



Original Article

Diagnostic accuracy and reliability of panoramic temporomandibular joint (TMJ) radiography to detect bony lesions in patients with TMJ osteoarthritis



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Abstract *Background/purpose:* The value of the temporomandibular joint (TMJ) projections of panoramic radiography for diagnosing TMJ osteoarthritis is not completely elucidated. This study aimed to assess the diagnostic accuracy and reliability of panoramic TMJ radiography to detect bony lesions in patients with TMJ osteoarthritis.

Materials and methods: This study included 55 TMJs of 44 subjects who were diagnosed with TMJ osteoarthritis. They underwent panoramic radiography (PanRad), lateral (LatTMJ) and frontal (FrnTMJ) projection panoramic TMJ radiography, and cone-beam computed tomography (CBCT). All images were examined by two observers for flattening, erosion, and osteophytes on the condylar head and articular eminence of the TMJ.

Results: For detecting flattening lesions on the mandibular condyle, the sensitivities of PanRad, LatTMJ, and FrnTMJ were less than 67% and the combination of LatTMJ and FrnTMJ (ComTMJ) had the highest sensitivity for both observers (67.6% and 79.7%, respectively). For erosion lesions, the sensitivity of ComTMJ for observer 1 was the highest, at 84.3%, whereas

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the specificity of ComTMJ was the lowest, at 37.5%. The sensitivities of all four methods for observer 2 were less than 54% and the specificities ranged from 75.0% to 100%. The overall diagnostic accuracy was highest for ComTMJ (64.3%), followed by LatTMJ (59.5%). The intraobserver reliability was good for one observer and excellent for the other, and the interobserver reliability was fair or moderate.

Conclusion: Panoramic TMJ radiography demonstrated limited diagnostic accuracy and acceptable reliability in detecting bony lesions of the TMJ, although it was better than conventional panoramic radiography.

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Introduction

Osteoarthritis is a slow-progressing degenerative disease of the joint characterized by cartilage degradation and subchondral bone remodeling. Osteoarthritis of the temporomandibular joint (TMJ) belongs to a subcategory of temporomandibular disorders (TMDs) involving the TMJ.¹ Patients with TMJ osteoarthritis often have signs and symptoms associated with pain and dysfunction of the TMJ. The clinical diagnosis of TMJ osteoarthritis depends on clinical features such as joint pain and crepitus noises.² Radiographic examination can provide additional diagnostic information by depicting radiographic bony alterations of the condylar head and articular eminence. Radiographically discernible bony changes include flattening, erosion, osteophytes, and sclerosis.^{3–5}

Panoramic radiography has many advantages over conventional plain radiography in the evaluation of dental and maxillofacial structures. It can visualize teeth, alveolar bones, jaw bones, maxillary sinuses, the nasal cavity, and TMJs simultaneously in a single projection. Other advantages include a low dose of radiation exposure, short and simple procedures for image taking, and low cost. It enables the evaluation of the whole TMJ, including the mandibular condyle, articular eminence, and articular fossa. However, panoramic radiography has a very limited value in the diagnosis of TMDs. Aberrant morphologic features observed in panoramic imaging generally do not indicate TMDs.⁶ Information obtained from panoramic radiography cannot alter the clinical diagnosis or treatment plan for most patients with TMDs.⁷ Panoramic radiography is inferior to TMJ tomography and cone-beam computed tomography (CBCT) for assessing bony changes of the TMJ.^{8,9}

Most panoramic X-ray machines currently produced and marketed have specialized programs optimized to image specific maxillofacial regions, in addition to the basic function for conventional panoramic radiography. Several types of special panoramic radiographs can be obtained from the programs for the TMJ (panoramic TMJ radiographs). One type is composed of a set of four lateral TMJ projections in both closed- and open-jaw positions for each TMJ. This type of radiographic image, similar to that obtained by transcranial radiography, permits evaluation of the range of translational movement of the mandibular condyle.¹⁰ Another type consists of a combination of frontal

and lateral projections at the maximally open jaw position for each TMJ; this type of image is advantageous in that the frontal view can provide additional information about bony changes observed on the lateral view (Fig. 1). Several studies have reported on the diagnostic accuracy of the lateral projection of panoramic TMJ radiography regarding TMJ bony changes using dry human skulls,^{8,11–13} but studies employing a frontal projection using human skulls are scarce.^{8,12} Furthermore, little is known about the diagnostic accuracy of these projections in patients with TMJ osteoarthritis.

