ORIGINAL PAPER

IS PANORAMIC RADIOGRAPHY SUFFICIENT ENOUGH FOR THE EVALUATION OF MANDIBULAR CONDYLE OSSEOUS CHANGES AND CORTICATION TYPES?

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ABSTRACT

Introduction: Temporomandibular disorders (TMDs) are identified by cranio-facial pain that affects the temporomandibular joint or masticatory muscles, along with symptoms, such as limited mouth opening, clicking, and crepitus.

Objectives: The aim of this study was to investigate the accuracy of panoramic radiography (PR) in detecting mandibular condyle osseous changes and mandibular condyle-articular eminence cortication types in patients with TMDs, using cone beam computed tomography (CBCT) as a gold standard.

Material and methods: Osseous changes in the mandibular condyle head and cortication types in both articular eminence and mandibular condyle head were examined using PR and CBCT images of patients with TMD symptoms.

Results: The most occurrences of flattening were detected in the mandibular condyle heads using PRs, and the most of erosions were found in CBCT images. In both imaging methods, cortication of both the mandibular condyle head and articular eminence was the same or higher than that of the surrounding structures. PR showed high specificity and negative predictive values in detecting mandibular condyle osseous changes. PR revealed greater sensitivity and positive predictive values if the cortication of the mandibular condyle head and articular eminence was the same or higher than that of the surrounding structures.

Conclusions: TMDs often result in the flattening and erosion of the mandibular condyle. PR and CBCT images demonstrate that the cortication of the mandibular condyle and articular eminence in patients with TMDs indicates the same or higher intensity than that of the surrounding structures. PR alone may be insufficient to evaluate osseous changes in the mandibular condyle and cortication of the temporomandibular joint. Three-dimensional imaging methods, such as CBCT, may be required for a more comprehensive evaluation.

Key words: CBCT, panoramic radiography, temporomandibular disorder, cortication, osseous change.

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INTRODUCTION

Temporomandibular disorders (TMDs) are identified by cranio-facial pain that affects the temporomandibular joint (TMJ) or masticatory muscles, along with symptoms, such as limited mouth opening, clicking, and crepitus [1]. TMDs are the main source of orofacial pain that is not related to dental issues [2]. It has a multifactorial etiology, including bruxism, malocclusion, hormones, or systemic disorders [3]. TMD causes degenerative osseous changes in TMJ osseous structures [4, 5]. Osseous changes as radiographic findings are essential

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part in finding a true diagnoses and proper treatment modality [5]. Panoramic radiography, computed tomography (CT), or cone beam computed tomography (CBCT) are preferred when evaluating TMJ osseous structures, while ultrasonography or magnetic resonance imaging are ideal in evaluating articular disc and chewing muscles [6, 7].

Panoramic radiography (PR) is often used in initial dental examination [8]. It enables the evaluation of teeth, alveolar bones, nasal cavity, maxillary sinuses, and the whole TMJ simultaneously [9]. However, panoramic radiography, a 2-dimensional imaging method, may not be sufficient to distinguish fully the complex 3D structure of TMJ [9-11]. CBCT is frequently employed in 3-dimensional imaging in dentistry. Previous studies have shown that CBCT is sufficient and reliable in evaluating TMJ bone structures [12-14]. The CBCT technology offers more cost-effective equipment, reduces patient's examination time, and delivers significantly lower radiation doses compared with conventional CT modality [15, 16].

OBJECTIVES

The purpose of the current study was to investigate the accuracy of panoramic radiography in detecting mandibular condyle osseous changes and mandibular condyle-articular eminence cortication types in patients with TMDs using CBCT as a gold standard. The null hypothesis was that panoramic radiography is sufficient enough to detect changes in the mandibular condyle and the difference in cortication in patients with TMDs.

