.6%) had a previous tooth extraction whereas 9 of them had exposed bone at the same time. Seven patients had exposed bone without extraction anamnesis. Hence totally 16 patients had exposed bone [Table 2].

The interpatient distribution of radiographic findings can be seen in [Table 3]. The most common PR findings were sclerosis (88.5%) and osteolysis (88.5%); CBCT findings were cortex irregularity (95.6%), sclerosis (95.6%), and osteolysis (95.6%). Periosteal response and sequestration were less common radiographic findings [Table 3].

Table 4 shows segmental distribution of radiographic findings. PR findings were calculated with 26 patients, CBCT findings with 23 patients, and 22 patients' findings were used for comparison values. Periosteal response was detected only at mandible with segment 4 predominancy (30.4% on CBCT). Sequestration was also detected with segment 4 predominancy (21.7% on CBCT). PR failed on detecting sequestration in whole maxilla (segments 1, 2, and 3) and as well in anterior mandible (segment 5). Sequestration and periosteal response could not be detected by PR. However there was no statistical significance between these findings. Just in segment 4, CBCT was found significantly higher than PR on detecting cortex irregularity and periosteal response ($P = 0.031$) [Table 4] and [Table 5].

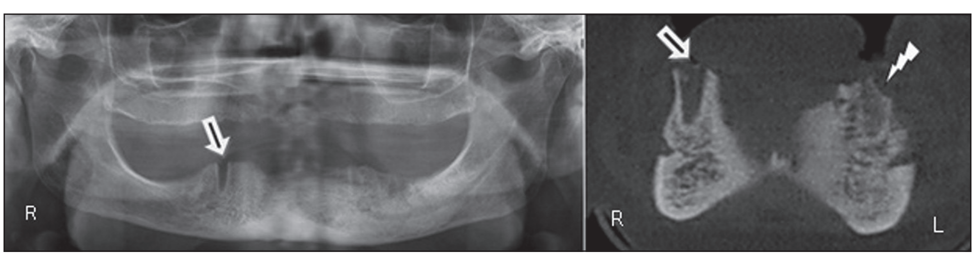

Figure 2: Panoramic radiography and coronal image of cone-beam computed tomography obtained from the same patient: Arrows show a persistent socket in segment 4 on both panoramic radiography and coronal cone-beam computed tomography section. Thunderbolt shows a second persistent socket in segment 6 on coronal cone-beam computed tomography section which is invisible on panoramic radiography

Table 1: The staging classification of BRONJ

Stage	Staging characteristics	Recommended treatment
At risk	Asymptomatic	
	No exposed bone	
	History of treatment with oral or intravenous bisphosphonates	
Stage 0	No exposed bone	Systemic management with pain medications and/or antibiotics
	Nonspecific symptoms	
	Odontalgia not caused by odontogenic factors	
	Dull bone pain	
	Sinus pain	
	Altered neurosensory function	
	Nonspecific clinical findings	
	Loosing of teeth not caused by periodontal disease	
	Intraoral fistula not associated with a necrotic pulp	
	Nonspecific radiographic findings	
	Alveolar bone loss/resorption not caused by periodontal disease	
	Persistent extraction socket	
	Thickening of periodontal ligament	
	Narrowing of inferior alveolar canal	
Stage 1	Exposed bone	Antibacterial oral rinse
	Asymptomatic with no evidence of infection	Clinical follow-up quarterly periods
		Patient education
Stage 2	Exposed bone	Antibacterial oral rinse
	Pain and clinical evidence of infection	Pain control
		Superficial debridement
Stage 3	Exposed bone	Pain medications
	Pain and clinical evidence of infection	Antibiotic therapy
	Necrotic bone extending beyond the alveolar bone area	Surgical debridement/resection
	Pathologic fracture	
	Extraoral fistula	
	Oroantral/oronasal communication	
	Osteolysis extending to borders of maxillary/mandibular jawbones	

BRONJ=Bisphosphonate-related osteonecrosis of the jaws

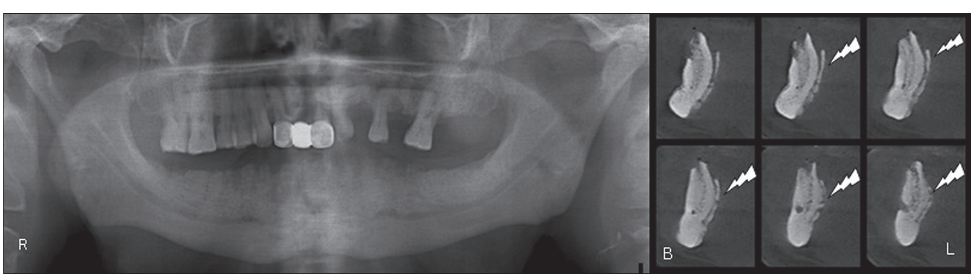

Figure 3: Panoramic radiography and cross-section images obtained from the same patient: Diffuse sclerotic change all over the mandible is seen on panoramic radiography. Thunderbolts show periosteal response around the lingual borders of segment 4 and 5