Therefore, the aims of this study were (1) to investigate the diagnostic accuracy and reliability of lateral and frontal panoramic TMJ radiography compared with cone-beam computed tomography (CBCT), which was set as a reference standard; and (2) to determine whether a combination of the two projections shows any benefits in diagnostic accuracy compared with each of the two projections and conventional panoramic radiography.

Materials and methods

Subjects

This was an observational, cross-sectional study. Ethical approval was obtained from the Chonnam National University Dental Hospital Institutional Review Board (CNUDH-2014-002). The included subjects were men and women aged 19 years or older who visited Chonnam National University Dental Hospital Department of Oral Medicine and were diagnosed with osteoarthritis of the TMJ on one or both sides during the period of June 2014 to March 2016. Those who had a history of traumatic injury, infection, or a tumor in the maxillofacial region, and pregnant women were excluded. TMJ osteoarthritis was diagnosed based on the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Axis I, Group III, IIIb.¹⁴ The RDC/TMD diagnosis of osteoarthritis requires the following conditions: (1) subjective pain in the TMJ area; (2) tenderness upon palpation of the TMJ area; and (3) crepitus sounds during mandibular movement. All subjects were examined by a trained specialist in orofacial pain and TMDs with 16 years of clinical experience (YG IM). Written informed consent was obtained from all subjects before joining the study. Initially, 51 subjects were recruited; 7 of these were

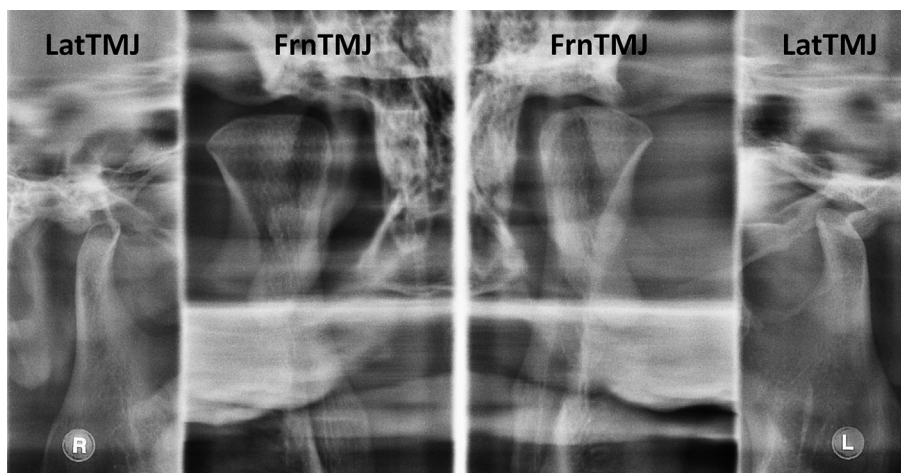


Fig. 1 Panoramic TMJ radiographs consisting of the combination of the frontal and lateral projections for each TMJ at the maximally open jaw position. TMJ: temporomandibular joint. LatTMJ: panoramic projection, lateral view of the TMJ. FrnTMJ: panoramic projection, frontal view of the TMJ.

excluded for various reasons, and the final sample consisted of 55 TMJs of 44 subjects (mean age: 46.8 ± 19.5 years) (Fig. 2).

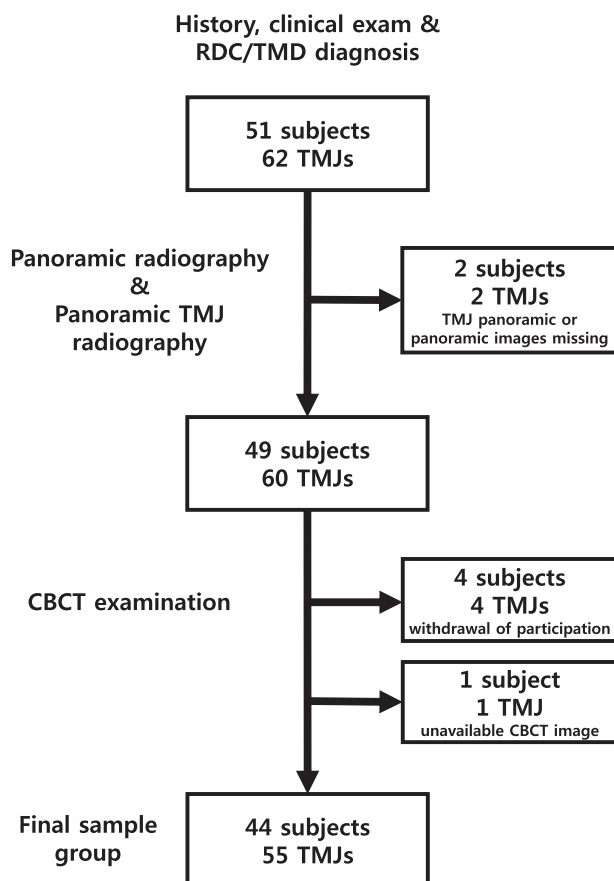


Fig. 2 Study sample flowchart. RDC/TMD: Research Diagnostic Criteria for Temporomandibular Disorders. TMJ: temporomandibular joint. CBCT: cone-beam computed tomography.