MATERIAL AND METHODS

This retrospective study was approved by the Non-Invasive Clinical Research Ethics Committee on Human Research at Aydın Adnan Menderes University Faculty of Medicine (protocol number: 2020/31), and followed the Helsinki Declaration guidelines. Panoramic radiographs and CBCT images of patients, who were referred to our clinic with TMDs' symptoms, such as mouth-opening limitation, noise and pain during jaw movements, and non-harmonic movements of the joints, were evaluated in the study. Patients with congenital cranio-facial deformities, a prior history of facial trauma or surgery, and those with systemic diseases, which could impact the TMJ bone were not included in the study. Also, PR and CBCT images of patients with incorrect position, containing motion artifacts, or images, which not fully visualized the TMJ, were excluded from the study. To avoid differences in osseous changes, CBCT and panoramic radiographs, which were not taken within 30 days or contained artifacts were not considered.

IMAGE ANALYSES

All CBCT images were acquired by Planmeca Promax 3D (Planmeca, Helsinki, Finland) with standard TMJ mode (field of view: 8 x 5 cm^2, 8 mA, 90 kV, 12 s, voxel size: 0.2 mm), and evaluated using Romexis software v. 3.83. During CBCT scanning, patients stood with their Frankfurt plane parallel to the floor. They were instructed to maintain centric occlusion and maximum intercuspation. Special chin rests and cephalostats were used to minimize movement. All panoramic radiographs were obtained in standard mode (66 kV, 6 mA, 16 s) using a digital panoramic X-ray device (Planmeca Promax, Planmeca, Helsinki, Finland), and were evaluated with Titan software v. 4.0.4.37. A dentomaxillofacial radiologist with 3 years of experience evaluated the images twice, with an interval of one month. While analyzing, PR and CBCT images were assessed separately from one another, without any information about patient associated with image. Additionally, TMJ images of both the right and left sides were individually considered.

Osseous changes in the mandibular condyle were evaluated on panoramic radiographs and both coronal and sagittal sections of CBCT. Osseous changes in images were described as: (1) osteophyte, a localized bony growth originating from a mineralized surface of a joint; (2) erosion, defined as an area characterized by reduced density in the cortical bone and the surrounding sub-cortical bone; (3) sclerosis, as an area where there is increased density in the cortical bone that extends into the bone marrow; (4) flattening, a change in bony contour from a convex to a flat appearance; (5) pseudo-cyst bone cavity, a clearly defined osteolytic region in the adjacent sub-cortical bone without involving cortical destruction; (6) posterior concavity, a concave form in the posterior cortical bone contour of the mandibular condyle [17, 18]. Cortication of the mandibular condyle (MCC) and articular eminence (AEC) were analyzed based on the classification by Yalçın *et al.* [19]: Type 1: Surfaces of the condyle and articular eminence show similar or higher density compared with the surrounding cortical areas; Type 2: Surfaces of the condyle and articular eminence exhibit lower density than the surrounding structures; Type 3: The condyle and articular eminence lack cortication. Initially, assessments were conducted using panoramic radiographs and then, CBCT scans were performed on the sagittal section where the mandibular condyle and articular eminence were most clearly visible.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA), and differences between categorical variables were evaluated using chi-square test. Values of $p < 0.05$ were considered statistically significant. Diagnostic accuracy (ratio of the sum of true positives and true negatives to all answers), sensitivity, specificity, positive predictive values, and negative predictive values of panoramic radiographs were assessed for osseous change and cortication type, using the corresponding CBCT as a gold standard. Intra-observer reliability between the two sessions was assessed with Cohen's k coefficient. The weighted k values were interpreted according to Landis and Koch criteria [20]: a k value of 0.0-0.2 = slight agreement; 0.21-0.40 = fair agreement, 0.41-0.60 = moderate agreement, 0.61-0.80 = substantial agreement, and 0.81-1.00 = almost perfect agreement.

RESULTS

The final study sample consisted of 134 subjects (268 joints). There were 96 females (71.6%) and 38 males (28.4%), with a mean age of 41.6 ± 16.07 years (range: 18-82 years). The intra-observer reliability coefficient ranged from 0.83 to 1.00 for osseous changes in the mandibular condyle, from 0.64 to 0.75 for cortication of the mandibular condyle, and from 0.64 to 0.72 for cortication of the articular eminence, indicating substantial to almost perfect agreement (Figures 1 and 2).