Figure 2 shows PR and coronal CBCT image of the same patient. While just one persistent socket in segment 4 was seen on PR, CBCT detected a second persistent socket in segment 6 which was invisible on PR.

Persistent socket finding was determined the same in segments on both imaging modality with a percentage of 90.9% while it was seen on just CBCT at segment 6 of only 2 patients. It seems like periosteal response findings was same in segments at 14 patients but all these patients had no periosteal reaction. It means all detected periosteal response findings were different in segments of 8 patients between PR and CBCT. Similarly, 11 of 13 patients had no sequestration which seems same

Table 2: The outlined aspect of medical anamnesis of included patients

Patient number	Age	Gender	Underlying disease	Bisphosphonates			Exposed bone	Extraction anamnesis
				Types	Administration routes	Duration		
1	73	Female	Osteoporosis	Ibandronic acid	Per oral	Unknown	–	+
2	51	Male	Thyroid cancer	Zoledronic acid	Intravenous	2 years	+	+
3	80	Male	Prostate cancer	Unknown	Unknown	Unknown	+	+
4	51	Female	Unknown	Unknown	Unknown	Unknown	–	–
5	82	Female	Osteoporosis	Ibandronic acid	Per oral	5 years	+	–
6	66	Female	Osteoporosis	Ibandronic acid	Per oral	5 years	–	–
7	60	Female	Multiple myeloma	Zoledronic acid	Intravenous	3 years	+	+
8	57	Male	Multiple myeloma	Zoledronic acid	Intravenous	4 years	+	+
9	69	Female	Breast cancer	Ibandronic acid	Intravenous	1.5 years	–	+
10	62	Female	Breast cancer	Ibandronic acid	Intravenous	1 year	–	+
11	83	Male	Prostate cancer	Zoledronic acid	Intravenous	3 years	+	–
12	63	Male	Renal cancer	Zoledronic acid	Intravenous	2 years	+	+
13	59	Female	Osteoporosis	Ibandronic acid	Per oral	3 years	–	+
14	46	Female	Breast cancer	Ibandronic acid	Intravenous	1 year	–	–
15	46	Female	Breast cancer	Ibandronic acid	Intravenous	5 years	–	–
16	83	Male	Prostate cancer	Zoledronic acid	Intravenous	3 years	+	–
17	65	Female	Breast cancer	Zoledronic acid	Intravenous	2 years	+	–
18	51	Female	Breast cancer	Zoledronic acid	Intravenous	2 years	–	–
19	55	Female	Osteoporosis	Ibandronic acid	Per oral	1 year	–	+
20	71	Female	Breast Cancer	Zoledronic acid	Intravenous	2 years	+	+
21	73	Male	Prostate cancer	Zoledronic acid	Intravenous	6 years	+	+
22	78	Female	Osteoporosis	Alendronate	Intravenous	10 years	–	+
23	69	Male	Prostate cancer	Zoledronic acid	Intravenous	Unknown	+	–
24	78	Female	Multiple myeloma	Zoledronic acid	Intravenous	2 years	+	+
25	70	Female	Multiple myeloma	Zoledronic acid	Intravenous	2 years	+	+
26	37	Female	Renal cancer	Zoledronic acid	Intravenous	2 years	+	–
27	58	Female	Osteoporosis	Ibandronic acid	Intravenous	2 years	+	–

in segments at 13 patients. Sequestration was detected same in segments only 2 of 13 patients whereas 9 patients findings were different in segments between PR and CBCT. On the other, cortex irregularity was detected different in segments of 14 patients. Osteolysis and sclerosis also were found mostly different in segments. The difference of detected findings for the same patients between orthopantomography (OPTG) and CBCT was found statistically significant for cortex irregularity ($P = 0.001$), periosteal response ($P = 0.005$), sclerosis ($P = 0.001$), osteolysis ($P = 0.001$), and sequestration ($P = 0.003$). The differences of persistent socket for the same patients between OPTG and CBCT was not found statistically significant ($P = 0.157$) [Table 6].

