Measurement accuracy of temporomandibular joint space in Promax 3-dimensional cone-beam computerized tomography images

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Objective. The aim of this study was to evaluate and compare the measurement accuracy of the temporomandibular joint (TMJ) space in the Promax 3D cone-beam computerized tomography (CBCT) images scanned with 2 different dental protocols.

Study Design. TMJ space impression models were made according to the occlusion. Forty joints were scanned with the standard and the large view protocol of the Promax 3D CBCT scanner. Two observers measured the joint spaces 3 times on both radiographs and the photocopies of the impression models.

Results. A total of 120 CBCT images were measured. There were no significant differences among the actual joint spaces and the CBCT measurements performed with the 2 scanning protocols (P = .305). The inter- and intraobserver variabilities were not significant.

Conclusions. The 2 scanning protocols provided by the Promax 3D CBCT scanner were reliable and similar for recording the TMJ space. (Oral Surg Oral Med Oral Pathol Oral Radiol 2012;114:112-117)

The relative position of a mandibular condyle to the associated glenoid fossa is often evaluated for patients with suspected temporomandibular joint disorders (TMD) and other related temporomandibular joint (TMJ) diseases or clinical conditions. However, the condylar position in the fossa is not accessible clinically. Therefore, varying types of radiographic modalities have been used for examination of the TMJ, including plain radiography, computerized tomography (CT), magnetic resonance imaging (MRI), and the recently developed cone-beam computerized tomography (CBCT).[1-8]

As with CT and MRI, CBCT can provide multiplanar and 3-dimensional (3D) images of the condyle and its surrounding structures to facilitate analysis and diagnosis of bone morphologic features, joint space, and dynamic function.[9] There is an increasing demand for CBCT because it is capable of providing accurate submillimeter-resolution images at lower doses and lower costs compared with multislice CT.[9]

With the wide use of CBCT, diagnostic benefit and dose detriment tradeoffs are important considerations when performing a CBCT examination. A recent study has revealed that when applying different dental protocols, the effective radiation doses of the CBCT scanner Promax 3D (Planmeca, Helsinki, Finland) are quite different.[10] For example, when it is scanned with a full field of view (FOV) of 8 × 8 cm and with the largest patient size at a normal resolution, a protocol that is called the standard view hereafter, the effective radiation dose is 298 μSv; however, when it is scanned with the large view protocol that is used to combine 3 volumes of full FOV horizontally by stitching, the effective radiation dose is 87 μSv, only about one-third that of the standard view protocol. This low dose is primarily contributed by the restriction of the low-dose settings by the manufacturer.

Should both sides of the TMJs be examined with a single scan of the large view protocol, the effective radiation dose will be considerably reduced. However, in theory, a low dose results in low image quality because of the increasing image noise. Therefore, the purpose of the present study was to evaluate and compare the measurement accuracy of the TMJ space in the Promax 3D CBCT images scanned with the standard and the large view protocols, respectively.

Statement of Clinical Relevance

Radiation dose to the patient is a critical concern. This study confirms the selection of Promax 3D CBCT protocols for patient radiation dose reduction without affecting diagnostic quality.

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Fig. 1. Orthodontic ligature wires were wrapped over the condylar head and neck surface within planes perpendicular to the horizontal axis of the condyle.

MATERIALS AND METHODS

Skulls

Forty joints in 20 dry human skulls were used. These skulls were supplied by Institute of Forensic Sciences, Ministry of Public Security, People's Republic of China. The 40 skull specimens were selected according to the following criteria:

1. Each dry skull specimen was undamaged and had no apparent evidence of joint pathology.
2. Dentition was sufficient to maintain stable intercuspal position and fixation of the jaws in centric occlusion for a unique relationship of condyle and fossa.

Owing to dry human skulls being used in the study, ethical approval by Institutional Review Board was not necessary.

TMJ space impression models

To document the position of joint space measurements, orthodontic ligature wire was wrapped over the condylar head and neck surface within the plane perpendicular to the horizontal axis of the condyle (Figure 1).[3] Middle, lateral, and medial thirds of the condyle were marked individually with 0.3-mm-thick wire. Wires were held in position with adhesive tape.

To document condylar position further, the TMJ spaces were recorded by autopolymerizing acrylic resin (Meliodent; Heraeus Kulzer, Hanau, Germany). This acrylic resin was mixed using a mixing ratio (powder to liquid) of 10:7 (w/w). About 5 minutes later, the mixture was put into both the glenoid fossas of 1 skull and the associated mandible was positioned to achieve its centric occlusion until the acrylic resin became rigid. Bone surfaces had been coated by separated liquid before making the record. The adhesive tape was used to ensure fixation of the mandible to the skull throughout the study.