Radiographic imaging

Panoramic radiography (PanRad) and panoramic TMJ projections of the lateral (LatTMJ) and frontal (FrnTMJ) planes were acquired using a panoramic machine (Orthopantomograph OP100; Instrumentarium Imaging, Finland). PanRad images were acquired with subjects gently biting the incisal guided bite block. The exposure parameters for PanRad were 85 kV, 12 mA, and 17.6 s. LatTMJ and FrnTMJ images of both right and left TMJs were produced at the maximum jaw opening position using Program 4 with exposure parameters of 85 kV, 12 mA, and 12.2 s. The affected TMJs of subjects diagnosed with osteoarthritis according to RDC/TMD were further examined by CBCT. TMJs were scanned using a dental CBCT machine (CB Mercuray, Hitachi, Japan) with a radiation field of 51×51 mm, voxel size of 0.1 mm, tube voltage of 120 kV, and tube current of 15 mA. The CBCT images were obtained with subjects in the maximum tooth intercuspation position, and their heads were aligned so that the Frankfort plane was parallel to and the midsagittal plane was perpendicular to the floor. The long axis of the mandibular condyles was determined by connecting the medial and lateral poles. Coronal and sagittal slice images of 0.1 mm thickness parallel and perpendicular to the long axis of the condyle, respectively, were produced, and three-dimensional (3D) images were reconstructed using a program (CB works, Cybermed, Korea).

Observers and viewing session

All images were examined by two independent observers twice each. The interval between the two examination sessions for a specific image was more than one month. All images were examined at least 6 months after the termination of study subjects' treatment. Observer 1 was a specialist in orofacial pain and TMDs (YG IM), who was involved in the treatment of the study subjects. Observer 2 was an oral and maxillofacial radiologist (JS LEE) with more

than 18 years' experience in the specialty. The two observers were informed that the radiographic images had been taken from patients diagnosed with the TMJ osteoarthritis. They were not calibrated before the examination, but were given a guideline and instructed on how to interpret and rate the images.

The observers viewed the images using the PACS (PiViewSTAR, Infinit, Korea) on a 21-inch, thin film transistor liquid crystal display monitor (IF2015MP, WIDE, Korea) with a screen resolution of 2048×2560 in a quiet room adequately illuminated to magnify or reduce them for better viewing conditions using the PACS program, if needed. For the CBCT examination, the observers could view the sagittal, coronal, and axial slice images, as well as the reconstructed 3D images. The patient information was set not to be displayed in the selected images on a monitor.

The observers judged whether radiographic bony lesions were "present" or "absent" on the condylar head and articular eminence of the TMJ. Three kinds of bony lesions were evaluated:

- (1) flattening: a flat contour deviating from the normally convex form
- (2) erosion: an area of discontinuous or irregular cortical outline with decreased density
- (3) osteophyte: outgrowth or projections at the joint margins

The articular surface of the condylar head was examined for flattening, erosion, and osteophytes, and the articular eminence was examined for flattening and erosion. "Not accessible" was designated for the PanRad and LatTMJ images when the posterior slope of the articular eminence was not visible, as well as for the FrnTMJ images when the entire outline of the condylar head was not visible. The combination of LatTMJ and FrnTMJ was defined as "ComTMJ," and its bony lesions were determined as "present" if the data of one or both LatTMJ and FrnTMJ were judged to indicate "present." The true presence of bony lesions (i.e., reference standard) was decided by consensus of the two observers based on the CBCT images (Fig. 3).