Figure 3 indicates the periosteal response of the lingual mandibular cortex on cross-section images which cannot be detected on PR.

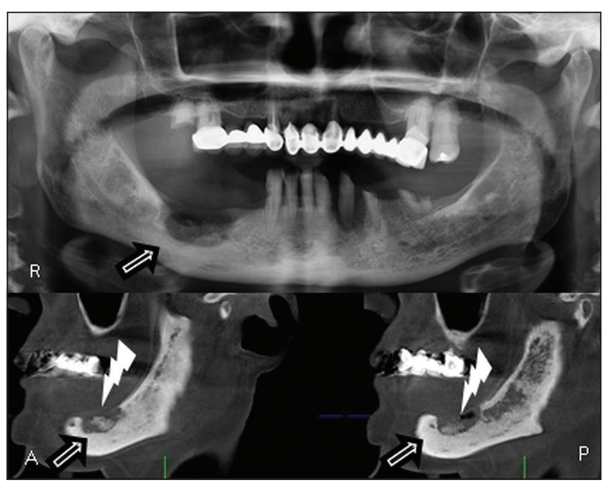

Figure 4: Panoramic radiography and sagittal images obtained from the same patient: Arrows show diffuse sclerosis around osteolytic area in segment 4. Thunderbolts show largely demarcated sequestration in segment 4 on the sagittal images

Table 3: Interpatient distribution of radiographic findings for all patients

Radiographic findings	PR (*n*=26) *n* (%)	CBCT (*n*=23) *n* (%)
Persistent socket	16 (61.5)	15 (65.2)
Cortex irregularity	22 (84.6)	22 (95.6)
Periosteal response	3 (11.5)	8 (34.9)
Sclerosis	23 (88.5)	22 (95.6)
Osteolysis	23 (88.5)	22 (95.6)
Sequestration	3 (11.5)	12 (52.2)

PR=Panoramic radiography; CBCT=Cone-beam computed tomography

Table 4: Segmental distribution of radiographic findings among all patients

Radiographic findings	PR (*n*=26) *n* (%)	CBTC (*n*=23) *n* (%)	*P* (*n*=22)
Persistent socket			
Segment 1	2 (7.7)	2 (8.7)	1.000
Segment 2	3 (11.5)	4 (17.4)	1.000
Segment 3	3 (11.5)	2 (8.7)	1.000
Segment 4	12 (46.2)	10 (43.5)	1.000
Segment 5	4 (15.4)	3 (13.0)	1.000
Segment 6	5 (19.2)	6 (26.1)	0.500
Cortex irregularity			
Segment 1	4 (15.4)	8 (34.8)	0.125
Segment 2	3 (11.5)	8 (34.8)	0.063
Segment 3	9 (34.6)	12 (52.2)	0.063
Segment 4	10 (38.5)	16 (69.6)	0.031*
Segment 5	7 (26.9)	6 (26.1)	1.000
Segment 6	7 (26.9)	10 (43.5)	0.125
Periosteal response			
Segment 4	2 (7.7)	7 (30.4)	0.031*
Segment 5	-	3 (13.0)	0.250
Segment 6	1 (3.8)	3 (13.0)	0.500
Sclerosis			
Segment 1	5 (19.2)	7 (30.4)	0.125
Segment 2	2 (7.7)	3 (13.0)	0.500
Segment 3	7 (26.9)	5 (21.7)	1.000
Segment 4	17 (65.4)	18 (78.3)	0.250
Segment 5	1 (3.8)	6 (26.1)	0.063
Segment 6	17 (65.4)	16 (69.6)	1.000
Osteolysis			
Segment 1	7 (26.9)	9 (39.1)	0.250
Segment 2	6 (23.1)	12 (52.2)	0.063
Segment 3	10 (38.5)	10 (43.5)	0.250
Segment 4	15 (57.7)	17 (73.9)	0.250
Segment 5	6 (23.1)	8 (34.8)	0.250
Segment 6	9 (34.6)	12 (52.2)	0.125
Sequestration			
Segment 1	-	2 (8.7)	0.500
Segment 2	-	3 (13.0)	0.500
Segment 3	-	2 (8.7)	0.500
Segment 4	2 (7.7)	5 (21.7)	0.250
Segment 5	-	1 (4.3)	1.000
Segment 6	1 (3.8)	1 (4.3)	1.000

McNemar test $^*P<0.05$. PR=Panoramic radiography; CBCT=Cone-beam computed tomography

Table 5: Comparison values for visibility of radiographic findings between PR and CBCT among all patients