CBCT images

The CBCT scanner used was the Promax 3D, which can provide different scanning protocols by the different combinations of patient size, volume size, and image resolutions.[10] The left and right TMJs were thus scanned by 2 of the protocols: the standard view and the large view. The exposure parameters for each scanning protocol examined in this study are presented in Table I. During the CBCT exposures, a 20-mm-thick water phantom was placed around the skull to simulate soft tissue (Figure 2).

Gold standard

The resin impression models were sectioned immediately after exposures at the plane of each ligature wire by straight handpiece (PM 1:1; Bien Air, Bienne, Switzerland) and diamond disk (order no. 112233; DFS-Diamon, Riedenburg, Germany). An example of the section impression model is shown in Figure 3. The sectioned resin impression models were photocopied (Aficio MP 2550B; Ricoh, Tokyo, Japan), and the narrowest anterior and posterior joint spaces were measured according to the method described by Pullinger and Hollender.[11] Two observers were employed to do the measurements 3 times on both the real impression model by digital caliper and their photocopies by ruler. There was no difference between the measurements on photocopies and impression models (Wilcoxon test: $P = .067$). This indicated that the measurements on the photocopies were comparable to those on the real impression models. The measurements obtained from the photocopies were therefore considered as the actual spaces between the glenoid fossas and condyles. Two observers individually measured all of the photocopies of the resin models, and there was no statistical differences between the measurements (Wilcoxon test: $P = .647$). The average measurements of the anterior and posterior distances by the 2 observers were calculated and used as a "gold standard" to evaluate the accuracy of measurements made in CBCT images.

Measurements in CBCT images

The CBCT images were displayed with the proprietary software (Planmeca Romexis Viewer; Planmeca) on a 17-inch flat panel monitor (L1750; Hewlett-Packard, Palo Alto, California) with 1,280 × 1,024 pixels. Slice thicknesses were 0.96 mm. The image reconstruction software and measuring tools are calibrated by the manufacturer for 1:1 measurement. In the sagittal view, the image was first arranged to the plane determined by a wire. Observers identified the narrowest anterior and

Table I. Exposure parameters for imaging temporomandibular joint

Protocol	*Patient size*	*Field of view (mm)*	*Voxel size (mm)*	*kV*	*mA*	*Exposure time (s)*
Standard view	Middle	80 × 80 × 80	0.32	84	12	12
Large view	Middle	150 × 110 × 80	0.32	84	6	8.5

Fig. 2. A 20-mm-thick water phantom was placed around the skull to simulate soft tissue during the CBCT exposures.

Fig. 3. A sectioned resin impression model of the temporomandibular joint space.

posterior joint spaces. The distance between the fossa and condyle was measured on the sagittal plane by the digital ruler of the software. Measurements were made using a computer mouse to position the 2-dimensional measurement tool cursor at one and then the other point of bone outlines of the fossa and condyle at the narrowest joint space positions. The length of the narrowest space distance was automatically calculated and displayed (Figure 4). The viewing took place in a room with dimmed lights. Two independent observers measured all distances, and each one repeated their measurements after ~1 week. All of the measurements were done in a blind and random manner.

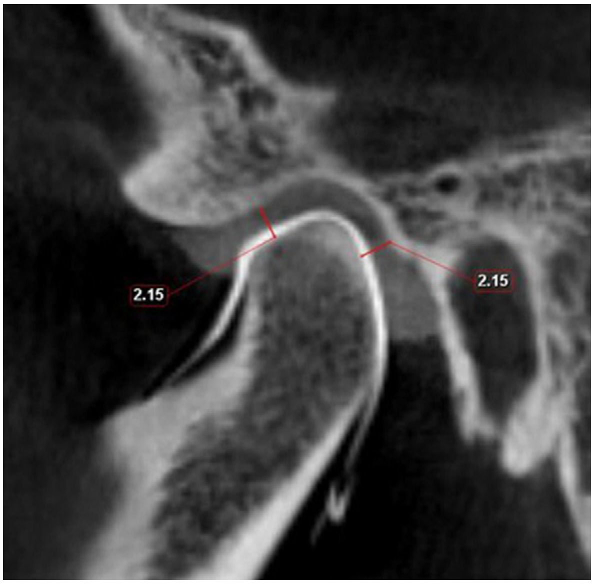

Fig. 4. Example of measurements on CBCT images.

Data analyses

All of the groups of measurements were not normally distributed. Therefore, Friedman test was used to analyze the differences among the actual joint spaces and the measurements in the CBCT images. The correlations of the TMJ space distances of 2 groups of CBCT images and actual joint space distances were analyzed by Spearman correlation coefficient. The deviation of the actual joint space distances and the radiographic measurement values was presented by scatter plot (Figures 5-7). Interobserver and intraobserver variability were analyzed by Wilcoxon test. A statistical difference was considered to exist when $P < .05$. Statistical analyses were performed using SPSS (v. 16.0).