Statistical analyses

The frequencies of the radiographic bony lesions were estimated from the ratio of the "present" and "absent" cases in the data set. The sensitivity and specificity for each of the two observers and the combined overall diagnostic accuracy for both observers for the four imaging types (PanRad, LatTMJ, FrnTMJ, and ComTMJ) were calculated. The intraobserver reliability between the two sessions and interobserver reliability between the two observers were assessed with Cohen's kappa. According to Maclure et al.,¹⁵ a kappa value of 0–0.2 is interpreted as slight agreement, 0.2–0.4 as fair agreement, 0.4–0.6 as

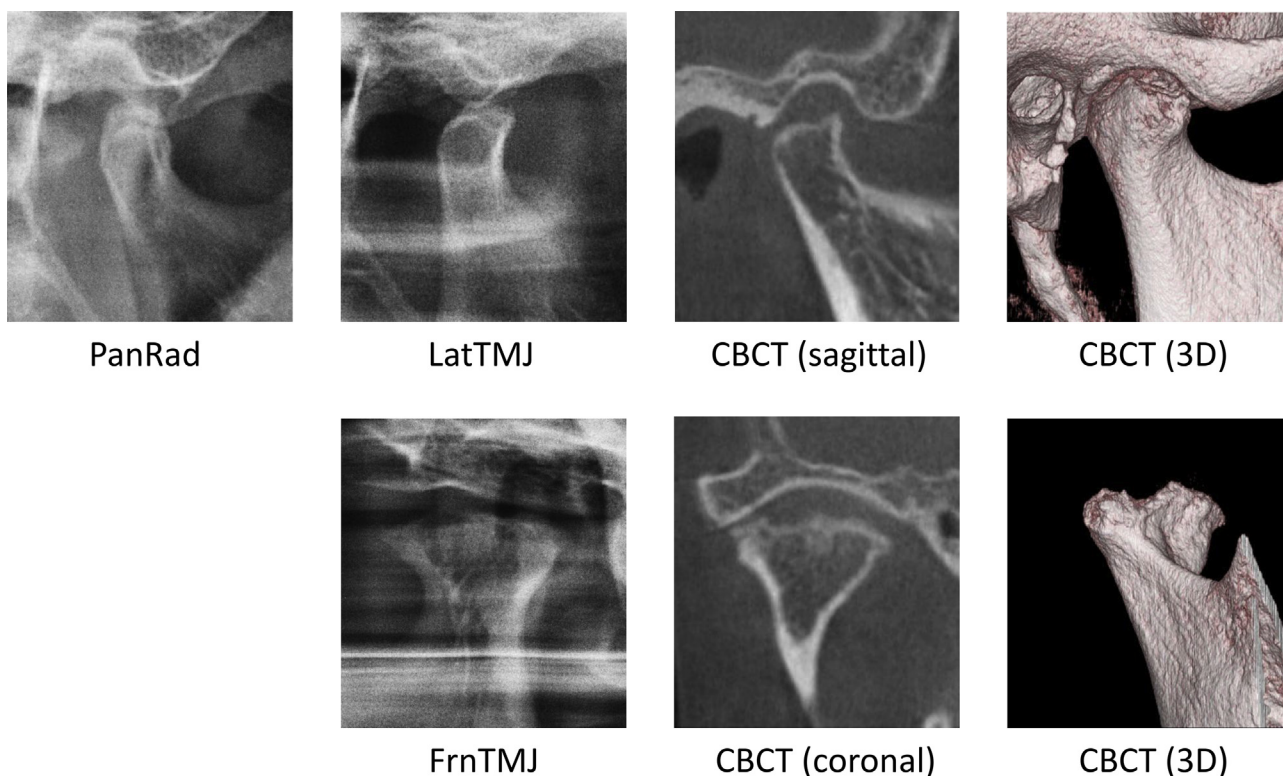


Fig. 3 Example of the four types of radiographic images in a patient with TMJ osteoarthritis. These cropped images were obtained from the same TMJ of a sample patient. Erosion and osteophyte lesions are noted on the articular surface of the mandibular condyle. TMJ: temporomandibular joint. PanRad: panoramic radiography. LatTMJ: panoramic projection, lateral view of the TMJ. FrnTMJ: panoramic projection, frontal view of the TMJ. CBCT: cone-beam computed tomography. 3D: three-dimensional reconstruction.

moderate agreement, 0.6–0.8 as substantial agreement, and 0.8–1.0 as almost perfect. Inter- and intraobserver reliabilities were calculated using SPSS 20.0 for Windows (IBM Corporation, New York, USA).

Results

The number of TMJ components accessible to radiographic examination by the two independent observers using the four imaging methods in 55 TMJs was counted. The mandibular condyle was accessible to both observers using PanRad in all TMJs. One of the 55 TMJs (1.8%) was not accessible with LatTMJ, and five of them (9.1%) were not accessible to the two observers using FrnTMJ. The articular eminence was not accessible with PanRad, LatTMJ, and FrnTMJ in 1–3 TMJs (1.8–9.1%). All joint components were accessible with CBCT.