Table 1 summarizes the osseous changes in the mandibular condyle examination performed from panoramic radiographs and CBCT images. The occurrence of flattening of the mandibular condyle was higher compared with all other bony changes on panoramic radiographs (p = 0.000). However, on CBCT, the presence of erosion in the mandibular condyle was higher compared with all other osseous changes (p = 0.000). When the osseous changes in the right-left mandibular condyle were

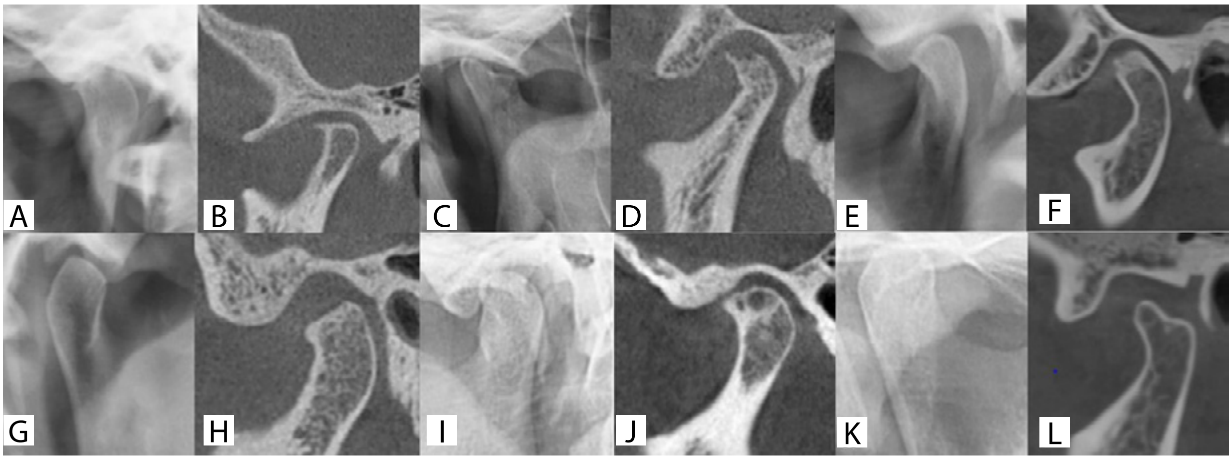

FIGURE 1. Osseous changes in the mandibular condyle in cone beam computed tomography sagittal section and cropped panoramic radiograph: **A-B**) osteophyte, **C-D**) erosion, **E-F**) sclerosis, **G-H**) flattening, **I-J**) pseudo-cyst, **K-L**) posterior concavity

