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ORIGINAL ARTICLE

Accuracy of the detection of simulated condylar lesions on panoramic radiography and cone-beam computed tomography

Swathi Mani, Shubhasini Raghavan, Praveen Birur, Shubha Gurudath, G. Keerthi

Department of Oral Medicine and Radiology, KLE Society's Institute of Dental Sciences, #20, Yeshwanthpur Suburb, Bengaluru - 560 022, Karnataka, India

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Correspondence:
Dr. Shubhasini Raghavan, Department of Oral Medicine and Radiology, KLE Society's Institute of Dental Sciences, No. 20, Yeshwanthpur Suburb, Bengaluru – 560 022, Karnataka, India. Phone: +91-8023474137. Fax: 080-23474305
E-mail: subhashiniar@gmail.com.

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Abstract

Background: Degenerative temporomandibular joint (TMJ) disease is characterized by destruction of the articular surface of mandibular condyle.
Aims and Objectives: The aim of the present study was to assess the smallest lesion on mandibular condyle that could be detected on panoramic radiograph compared to cone-beam computed tomography (CBCT).
Materials and Methods: A total of 15 dry human mandibles were included in the study. Three surgical carbide drill bits of diameters 1.8 mm, 2.3 mm, and 4.5 mm length were used to drill holes on anterior, posterior, lateral, medial, and superior surfaces of the condyles. Panoramic and CBCT images were obtained and evaluated by two observers to detect lesions. Interobserver variability was obtained by the application of Cohen's kappa coefficient statistical measure.
Results: On panoramic images, kappa value showed fair (0.324), moderate (0.537), and substantial agreement (0.667) for small, shallow, and deeper lesion on condyle, respectively. 16.6% of small, 43.3% of shallow, and 46.3% of deeper lesions were visualized on panoramic images compared to CBCT images. These lesions were predominantly on the superior surface of the condyle.
Conclusion: Panoramic radiography can be used to detect lesions on the superior surface of the condyle of more than 2.3 mm diameter or more than 4.5 mm depth. Additional imaging modality such as CBCT is recommended for TMJ degenerative disorders.

Introduction

Temporomandibular disorders (TMD) refer to a set of conditions that affect the masticatory muscles and/or the temporomandibular joint (TMJ). It constitutes a complex set of specific entities with a reported prevalence of 5–12%.[1] Degenerative TMJ disease is characterized by destruction of the articular surface of mandibular condyle. As the disease gradually progresses, subarticular and cortical bone layers are resorbed, resulting in erosion and radiographic signs such as osteophyte formation, deformity, and marginal proliferation.[1]

The primary assessment of TMD is based on a clinical examination of the masticatory system. However, clinical examination alone is insufficient to fully assess the osseous and soft tissue components of the TMJ, and thus, imaging is used to augment the diagnostic process.[2] Consequently, several imaging modalities are used to verify the clinical findings.[3]

Cone-beam computed tomography (CBCT) is considered as imaging technique of choice for TMJ pathology and to detect mandibular condylar changes such as erosion, flattening, osteophytes, resorption, hypoplasia, and sclerosis.[4] CBCT images provide superior reliability and greater accuracy than corrected angle linear tomography and TMJ panoramic projections in the detection of condylar cortical erosion. Hussain *et al.* concluded that CBCT can provide high sensitivity, specificity, and diagnostic accuracy for the assessment of mandibular condyle.[5]

Panoramic radiographs are an excellent screening tool to detect bony degenerative changes and are useful in evaluating gross TMJ osseous pathology. The technique is simple and relatively inexpensive. Extensive erosions and large osteophytes in the TMJ can be identified with panoramic imaging. However, panoramic radiographs suffer from significant superimposition of the overlying structures, which compromise their ability to detect pathological TMJ changes. Despite their limitations and controversy in assessment of TMJ, they are considered appropriate for initial diagnosis.[6]

The present study was conducted to assess the size of smallest lesion on mandibular condyle that can be detected on panoramic radiograph.