Table 1 summarizes the number of joint components completely accessible with panoramic radiography (PanRad, LatTMJ, and FrnTMJ) and the number of radiographic bony lesions according to the reference standard (CBCT). Because only those joint components that were recorded as accessible to both observers using all three imaging methods were included in further analysis, the study sample number was reduced from 55 to 49 TMJs. For the mandibular condyle, erosion was most frequently observed (91.8%), followed by flattening (71.4%) and osteophytes (69.4%). For the articular eminence, flattening and erosion were present in approximately one-third of the TMJs (30.6% and 34.7%, respectively).

Table 2 presents the sensitivity and specificity values to detect radiographic bony lesions on the mandibular condyle using the four imaging methods. In detecting flattening lesions, the sensitivities of PanRad, LatTMJ and FrnTMJ were less than 70%. Although ComTMJ showed the highest sensitivity for both observers, it was less than 80%. The specificities of PanRad, LatTMJ, and FrnTMJ varied from 61.1% to 96.7%. The specificity of ComTMJ was similar to that of LatTMJ. There was a notable difference in the sensitivity and specificity for the two observers in detecting erosion lesions. For observer 1, the sensitivity of LatTMJ was 72.0%, which was higher than that of PanRad and FrnTMJ. The sensitivity of ComTMJ was the highest among the four examination methods, at 84.3%. However, the specificity of LatTMJ was 50.0%, which was lower than

those of PanRad and FrnTMJ. The specificity of ComTMJ was the lowest, at 37.5%. By contrast, the sensitivities of all four examination methods for observer 2 were less than 54%. The specificities varied from 75.0% to 100%. In detecting osteophyte lesions, both observers showed very low sensitivity (lower than 30%) and high specificity (higher than 85%) for all four examination methods.

Table 3 shows the sensitivity and specificity values for detecting radiographic bony lesions on the articular eminence with the four imaging methods. For detecting flattening and erosion lesions on the articular eminence, the sensitivity of all four examination methods was lower than 40%. The specificity for all four methods was higher than 90%, and there was no large difference among them.

Fig. 4 presents the overall diagnostic accuracy for detecting radiographic bony lesions of the mandibular condyle, articular eminence, and temporomandibular joint by the four imaging methods. The overall diagnostic accuracy for bony lesions of the mandibular condyle was highest for ComTMJ (61.4%), followed by LatTMJ (54.5%). The diagnostic accuracy for articular eminence lesions was similar across the four methods (66.8–69.2%), although ComTMJ demonstrated the highest value for the two observers.

Table 4 shows the intraobserver and interobserver reliability of the four examination methods in detecting radiographic bony lesions. The intraobserver reliability was substantial for observer 1 (0.623–0.706) and almost perfect for observer 2 (0.918–0.957). The interobserver reliability between observers was fair for FrnTMJ and moderate for the other examinations.

Discussion

Panoramic radiography is used to examine TMD patients mainly to exclude specific maxillofacial pathology rather than to accurately diagnose bony changes of the TMJ. This study assessed the diagnostic accuracy and reliability of panoramic TMJ radiography, as well as conventional panoramic radiography, in detecting bony lesions of the TMJ. The results showed that, in general, LatTMJ showed higher sensitivity values than did PanRad, and ComTMJ displayed the highest sensitivity value of the imaging methods without a significant loss of specificity. However, the differences were not large, and panoramic TMJ radiography demonstrated only slightly better diagnostic accuracy than did PanRad.

The results concerning the diagnostic accuracy of PanRad in our study generally corroborate the data of other studies. Dahlstrom et al.¹⁶ assessed the diagnostic validity of panoramic radiography compared with tomography in 50 TMD patients and 20 non-TMD subjects. The sensitivity and specificity values of panoramic radiography for detecting bony lesions of the mandibular condyle ranged from 0.29 to 0.60 and from 0.71 to 0.95, respectively. Those values were 0.00–0.25 and 0.59–0.86, respectively, for detecting lesions of the articular eminence. Ladeira et al.¹⁷ evaluated the diagnostic validity of panoramic radiography in the images of 212 subjects, with CBCT was set as a reference standard. The sensitivity and specificity for panoramic radiography to detect flattening lesions were

Table 1 Number of joint components completely accessible to panoramic radiography (PanRad, LatTMJ, and FrnTMJ) and the number of radiographic bony changes according to the reference standard (CBCT).

	Radiographic bony changes		
	Flattening	Erosion	Osteophyte
Mandibular condyle	35/49 (71.4%)	45/49 (91.8%)	34/49 (69.4%)
Articular eminence	15/49 (30.6%)	17/49 (34.7%)	Not assessed

Number with changes/number accessible to examination (%).