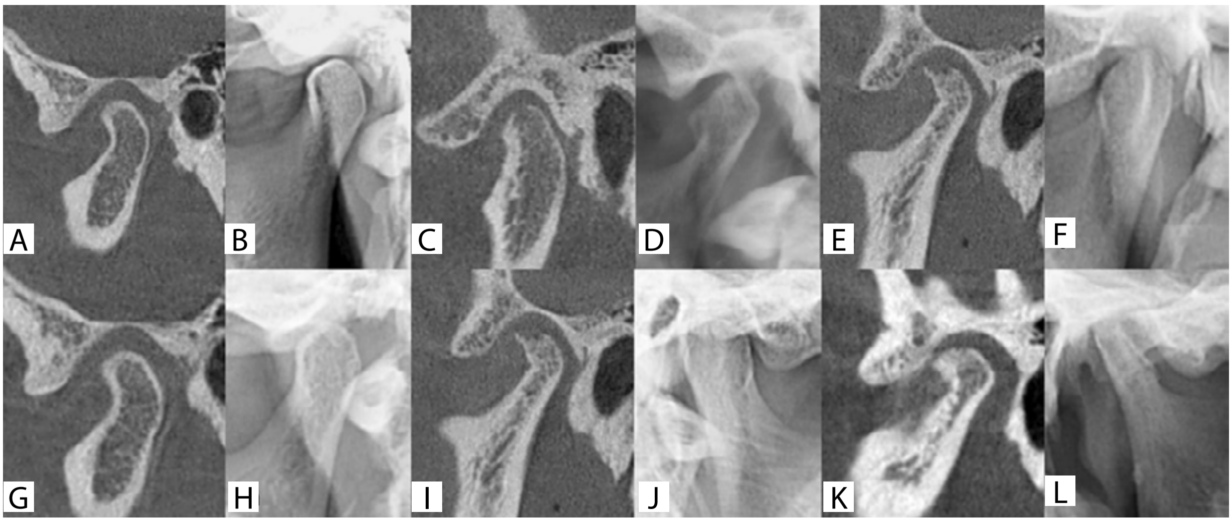

FIGURE 2. Mandibular condyle and articular eminence cortication types in cone beam computed tomography sagittal section and cropped panoramic radiograph: **A-B**) type 1 cortication on mandibular condyle, **C-D**) type 2 cortication on mandibular condyle, **E-F**) type 3 cortication on mandibular condyle, **G-H**) type 1 cortication on articular eminence, **I-J**) type 2 cortication on articular eminence, **K-L**) type 3 cortication on articular eminence

TABLE 1. Distribution of mandibular condyle osseous changes in panoramic radiography and cone beam computed tomography

	Panoramic radiography		Cone beam computed tomography	
	Right	Left	Right	Left
Osteophyte	9 (6.7%)	10 (7.5%)	8 (6.0%)	8 (6.0%)
Sclerosis	6 (4.5%)	11 (8.2%)	12 (9.0%)	17 (12.7%)
Erosion	12 (9.0%)	26 (19.4%)	38 (28.4%)	36 (26.9%)
Flattening	52 (38.8%)	42 (31.3%)	25 (18.7%)	26 (19.4%)
Pseudo-cyst	6 (4.5%)	6 (4.5%)	2 (1.5%)	5 (3.7%)
Posterior concavity	1 (0.7%)	1 (0.7%)	3 (2.2%)	1 (0.7%)
No change	48 (35.8%)	38 (28.4%)	46 (34.3%)	41 (30.6%)
Total	134 (100.0%)	134 (100.0%)	134 (100.0%)	134 (100.0%)

TABLE 2. Distribution of cortication types in panoramic radiography and CBCT

	Panoramic radiography			Cone beam computed tomography		
	Right	Left	Total	Right	Left	Total
Mandibular condyle						
Type 1	109 (81.3%)	105 (78.4%)	214	92 (68.7%)	85 (63.4%)	177
Type 2	22 (16.4%)	27 (20.1%)	49	28 (20.9%)	38 (28.4%)	66
Type 3	3 (2.2%)	2 (1.5%)	5	14 (10.4%)	11 (8.2%)	25
Articular eminence						
Type 1	108 (80.6%)	106 (79.1%)	214	116 (86.6%)	121 (90.3%)	237
Type 2	24 (17.9%)	23 (17.2%)	47	11 (8.2%)	12 (9.0%)	23
Type 3	2 (1.5%)	5 (3.7%)	26	7 (5.2%)	1 (0.7%)	8

TABLE 3. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of panoramic radiography in detecting mandibular osseous changes

	SE (95% CI)	SP (95% CI)	PPV (95% CI)	NPV (95% CI)	AC
Osteophyte	0.125 (0.022-0.363%)	0.993 (0.926-0.948%)	0.105 (0.019-0.306%)	0.944 (0.937-0.959%)	88%
Sclerosis	0.103 (0.028-0.246%)	0.941 (0.932-0.959%)	0.176 (0.047-0.419%)	0.896 (0.888-0.913%)	85%
Erosion	0.189 (0.118-0.269%)	0.876 (0.849-0.907%)	0.368 (0.230-0.525%)	0.739 (0.716-0.765%)	68%
Flattening	0.490 (0.362-0.618%)	0.682 (0.652-0.712%)	0.266 (0.196-0.335%)	0.851 (0.813-0.888%)	64%
Pseudo-cyst	0.000 (0.000-0.405%)	0.954 (0.954-0.965%)	0.000 (0.000-0.236%)	0.973 (0.973-0.984%)	92%
Posterior concavity	0.000 (0.000-0.392%)	0.992 (0.992-0.998%)	0.000 (0.000-0.784%)	0.985 (0.985-0.991%)	97%

SE – sensitivity, SP – specificity, PPV – positive predictive value, NPV – negative predictive value, AC – accuracy (overall fraction correct), CI – confidence interval

compared, it was calculated that the number of osseous changes on the left side was higher than that on the right side using both imaging techniques (for panoramic radiography: $p = 0.005$; for CBCT: $p = 0.012$).