Materials and Methods

The objective of the study was to evaluate and compare simulated lesions on dry human mandibular condyles that can be detected on panoramic radiograph and CBCT images. Ethical clearance was obtained to conduct the *in vitro*, cross-sectional study, from the institutional ethics committee. 25 dry human mandibles, which were unbroken, intact, and complete, were included in the study. Damaged, mutilated, and deformed mandibles were excluded from the study.

Materials used

Each dry human mandible was numbered by direct inspection. Surgical carbide drill bits (SS White 06, SS White 08, and SS White 702), micromotor, and handpiece were used to drill holes onto the surface of the mandibular condyle to simulate erosive lesions. The surface of mandibular condyle was divided into superior, anterior, posterior, medial, and lateral poles. 10 sites of each surface were chosen in a random manner.

Methods

Using small round drill bit (#06, diameter of bur: 1.8 mm), small holes were drilled onto specified mandibular condylar surface, to create simulated lesion, after which the mandible was submitted for panoramic radiography followed by CBCT. The first set of panoramic and CBCT images was obtained (set 1). Existing hole on the same condyle surface was enlarged, using round drill bit of diameter 2.3 mm (#08) and submitted for panoramic radiography followed by CBCT to obtain the second set of images (set 2). Cylindrical drill bit of length 4.5 mm (#702) was used to drill deeper into the existing hole, and the condyles were submitted for panoramic radiography followed by CBCT again to obtain the third set of images (set 3). The same holes were enlarged in subsequent steps to eliminate any chance of superimposition of different lesions on panoramic radiography. The purpose of using three different sized drill bits was to determine whether small (drill bit #06), wider (drill bit #08), or deeper (drill bit #702) lesion can be detected on panoramic radiography in comparison to CBCT images.

Image acquisition protocol

Kodak 9300 unit machine was used to produce panoramic and CBCT images. Kodak Document Imaging software was used to obtain panoramic radiographs. The image acquisition protocol was 50 kVp, 2 mA current, and exposure time 16 s. The images were stored in the JPEG format. CBCT acquisition protocol that was used was multiplanar reformation (MPR) - axial, coronal, and sagittal slices, with 1 mm slice thickness, voxel thickness of 180 μ, field of view 10 cm × 8 cm, 4 mA current, 60 kVp, and exposure time of 16 s. The software used for viewing CBCT images was CS 3D Imaging Software.

Images obtained

For every condylar surface, three panoramic radiographs and three CBCT images were taken. A total of 75 panoramic radiographs and 75 CBCT images were obtained (25 mandibles × 3 panoramic/CBCT imaging). These radiographic data were evaluated by two maxillofacial radiologists for any detectable lesion on the mandibular condyles on panoramic radiographs and CBCT images. The panoramic images were viewed in JPEG format. The CBCT images were viewed using CS 3D imaging software for CBCT images.

Assessment of the images

The images were observed by the two observers individually. The observers were blinded as to which surface of the condyles had the simulated lesion; however, they were not blinded for the three consecutive set of images (set 1, set 2, and set 3). The observers were provided with laptop mouse while viewing CBCT images and were free to scroll through the images in all planes. The observers recorded as "Yes" if there was any detectable lesion on the condyles and recorded "No" if there was no detectable lesion on the condyle. The observations for panoramic image were recorded for the right and left condyle [Figure 1], and for the CBCT images, observations were recorded for each surface of the condyle (anterior, posterior, medial, lateral, and superior) and for each plane of the image (axial, coronal, and sagittal) [Figures 2 and 3].

Statistical analysis

Statistical evaluation of interobserver variability, by application of Cohen's kappa coefficient statistical measure, was done to evaluate the percentage of agreement and degree of accuracy of panoramic radiographs in detecting mandibular condylar lesions by observer's examination.