Radiographic findings	Mean±SD (median) PR	Mean±SD (median) CBCT	*P*
Persistent socket	1.05±1.09 (1)	1.14±1.08 (1)	0.157
Cortex irregularity	1.5±1.14 (1)	2.59±1.3 (3)	0.001**
Periosteal response	0.09±0.29 (0)	0.59±0.91 (0)	0.009**
Sclerosis	1.68±0.99 (2)	2.41±1.18 (3)	0.001**
Osteolysis	2.09±1.57 (2)	3.09±1.69 (3)	0.002**
Sequestration	0.09±0.29 (0)	0.55±0.6 (0.5)	0.004**

Wilcoxon signed ranks test $^{**}P<0.01$. SD=Standard deviation; PR=Panoramic radiography; CBCT=Cone-beam computed tomography

Table 6: The incidence of radiographic findings viewed by both PR and CBCT for the same patients

Radiographic findings	*n* (%)	*P*
Persistent socket		
Same	20 (90.9)	0.157
Different	2 (9.1)	
Cortex irregularity		
Same	8 (36.4)	0.001***
Different	14 (63.6)	
Periosteal response		
Same	14 (63.6)	0.005***
Different	8 (36.4)	
Sclerosis		
Same	9 (40.9)	0.001***
Different	13 (59.1)	
Osteolysis		
Same	10 (45.5)	0.001***
Different	12 (54.5)	
Sequestration		
Same	13 (59.1)	0.003***
Different	9 (40.9)	

Kendall's W correlation test $^{***}P<0.01$. PR=Panoramic radiography; CBCT=Cone-beam computed tomography

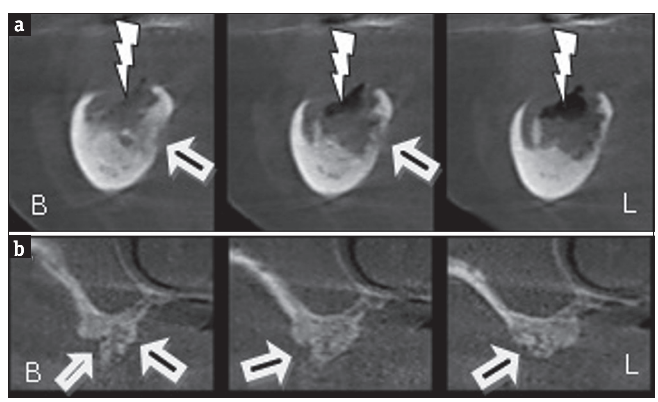

Figure 5: (a) Cross-section images show lingual cortex irregularity in segment 4 (arrows). Thunderbolts show osteolytic changes. Diffuse sclerosis is also seen all around osteolyitc area. (b) Arrows show cortex irregularity in segment 3 with osteolytic changes

A largely demarcated sequestration in segment 4 was detected by CBCT while PR failed to indicate [Figure 4].

Cortex irregularity in segments 3 and 4 is clearly demonstrated on cross-section CBCT images in Figure 5.

Discussion

The occurrence of BRONJ was stated in different ranges depends on the underlying disease and the difference route of administration.[8-10] The route of administration differed between underlying diseases in patients because of the treatment approach of medical doctors. For instance, only the imaging findings were evaluated in this study.

The majority of patients (44.5%) were determined at Stage 2 in this study whereas Stage 1 was not detected. Similarly Treister *et al*.[6] was reported Stage 2 dominance with 61.5%. As the reason of no detection of Stage 1, it can be said that the symptoms are the most important stimulation compelling the patients to see a doctor. In addition, it is known that the healing period of BRONJ is considerably long. Therefore none of the patients included to this study was asymptomatic.

The clinical and radiographic symptoms were detected more often in mandible versus maxilla with posterior segment dominance by Elad *et al*.[16] with a percentage of 64.8, and 4 patients were reported that both jaws were involved. Guggenberger *et al*.[3] also reported that the majority of radiographic findings were localized in posterior mandible. Supportively; first segment 4 and then segment 6 predominancy predominance of all radiographic symptoms were found in this study. The biggest difference was periosteal response which was not detected in maxilla at all. In addition, periosteal response was detected only in mandibular segments and all detected periosteal response findings were different in segments between PR and CBCT.

As the definition of avascular necrosis by Marx,[5] Ruggiero *et al*.[11] represented that a nonhealing wound is developed with a minor injury or disease such as dental trauma and periodontal infection when bisphosphonates compromise vascular supply of the jaw bones. This may turn into widespread progress of necrosis and osteomyelitis.