RESULTS

A total of 120 CBCT images were measured at the level of lateral, central, and medial aspects of the 40 joints. There were no significant differences among the measurements of joint spaces in CBCT images and the actual joint spaces ($P = .305$). There was high correlation between the 3 groups (Table II). There were no significant differences between the observers ($P = .217$) or within the observers (observer 1: $P = .729$; observer 2: $P = .394$).

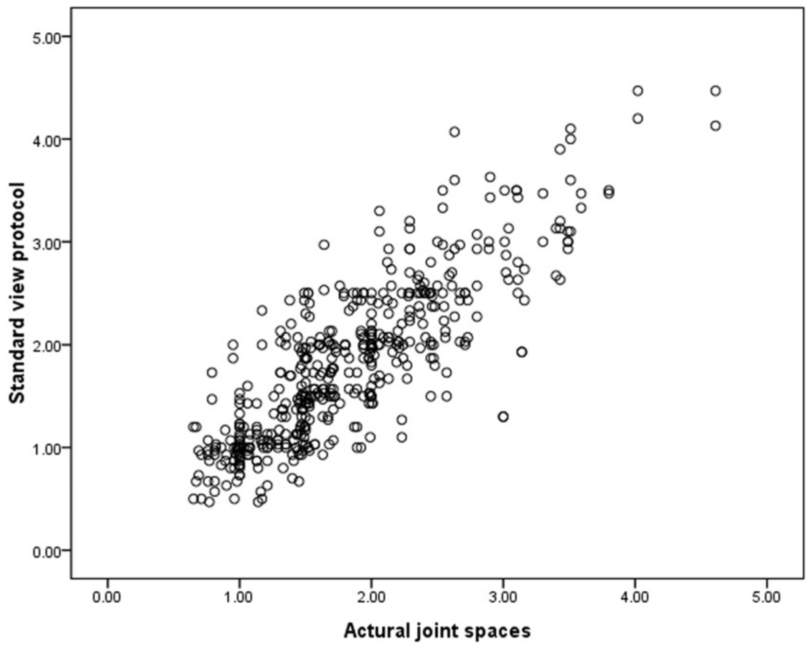

Fig. 5. Scatter plot of the actual joint spaces and the measurements in the CBCT images scanned by the standard view protocol.

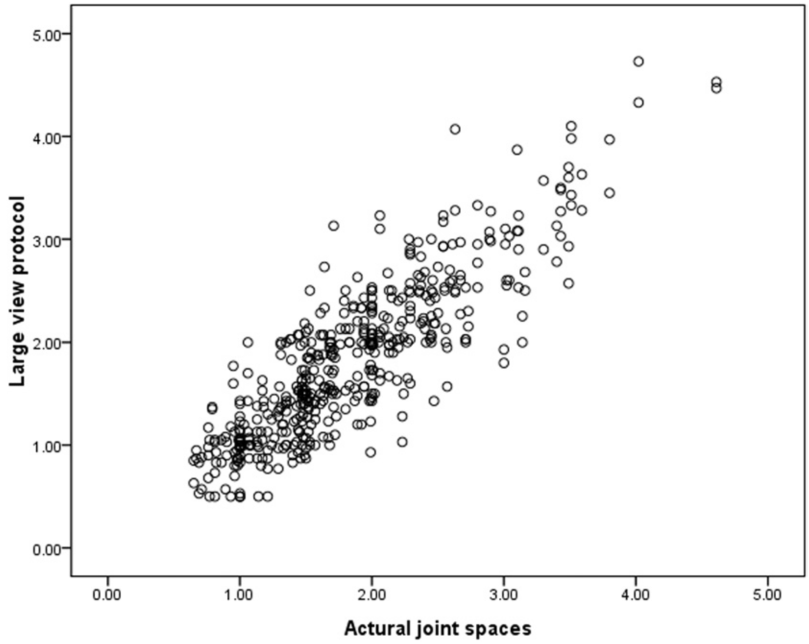

Fig. 6. Scatter plot of the actual joint spaces and the measurements in the CBCT images scanned by the large view protocol.

DISCUSSION

The present results showed that the measurement accuracy of TMJ space in CBCT images scanned with both standard and large view scanning protocols had high correlation with the actual joint spaces and there was no significant difference between the CBCT measurements performed with the 2 scanning protocols (large and standard views).