Results

On panoramic images, observations of kappa value show fair (0.324), moderate (0.537), and substantial agreement (0.667) for set 1, set 2, and set 3, respectively. The interobserver agreeability was statistically significant for the set 2 ($P = 0.003$) and set 3 ($P < 0.001$) panoramic images [Table 1].

The interobserver agreeability was statistically significant in all the three sets of CBCT images of condyles ($P < 0.001$) [Table 2]. The highest agreement was found on axial and sagittal sections for lesions on anterior and posterior surfaces; axial and coronal surfaces for lesions on medial and lateral surfaces; and on sagittal and coronal surfaces for lesions on the superior surface.

Discussion

The craniomandibular articulation is a complex synovial system composed of two TMJ together with their articular ligaments and masticatory muscles. It is structurally the most complex synovial system in the body. In conventional radiographs, TMJ imaging is very challenging because the bony components are small and superimposition from the base of the skull often results in a lack of clear delineation of the joint.[1,7]

The appearance of mandibular condyle varies greatly among different age groups and individuals. Mandibular condyle may be categorized into five basic types, flattened, convex, angled, rounded, and concave. Morphological changes of condyle occur due to developmental variations, remodeling, various diseases, trauma, endocrine disturbances, and radiation therapy.[8,9]

TMD is an umbrella term under which multiple disorders are grouped. TMD has an estimated prevalence of 5–12%. Most of the patients with TMD are young adults aged between 20 and 40 years, and more commonly, females.[10] Early intervention can reduce the severity of disease. TMJ osteoarthritis represents a destructive process in which the bony surfaces of condyle and fossa become altered. Osseous changes involving the condyle and temporal bone occur as sequel of disk displacement, frequently with long-standing disk displacement without reduction.[11] Rheumatoid arthritis is an inflammation of synovial membranes, leading to several osseous changes. It can cause painful symptoms of joint and surrounding structures and cause destruction of the temporomandibular articular surfaces if not evaluated and treated in time.[7]

The primary assessment of TMD is based on a clinical examination of the TMJ and masticatory system. However, clinical diagnoses are unreliable with respect to the status of the TMJ. Panoramic radiography has been proposed for the initial assessment of TMJ. Although usefulness of panoramic radiograph in the assessment of the TMJ is controversial, it is useful in evaluating gross TMJ osseous pathology.[1]

In the TMJ, the presence of erosion is a radiographic clue that an active degenerative disease process may be occurring, whereas the presence of osteophytes is an indication that the condyle is adapting, or has adapted, to degenerative changes produced in the past.[12] To be able to clearly identify the presence of erosion

Table 1: Interobserver agreement on panoramic images

Set	OPG-observer 1	OPG-observer 2		Total	Kappa value	*P* value
		Yes	No			
Set 1	Yes	2	11	13	−0.324	0.064
	No	18	18	37		
	Total	20	30	50		
Set 2	Yes	19	3	22	0.537	0.003
	No	8	20	28		
	Total	27	23	50		
Set 3	Yes	20	5	25	0.667	<0.001
	No	3	22	25		
	Total	23	27	50		

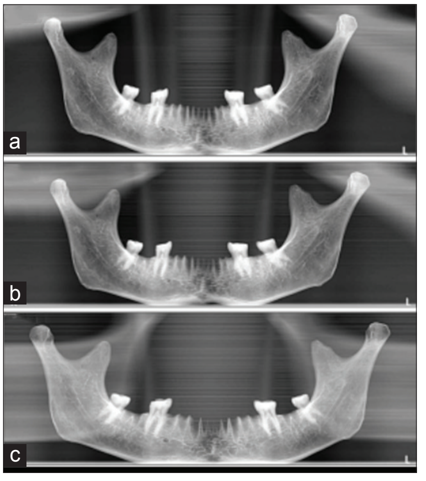

Figure 1: Panoramic radiograph of mandible having lesions on anterior surface on the right side and lateral surface of the left side. (a) Set 1, (b) Set 2, and (c) Set 3