Table 2 Sensitivity and specificity for the detection of radiographic bony lesions in the mandibular condyle using the four imaging methods.

	Radiographic bony changes											
	Flattening				Erosion				Osteophyte			
	PanRad	LatTMJ	FrnTMJ	ComTMJ	PanRad	LatTMJ	FrnTMJ	ComTMJ	PanRad	LatTMJ	FrnTMJ	ComTMJ
Sensitivity												
Observer 1	52.7 (40.7–64.4)	54.1 (42.1–65.7)	34.3 (23.3–46.6)	67.6 (55.7–78.0)	47.1 (37.1–57.2)	72.0 (62.1–80.5)	55.4 (44.7–65.8)	84.3 (75.8–90.8)	7.5 (2.8–15.6)	15.4 (8.2–25.3)	12.5 (5.9–22.4)	25.0 (16.0–35.9)
Observer 2	66.2 (54.3–76.8)	64.9 (52.9–75.6)	47.1 (35.1–59.4)	79.7 (68.8–88.2)	44.1 (34.3–54.3)	51.0 (40.8–61.1)	25.0 (16.6–35.1)	53.9 (43.8–63.8)	13.8 (7.1–23.3)	20.5 (12.2–31.2)	13.9 (6.9–24.1)	27.5 (18.1–38.6)
Mean	59.5	59.5	40.7	73.7	45.6	61.5	40.2	69.1	10.7	18.0	13.2	26.3
Specificity												
Observer 1	63.9 (46.2–79.2)	70.6 (52.5–84.9)	96.7 (82.8–99.9)	69.4 (51.9–83.7)	62.5 (24.5–91.5)	50.0 (15.7–84.3)	87.5 (47.3–99.7)	37.5 (8.5–75.5)	93.3 (77.9–99.2)	86.7 (69.3–96.2)	93.3 (77.9–99.2)	86.7 (69.3–96.2)
Observer 2	75.0 (57.8–87.9)	64.7 (46.5–80.3)	73.3 (54.1–87.7)	61.1 (43.5–76.9)	75.0 (34.9–96.8)	100.0 (63.1–100.0)	87.5 (47.3–99.7)	87.5 (47.3–99.7)	100.0 (88.4–100.0)	100.0 (88.4–100.0)	100.0 (88.4–100.0)	100.0 (88.4–100.0)
Mean	69.5	67.7	85.0	65.3	68.8	75.0	87.5	62.5	96.7	93.4	96.7	93.4

The data of session 1 and session 2 were pooled.

Sensitivity and specificity values with 95% confidence intervals in ().

Observer 1: specialist in orofacial pain and TMDs; Observer 2: oral and maxillofacial radiologist.

PanRad: panoramic radiography.

LatTMJ: panoramic projection, lateral view of the TMJ.

FrnTMJ: panoramic projection, frontal view of the TMJ.

ComTMJ: combination of the lateral and frontal projections.

0.33–0.35 and 0.77–0.80, respectively. Those values for detecting osteophytes were 0.05–0.08 and 0.97–1.00, respectively. In addition, when magnetic resonance imaging (MRI) was used as a reference standard to diagnose TMJ osteoarthritis, the sensitivity and specificity of panoramic radiography were 69.0% and 67.9%, respectively.¹⁸

By contrast, it was difficult to compare the findings of our study concerning the diagnostic validity of panoramic TMJ radiography with those of other studies because such reports are scarce. In a study by Honey et al.,¹² the overall diagnostic accuracy of panoramic radiography and panoramic TMJ radiography to detect erosive lesions of the mandibular condyle was evaluated for a sample of 37 mandibular condyles in 30 human skulls. The diagnostic accuracy, defined as the area under the ROC curve, of panoramic radiography was 0.644, and that of panoramic TMJ radiography was 0.545. Although the diagnostic accuracy of panoramic TMJ radiography was lower than that of panoramic radiography in that study, these values were not very different from values in our study.

In our study, there were notable differences in the sensitivity and specificity of radiographic lesions, such as differences between the two observers in detecting erosion of the mandibular condyle, which could be explained by observer characteristics. Observer 1, an orofacial pain specialist, had expertise in examining and diagnosing patients with TMJ osteoarthritis. He might have had a propensity to conclude the presence of erosion lesions. By

contrast, observer 2, the oral and maxillofacial radiologist, might have been skeptical in judging the same lesions as present.