In the search of literature, we did not find a study performed in vitro for the evaluation of linear measurement accuracy of TMJ space in CBCT images. However, a few studies have been performed for the determination of optimal TMJ space in health human adults with CBCT images.[6,7] In one study, 5 different methods evaluating TMJ spaces were compared, and the results showed no significant differences.[6] The

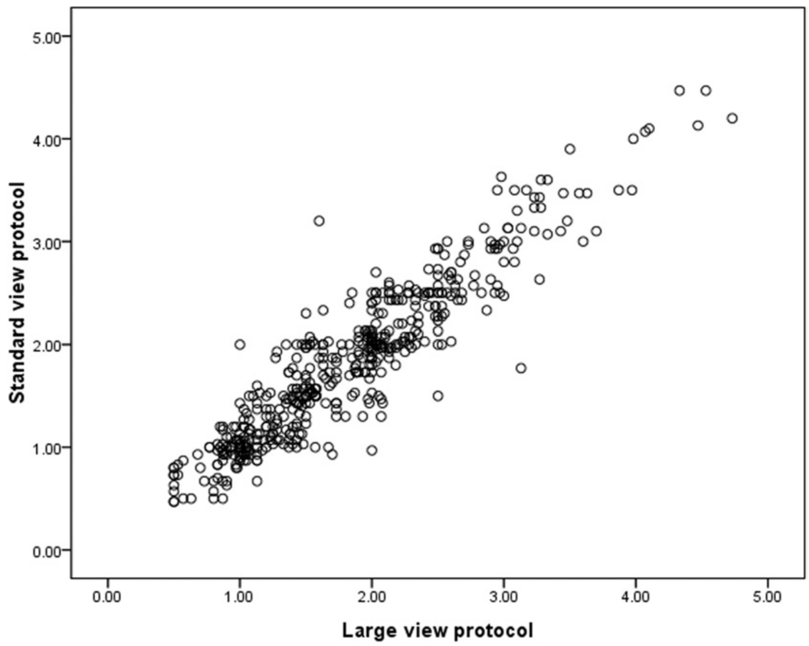

Fig. 7. Scatter plot of the measurements in the CBCT images scanned with the standard and the large view protocols.

Table II. Spearman correlation coefficient and *P* values for actual joint space and measurements performed with the 2 scanning protocols

	Standard view		*Large view*	
	Correlation coefficient	*P value*	*Correlation coefficient*	*P value*
Actual joint space	0.82	.000	0.851	.000
Standard view	—	—	0.918	.000

method used in the present study is the subjective determination of the narrowest space. This method was described by Pullinger and Hollender and has been proved to be effective.[3,11] It is a method still widely used in clinics today.

Other studies regarding linear measurement accuracy in CBCT images also showed promising results. These studies were mainly performed for the demand of orthodontic and orthognathic treatment, implant placement, periodontal bone evaluation, etc.[12–18] In the study conducted by Hilgers et al.,[18] the size of the condyle (height, width, and length) and intercondylar, TMJ-mandible, and mandibular spacial relationships were investigated with linear measurement in 25 dry human skulls scanned with the iCAT (Xoran Technologies, Ann Arbor, Michigan; Imaging Sciences International, Hatfield, Pennsylvania) CBCT scanner. The results demonstrated that no linear measurements made with iCAT images differed significantly from the anatomic truth.[18] Lascala et al.[17] evaluated the accuracy of the linear measurements in CBCT images in dentomaxillofacial as well as other cranial areas. They reported that the real distances measured on dry skulls were always greater than those obtained from the CBCT (NewTom 9000; Quantitative Radiology, Verona, Italy) images. However, these differences were only significant for measurements taken between structures at the skull base and not for other dentomaxillofacial structures.[17] In those studies, caliper measurements of anatomic landmarks on the surface of skulls served as actual distances.[14,15,17,18] In the present study, however, the TMJ space was difficult to measure directly, so we made the joint space impression. The impression recorded the unique relationship of condyle and fossa of the skull with a stable dentition.

A limitation of the present study was the use of the wires which were wrapped over the condyle for the determination of the measurement position. These wires that identified the lateral, central, and medial aspects of the joint tended to obscure the cortical outline of the condyle and possibly affected the precision and accuracy of the measurements taken from the radiographs. We did not find beam-hardening artifacts from the wires which would have further influenced the precision and accuracy of the measurements. This may be explained partly by the small diameter of the wire used and the elimination of the artifacts by the proprietary software of the Promax 3D.

In conclusion, Promax 3D CBCT images could accurately depict the TMJ space. Standard view and large view protocols of Promax 3D CBCT were reliable and comparable for TMJ space measurement. Considering that the large view protocol had a larger examination area and lower radiation dose, it should be recommended for the evaluation of condyle-fossa relationship in clinical practice.

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