Table 2: Interobserver agreement on different sections of CBCT

Simulated lesion	Plane	Set 1			Set 2			Set 3		
		Axial	Coronal	Sagittal	Axial	Coronal	Sagittal	Axial	Coronal	Sagittal
Posterior surface	Kappa	1.000	0.667	0.841	1.000	0.842	1.000	1.000	0.754	1.000
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Anterior surface	Kappa	1.000	0.918	1.000	1.000	0.918	0.923	1.000	0.842	1.000
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Medial surface	Kappa	0.842	0.923	0.471	1.000	0.923	0.842	0.923	1.000	0.923
	P value	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lateral surface	Kappa	1.000	1.000	0.842	0.923	1.000	0.923	1.000	1.000	0.918
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Superior surface	Kappa	0.923	0.923	1.000	1.000	1.000	1.000	0.923	1.000	0.918
	P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

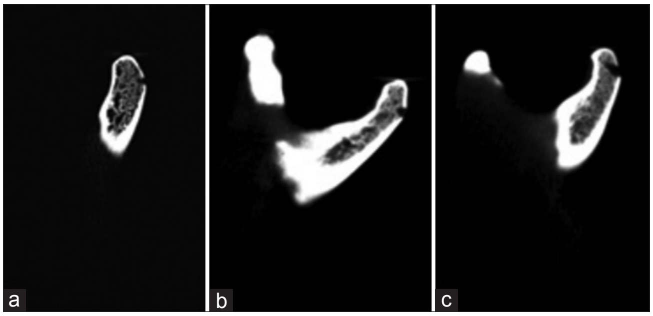

Figure 2: Cone-beam computed tomographic images of a condyle showing simulated lesions on the posterior surface on sagittal sections. (a) Set 1, (b) Set 2, and (c) Set 3

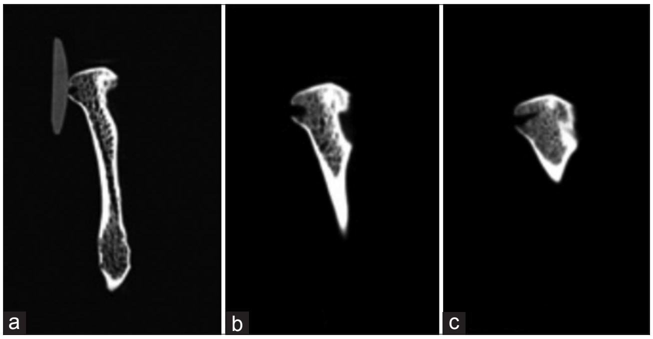

Figure 3: Cone-beam computed tomographic images of a condyle showing simulated lesions on the lateral surface on coronal sections. (a) Set 1, (b) Set 2, and (c) Set 3

and osteophytes and accurately diagnose osseous morphology in patients with TMD, an unobstructed image of the joint and surrounding structures is required.[12]

The most commonly involved condylar surface in TMJ osteoarthritis is the anterior aspect. Osteoarthritic change is more frequently observed in area of anterosuperior part of the mandibular condyle which can be attributed to the close relationship between condylar surface and loading during joint function. Osteophytes are mainly seen on the medial aspect of the condyles. In patients with rheumatoid arthritis, the superior aspect of condyle shows radiological involvement more often.[9]

The technique of panoramic radiography is simple and relatively inexpensive; however, it has several limitations that minimize its value for TMJ assessment. The condylar head and the interarticular space are not depicted clearly due to superimposition of surrounding structures and the oblique projection of the joint.[13] Masood *et al.* suggested that only extensive erosions and large osteophytes in the TMJ can be identified with panoramic imaging.[2]

As the structures on CBCT images can be viewed in multiplanar sections such as anatomic sagittal, coronal, and axial planes, TMJ visualization is easier. The image volume can be reconstructed in planes parallel and perpendicular to the long axis of the condyle instead of true anatomic coronal and sagittal planes. These reconstructed sections allow better evaluation of the condyle within the glenoid fossa.[12]

We simulated osseous erosive lesions on the condyles by drilling holes on different surfaces of the condyle in a random manner, ensuring 10 surfaces for each drill bit. This pattern was to simulate small (bur diameter of 1.8 mm), shallow (bur diameter of 2.3 mm), and deeper (bur length of 4.5 mm) lesions of the condyles. We planned to visualize lesions on all surfaces to determine accuracy of panoramic images in comparison with CBCT.