Table 2 summarizes the distribution of MCC and AEC types according to sides seen on panoramic radiographs and CBCT images. In both imaging methods, type 1 MCC and AEC were observed more than type 2 and type 3 on each side ($p = 0.000$). Type 2 MCC and AEC were more common than type 3 on each side, but it was not statistically significant.

Tables 3 and 4 present data corresponding to the assessment of diagnostic validity of panoramic radiography in detecting osseous changes of the mandibular condyle and cortication types using CBCT images as the gold standard. The specificity values for each osseous change were higher than the sensitivity values (Table 3). Moreover, it was observed that sensitivity ranged from 0 to 49% and specificity from 68 to 99%. The positive predictive value ranged from 0 to 36%, and the negative predictive value from 73 to 98%. The negative predictive values were found higher

TABLE 4. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of panoramic radiography in detecting cortication types in the mandibular condyle and articular eminence

	SE (95% CI)	SP (95% CI)	PPV (95% CI)	NPV (95% CI)	AC
MCC type 1	0.831 (0.794-0.869%)	0.264 (0.192-0.338%)	0.687 (0.656-0.718%)	0.444 (0.323-0.569%)	63%
MCC type 2	0.197 (0.119-0.293%)	0.822 (0.796-0.853%)	0.265 (0.160-0.395%)	0.758 (0.734-0.787%)	66%
MCC type 3	0.268 (0.100-0.540%)	0.953 (0.943-0.967%)	0.250 (0.087-0.473%)	0.960 (0.950-0.974%)	91%
AEC type 1	0.789 (0.778-0.810%)	0.129 (0.043-0.293%)	0.874 (0.861-0.898%)	0.074 (0.025-0.168%)	71%
AEC type 2	0.087 (0.015-0.281%)	0.816 (0.810-0.835%)	0.043 (0.007-0.137%)	0.905 (0.898-0.925%)	75%
AEC type 3	0.000 (0.000-0.337%)	0.973 (0.973-0.983%)	0.000 (0.000-0.385%)	0.969 (0.969-0.980%)	94%

**MCC – mandibular condyle cortication, AEC – articular eminence cortication, SE – sensitivity, SP – specificity, PPV – predictive positive value, NPV – negative predictive value, AC – accuracy (overall fraction correct), CI – confidence interval*

than the positive predictive values in detecting all osseous changes.

Sensitivity of panoramic radiography in detecting MCC type 1 and AEC type 1 was higher than sensitivity of detecting other types. Accuracy of panoramic radiography in detecting MCC type 3 and AEC type 3 was over 90% (Table 4).

DISCUSSION

In patients with TMDs, osteoarthritic changes can be seen in TMJ components [4]. Osseous changes in temporomandibular joint disorders are more common in females than in males [4, 21, 22], which may be due to estrogen, progesterone, and relaxin hormones differences [23, 24]. Estrogen and relaxin are believed to play a role in TMJ degeneration by enhancing the production of tissue-degrading enzymes from the matrix metalloproteinase family in TMJ fibrocartilage [24]. The majority of patients with TMDs, who met the inclusion criteria of the current study were females (71.6%). Here, osseous changes in the mandibular condyle in patients with TMD were evaluated both on panoramic radiographs and CBCT images. Similar to previous studies, flattening and erosion were most common in the mandibular condyle [9, 21, 22, 25].

Panoramic radiographs taken during a dental examination can provide a general impression of the TMJ. However, their sensitivity in evaluating changes in the condyle is low due to structural distortion, not showing the entire joint surface of the TMJ, and overlapping the surrounding bone structures, such as the zygomatic process [26, 27]. Because of these superimpositions, it was thought that erosion in the cortical layer on panoramic radiography images would be less noticeable than flattening.