According to Suei,[13] the osteonecrotic change may induce an osteomyelitic lesion caused by an infection known as bisphosphonate-related osteomyelitis of the jaws which is recognized as an advanced condition of BRONJ. In the same study, the radiographic findings of BRONJ was compared with different kinds of osteomyelitis and osteosclerotic changes were found not specific; periosteal reaction was reported 60% of BRONJ cases with unique characteristics such as solid type and related to the border of osteolytic area. Similarly, 61% of 23 cases and 63.6% of 11 cases were showed periosteal response at the studies by Guggenberger *et al*.[3] and Popovic and Kocar,[17] respectively. On contrary, periosteal response was reported in only 6 of 29 cases with a percentage of 20.7% in a CT study of Elad *et al*.[16] Despite of the low incidence, it was reported that none of the periosteal reactions had the onion peel appearance. Just as Suei,[13] solid type periosteal response was stated.[16] Periosteal response was detected 52.5% of CBCT findings and only at mandible in our study. PR was not as successful as CBCT on detecting periosteal response (11.5%). Only in segment 4 of 2 patients and in segment 6 of 1 patients could be seen on PR. Supportively, bone modeling in response to mechanical stress was showed at the animal experiment of Feher *et al*.,[22] and it was suggested that periosteal bone formation is not suppressed by bisphosphonates.

Sequestrum formation was described as a large part of the cancellous bone is demarcated by the osteolytic area, and it was claimed that the finding of large sequestrations were only observed in BRONJ cases at the comparison study of Suei[13] with a 91% incidence. As the same formation, sequestration was observed 78.3% of CBCT findings in this study. CBCT was again more effective than PR (11.5%) as in periosteal response. Otherwise Elad *et al*.[16] reported sequestrum with also marked margins but less incidence (23.3%).

In this study, periosteal response and sequestration were predominant in advanced stages of disease. Bedogni *et al*.[18] reported the same predominancy through the 11 patients tomography scans.

Sclerotic changes were observed at the periphery of the osteolytic focus which were detected in 10 lesions at the CT study of Elad *et al*.[16] Sclerosis and osteolysis were observed in the same incidence with predominance of segment 4 in this study (88.5% of 26 patients in PR and 95.6% of 23 patients in CBCT). Our findings mostly supported sclerosis around osteolytic areas. But there were sclerotic changes also in the independent areas from lytic regions. While Suei[13] reported no unique characteristics of sclerosis or osteolysis at BRONJ cases, Hutchinson *et al*.[15] supported the need of better understanding for radiographic features and to determine whether osteosclerosis is a specific indicative finding for the risk of BRONJ progression to advance stages.

It should be pronounced that the effected bone area goes much beyond the limits of clinically diagnosed exposed bone. Radiographic examinations are needed in evaluating bone involvement.[18] PR provides an excellent general assessment and allows quick visualization of the entire jaw or the affected area, but at least 30–50% mineral loss is needed for any changes to be visible in bone at plain films.[23,24] Furthermore, it is accepted that three-dimensional imaging can reveal bucco-lingual borders and cortex continuity more clearly than plain films.[12,18,20] CBCT also provides the greatest level of detail without any magnification and superposition with relatively lower dose of radiation.[2,3,23] Although PR is based on the principles of tomography technique, still it is a two-dimensional image of three-dimensional and complex anatomical structures. Therefore many disadvantages might occur such as distortion, magnification, and superimposition. Positioning and technician errors might increase these disadvantages.[3,6,14] Conversely CBCT is a reconstructive image of 150-600 sagital raw images and so provides the greatest level of detail without any magnification and superposition with relatively lower dose of radiation.[2,3,14,23] Furthermore, CBCT allows simultaneous evaluation of orthogonal planes on the same screen and cross-sections can be obtained from orthogonal planes.[14,16,20] That being said three-dimensional imaging can reveal bucco-lingual borders and cortex continuity more clearly than plain films.[12,18,20]

Despite the current study has usual limitations of a retrospective investigation and small sample size; as our knowledge, this study is the first comparison study between 2 different imaging modalities which are used routinely in dental practice.

Conclusion

The radiographic findings of BRONJ were mostly determined at posterior mandible with predominance of stage 2. This study showed that CBCT findings except extraction socket were significantly higher than PR; CBCT combined with clinical examination can be used effectively to determine the borders of effected areas especially at advanced cases. Since early stages of BRONJ are related to nonspecific clinical symptoms, further studies with larger samples are needed by focusing on the potential of CBCT to detect early symptoms for preventing the progression of BRONJ to advanced stages.

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Conflicts of interest

There are no conflicts of interest.

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