Our study showed fair to moderate interobserver reliability between the two observers, both of whom examined the radiographic images twice. This may be explained by the lack of pre-calibration, as the two observers primarily relied on a guideline for interpreting radiographic bony lesions. Although they were given the same guideline, they might have had somewhat different perspectives on how to evaluate those lesions. The intraobserver reliability was substantial for observer 1, ranging from 0.623 to 0.706. These values are well in accordance with the corresponding values for intraobserver reliability before calibration for panoramic radiography in the study by Dahlstrom et al.¹⁶ Observer 2 showed almost perfect agreement between the two sessions, with intraobserver reliability greater than 0.9 in all cases. Observer 2's very high intraobserver reliability might be due to certain factors, including excellent expertise in radiographic interpretation. This finding contrasts with the study by Dahlstrom et al.,¹⁶ who reported that the intraobserver reliability of an oral radiologist was not very different from that of a TMD specialist.

In the study by Honey et al.,¹² 10 dentists with various levels of expertise in TMJ imaging participated to compare the diagnostic accuracies of panoramic radiography, tomography, and CBCT in detecting cortical erosion of the mandibular condyle when human skulls were set as a

Table 3 Sensitivity and specificity for the detection of radiographic bony lesions in the articular eminence using the four imaging methods.

	Radiographic bony changes							
	Flattening				Erosion			
	PanRad	LatTMJ	FrnTMJ	ComTMJ	PanRad	LatTMJ	FrnTMJ	ComTMJ
Sensitivity								
Observer 1	5.9 (2.2–15.1)	16.7 (6.4–32.8)	8.8 (1.9–23.7)	25.0 (12.1–42.2)	16.7 (7.0–31.4)	11.9 (4.0–25.6)	12.5 (4.2–26.8)	25.0 (13.2–40.3)
Observer 2	26.5 (12.9–44.4)	33.3 (18.6–51.0)	11.8 (3.3–27.5)	38.9 (23.1–56.5)	0.0 (0.0–8.8)	13.2 (4.4–28.1)	10.0 (2.8–23.7)	21.4 (10.3–36.8)
Mean	16.2	25.0	10.3	32.0	8.4	12.6	11.3	23.2
Specificity								
Observer 1	93.2 (80.3–99.3)	95.8 (88.3–99.1)	98.6 (92.3–100.0)	94.6 (86.7–98.5)	93.9 (85.2–98.3)	90.9 (81.3–96.6)	96.9 (89.2–99.6)	87.9 (77.5–94.6)
Observer 2	97.3 (90.6–99.7)	91.7 (82.7–96.9)	100.0 (94.9–100.0)	91.9 (83.2–97.0)	100.0 (94.6–100.0)	97.0 (89.5–99.6)	100.0 (94.4–100.0)	97.0 (89.5–99.6)
Mean	95.3	93.8	99.3	93.3	97.0	94.0	98.5	92.5

The data of session 1 and session 2 were pooled. Sensitivity and specificity values with 95% confidence intervals in (). Observer 1: specialist in orofacial pain and TMDs; Observer 2: oral and maxillofacial radiologist. PanRad: panoramic radiography. LatTMJ: panoramic projection, lateral view of the TMJ. FrnTMJ: panoramic projection, frontal view of the TMJ. ComTMJ: combination of the lateral and frontal projections.

reference standard. The mean intraobserver reliability of the 10 observers for panoramic TMJ radiography (0.466) was lower than that for standard panoramic radiography (0.716). The intraobserver reliability for panoramic TMJ radiography showed larger variation than did that for panoramic radiography. In the study by Ladeira et al.,¹⁷ the

interobserver reliability for panoramic radiography among four appraisers ranged from 0.22 to 0.39.

Degenerative bony changes are common in TMJ with osteoarthritis.^{3,4} However, TMJs in asymptomatic adults frequently show degenerative bony alterations.¹⁹ In our study, the frequency of radiographic bony lesions was very high for the mandibular condyle. For example, erosion was present in more than 90% of TMJs that were accessible to all four imaging methods. Bony lesions of the articular eminence were less frequent than those of the mandibular condyle, but were still present in about one-third of TMJs.

TMJ osteoarthritis is a self-limiting degenerative condition that is neither life threatening nor severely debilitating. It can be successfully managed with conservative treatments in most patients.¹ As shown in our study, panoramic TMJ radiography was slightly better than conventional panoramic radiography in terms of diagnostic accuracy. The sensitivity of panoramic TMJ radiography was not high, but its specificity in detecting bony lesions of the TMJ was very high. False-positive findings can lead to unnecessary or even harmful treatments, whereas false-negative findings result in less serious problems such as a delay in treatment. Considering these facts, panoramic TMJ radiography may be used in an indicated individual rather than as a diagnostic test for TMDs. For a definitive diagnosis, additional imaging studies using CBCT or tomography could be considered when the clinical diagnosis indicates pathologic bony changes of the TMJ and their confirmation is important for treatment planning and prognosis.