In our study, the observation of panoramic images by both observers showed fair (kappa value of 0.324), moderate (kappa value of 0.537), and substantial agreement (kappa value of 0.667) for set 1, set 2, and set 3, respectively, between the two observers. The interobserver agreeability is statistically significant for the set 2 ($P = 0.003$) and set 3 ($P < 0.001$) panoramic images. It implies that visibility of deeper lesions was more easy to interpret when compared to small or shallow lesions. The observers identified very few panoramic images that had condylar lesions in the set 1 image. This implies that small and shallow erosive lesions <1.8 mm in diameter are difficult to visualize on panoramic radiographs.

In the set 2 and set 3 panoramic images, more number of lesions were identified on the superior surface of the condyle. This implies that condylar lesions that affect the superior surface can be visualized on panoramic radiographs. The erosive changes on the superior condylar surface more than 2.3 mm diameter or more than 4.5 mm depth can be visualized on panoramic radiographs.

A few studies have compared the diagnostic accuracy of panoramic and CBCT images. The studies concluded that

CBCT images provided superior reliability and greater accuracy than panoramic radiographs in the detection of condyle height or condylar cortical erosion, which is similar to the findings of the present study.[4,14,15]

CBCT may be considered a valuable imaging tool for the identification of simulated bone lesions. The cross-sectional slices and axial or MPR images are highly accurate in the identification of simulated mandibular bone lesions proving to be useful for bone lesion assessment. The accuracy, sensitivity, and specificity of CBCT are greater than other studied methods in the detection of simulated defects with different sizes.[16]

In our study, nearly 16.6% of the set 1 simulated lesions, 43.3% of set 2 simulated lesions, and 46.3% of set 3 simulated lesions were visualized on panoramic images, in comparison to CBCT images. This implies that panoramic radiographs are fairly reliable in the detection of broad, shallow erosive lesions and also deeper osteolytic lesions. However, small erosions of <1.8 mm diameter may be difficult to detect.

Simulated osteophytic lesions with bone chips and drilled erosions of the condyles show well-defined margins and sharper edges than would normally be observed in clinical situations. Since the simulated lesions are not an exact representation of the actual disease pathosis, the diagnostic accuracy of the imaging modalities in certain *in vitro* studies and may be somewhat higher compared with an *in vivo* assessment.[2] This could be one of the limitations of our study. Simulated bone lesions have been widely used to compare radiological techniques for bone observation. In these *in vitro* experiments, water was added to produce an environment closer to bone *in vivo* and to attenuate the X-ray beam. Since the X-rays were not attenuated in our study, it could have resulted in more accurate identification of the defects. This could potentially be another limitation of our study.[16]

Conclusion

The aim of the study was to detect smallest simulated mandibular condylar lesion on panoramic images in comparison with CBCT images. We conclude that the detection of simulated lesions on CBCT images is substantially better than on panoramic images. Panoramic radiography can be used to detect lesions on the superior surface of the condyle of more than 2.3 mm diameter or >4.5 mm depth.

The present study was an *in vitro*, cross-sectional study, conducted on dry human mandibles with simulated lesions on condyles. Future research should be conducted on patients with signs and symptoms of TMD with larger sample size, to emphasize the diagnostic accuracy of panoramic images of TMJ in comparison with CBCT images.

Clinical significance

Panoramic radiographs can be used as the initial imaging modality for TMJ osteoarthritis. Additional imaging modality such as CBCT is recommended for TMJ degenerative disorders as it has statistically significant superiority than panoramic imaging in the detection of erosive lesions with smaller sizes.

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