In adults, cortication of bony surfaces of the temporomandibular joint is not seen before approximately 18 years of age [28]. Bayrak *et al.* [29] reported that the left and right condyle cortication types of the same person may be different, and that the cortication of the mandible condyle in males is completed later than in females. There are studies showing that the level of mandibular condyle cortication increases with growing age [19, 29, 30]. Yalcın *et al.* [19] evaluated the MCC and AEC according to age on CBCT images, and found that mostly type 1 cortication was observed in the mandibular condyle, and mostly type 2 cortication was observed in the articular eminence. In the present study, cortication types were evaluated from both panoramic radiographs and CBCT images of patients over 18 years of age with TMDs. In both imaging techniques, mostly type 1 cortication was observed in both MCC and AEC. Considering the increase of cortication with age, this result was deemed normal. According to the results of the study, it can be said that the mandibular condyle and articular eminence cortication do not change when compared with the surrounding tissues in patients with TMDs. In future studies, MCC and AEC can be compared in different age groups, and in both healthy and TMDs patients.

In previous studies, CBCT has been shown to provide reliable and precise evaluation of TMJ [13, 31, 32]. Hilgers *et al.* [13] reported that CBCT images allow for reproducible and accurate measurement in TMJ. Honda *et al.* [31] showed CBCT as an alternative to helical CT, with its less cost and less effective radiation dose while diagnosing osseous changes in the mandibular condyle. Like in the present research, many studies have considered CBCT the gold standard when investigating the accuracy of panoramic radiography in TMJ evaluation [10, 22, 33].

In a study, Hedge *et al.* [34] simulated osseous lesions and investigated the diagnostic accuracy of PR; they found high specificity (100%) but low sensitivity (24.14%) values. In a study investigating the diagnostic accuracy of panoramic radiography where CBCT was considered the gold standard, the sensitivity and specificity values for flattening were found to be ranging 0.33-0.35 and 0.77-0.80, respectively. In the same study, sensitivity for osteophytes was reported between 0.05 and 0.08, and specificity as 0.97-1.00 [10]. According to a meta-analysis, the highest specificity value of PR for osseous changes in the mandibular condyle was for osteophytes, and the highest sensitivity value was for flattening [35]. In the current study, the results regarding the accuracy of panoramic radiography in identifying mandibular condyle osseous changes are generally similar to other studies. Based on previous research, we can say that due to the low sensitivity, panoramic radiography presents a weak potential as a screening tool for detecting mandibular condyle osseous changes. Here, the sensitivity of PR was found to be high in determining type 1 cortication, which represents the cortical border of the mandibular condyle and articular eminence being similar to or higher than the surrounding tissues. However, PR specificity values were higher than sensitivity ones in detecting type 2 and type 3 cortications. This once again proved that PR cannot produce a clear answer about cortication due to overlapping of surrounding structures. We should keep in mind that the high accuracy of PR in determining type 2 and type 3 cortications mentioned in the results section, is due to the excess of true negative responses.

A limitation of this retrospective study was that the diagnostic criteria for temporomandibular disorders (DC/TMD) were not applied to select patients. It would be appropriate to use DC/TMD to standardize patients in future research. The current study focused exclusively on patients with TMDs; future research can achieve comparative results by including both healthy individuals and patients with TMDs.

CONCLUSIONS

Flattening and erosion of the mandibular condyle are frequently observed in patients with TMDs. The mandibular condyle cortication and articular eminence cortication of patients with TMDs are often seen at the same or higher intensity than the surrounding structures on panoramic radiographs and CBCT images. Panoramic radiography may be insufficient to evaluate the mandibular condyle osseous changes and cortication of the temporomandibular joint. Using three-dimensional imaging methods, such as CBCT, may be necessary since CBCT allows for detailed examination of TMJ bone structures in 3 dimensions in axial, coronal, and sagittal sections.

DISCLOSURES

1. Institutional review board statement: The study was approved by the Non-Invasive Clinical Research Ethics Committee on Human Research of the Aydın Adnan Menderes University Faculty of Medicine, with approval number: 2020/31.
2. Assistance with the article: None.
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