Panoramic TMJ radiography shows only the TMJs and does not provide the other information available on

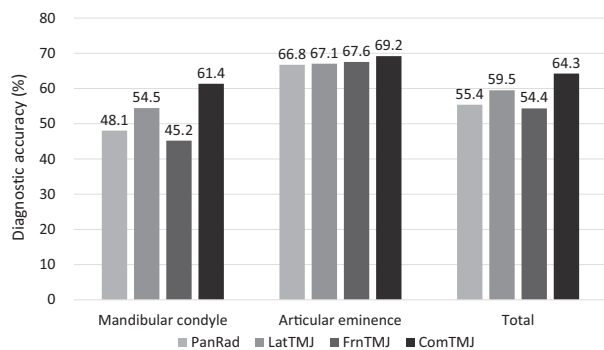


Fig. 4 The combined overall diagnostic accuracies for the two observers for detecting radiographic bony lesions of the mandibular condyle, articular eminence, and temporomandibular joint using the four imaging methods. Diagnostic accuracy = (TP + TN)/(TP + FP + TN + FN) × 100 (TP: true positive, FP: false positive, TN: true negative, FN: false negative). Mean values of the two observers (%). PanRad: panoramic radiography. LatTMJ: panoramic projection, lateral view of the TMJ. FrnTMJ: panoramic projection, frontal view of the TMJ. ComTMJ: combination of the lateral and frontal projections.

Table 4 Intra- and interobserver reliability in detecting radiographic bony lesions.

		Intraobserver reliability between the two sessions			
		PanRad	LatTMJ	FrnTMJ	ComTMJ
Observer 1	Cohen's kappa (κ)	0.706	0.623	0.662	0.629
	Number of valid cases	273	270	255	275
Observer 2	Cohen's kappa (κ)	0.928	0.945	0.957	0.918
	Number of valid cases	272	268	255	274
		Interobserver reliability between the two observers			
		PanRad	LatTMJ	FrnTMJ	ComTMJ
Session 1	Cohen's kappa (κ)	0.478	0.430	0.388	0.454
	Number of valid cases	272	268	255	274
Session 2	Cohen's kappa (κ)	0.420	0.453	0.304	0.497
	Number of valid cases	272	268	255	274

Observer 1: specialist in orofacial pain and TMDs; Observer 2: oral and maxillofacial radiologist.

PanRad: panoramic radiography.

LatTMJ: panoramic projection, lateral view of the TMJ.

FrnTMJ: panoramic projection, frontal view of the TMJ.

ComTMJ: combination of the lateral and frontal projections.

standard panoramic radiography. Furthermore, it has shortcomings in depicting the TMJ structure as well as advantages over conventional panoramic radiography. In a few patients, all of the TMJ structures, including the bilateral condylar head, articular eminence, and articular fossa, cannot be imaged with a single exposure set. The articular fossa of one of the two TMJs can be cut out of the scanning area in LatTMJ. Similarly, the lateral pole area of the mandibular condyle of one of the two TMJs can be cut due to positioning outside the scanning area in FrnTMJ. Additionally, in patients with severely limited mouth opening, the condylar head and articular eminence are superposed, making radiographic interpretation difficult in these images. In this study, for example, the articular eminence was recorded as non-accessible to examination with LatTMJ in up to 3 of 55 (5.5%) TMJs with LatTMJ and FrnTMJ images. Hinze et al.¹¹ reported a similar finding: the articular eminence was not accessible with LatTMJ in 2–15 of 159 (1.3–9.4%) TMJs.

This study has the following limitations. First, one of the two observers (observer 1, YG IM) was directly involved in the diagnosis and treatment of the patients. For completely blind observation, radiographic images should have been examined by an observer who was not associated with these subjects. Second, the images were examined and judged by only two observers. It is usually recommended that more observers participate in these steps. Third, CBCT images were used as a reference standard instead of dry human skulls. Although CBCT images have excellent diagnostic accuracy, they may distort or may not depict some bony changes of the TMJ.

In conclusion, panoramic TMJ radiography has some advantages in detecting bony lesions of the TMJ, and it may provide additional information in the diagnosis of TMJ osteoarthritis compared with conventional panoramic radiography in specific conditions. However, its diagnostic validity and reliability are still limited, and other diagnostic imaging modalities such as CBCT could be indicated for

thorough evaluation and definitive diagnosis of bony lesions of the TMJ.

Conflicts of interest

No conflict of interest has been reported by the authors or by any individual in control of the content of this article.

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