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A new method for assessing the temporomandibular joint quantitatively by dental scan

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SUMMARY. **The objective of this study was to assess the applicability of a multiplanar reformatting program (dental scan) for delineation and quantitative evaluation of the temporomandibular joint (TMJ) in the sagittal and coronal planes using the data of axial computed tomography. The resulting images were compared with standardized linear tomograms and direct sagittal and frontal computed tomography. Standardized linear tomograms and computed tomography of the TMJ in axial, frontal and sagittal planes were obtained in 11 patients. The axial computed tomography slices were then reconstructed in oblique frontal and sagittal planes according to the horizontal condylar angle of the TMJ by dental scan software. For each patient and each of the three imaging methods, 14 measurements were undertaken and 24 qualitative characterizations were assessed.**

Axial computed tomograms in combination with their corresponding coronal and sagittal reconstructions were more accurate than conventional tomograms. Direct coronal and sagittal scans gave the most detailed images, but required additional radiation dose, time and cost.

Reconstructions of axial computed tomography slices of the TMJ using the dental scan software show several advantages over linear tomograms. They allow qualitative as well as quantitative evaluation of the TMJ.

INTRODUCTION

Progress in the management of diseases of the temporomandibular joint (TMJ) is closely related to a better aetiological understanding of the various conditions affecting this region as well as to improved diagnostic methods (*Laskin*, 1993). Since its introduction by Hounsfield more than 20 years ago (*Cormack*, 1964; *Hounsfield*, 1973) computed tomography (CT) has become an established routine method in the diagnosis of maxillofacial diseases. As many of the disorders of the TMJ present similar signs and symptoms (*Paesani* et al., 1992), information about reliability and validity of different imaging modalities is of the utmost value to the clinician when determining if the imaging can provide the desired additional information (*Westesson*, 1993).

In our clinic, linear tomograms were performed as a standard method for radiological evaluation of the TMJ. They can be used to assess the osseous structures as well as the condylar position (*Pharoah*, 1993). Conventional tomograms do not entirely provide lateral views of the joint and they are blurred by overlapping parts of the skull (*Kundert* and *Palla*, 1977).

Digital radiology has provided the physician with the ability to store, manipulate and quantitatively assess radiographic information (*Jeffcoat*, 1992). Since different views of the object can be visualized using the data of a single exposure, we might be able to obtain the necessary information with decreased radiation exposure. Furthermore, it is impossible for some patients to bend their necks sufficiently to obtain direct radiographs. This holds especially true for direct sagittal scanning. Therefore, the physician might ask for coronal and sagittal reconstructions of axial CT scans.

The purpose of this study was to evaluate the advantages and disadvantages of reconstructed images of axial CT scans of the TMJ using for the first time a custom-made dental scan software which is normally applied for the metric evaluation of the upper and the lower jaw before insertion of dental implants.

MATERIALS AND METHODS

Radiological equipment

Linear tomograms were performed with a tomograph type Ultracranio srl U-T (Isotopan, Sant'Angelo Romano, Italy) according to previous measurements of the condylar angle on Rundstroem IV radiographs. A cephalostat (*Engelke*, 1987) was used to ensure the reproducibility of the tomograms.

CT slices were obtained by an SR 7000 computed tomograph (Philips Medical Systems, Best, The Netherlands). Axial slices of 1.5 mm thickness were taken with 150 mA, 2 s, 120 kV and with a table increment of 1 mm (overlapping technique). Direct coronal and direct sagittal scans were performed in

the same manner, but the table increment was 1.5 mm (continuous technique). Coronal and sagittal reconstructions of the axial CT slices were obtained using dental scan software (by ISG Technologies, Toronto, Canada) on a GYROVIEW-workstation (Philips Medical Systems, Best, The Netherlands). To apply this program, one axial CT slice is chosen in which the physician indicates two points lying about 2 mm laterally/medially to the lateral/medial pole of the condyle respectively (Figs 1 and 2). Then, the software calculates the coronal plane connecting these two points. Four further frontal images are computed, 2 and 4 mm more anteriorly as well as 2 and 4 mm more posteriorly. In addition, perpendicular sagittal planes through the condyle are calculated every 2 mm between the two points initially indicated. In all, about 10 sagittal isometric images are created this way. The dental scan software calculates these frontal and sagittal images on a 1:1-scale, so that the user can perform direct measurements on the film (Figs. 3 and 4).

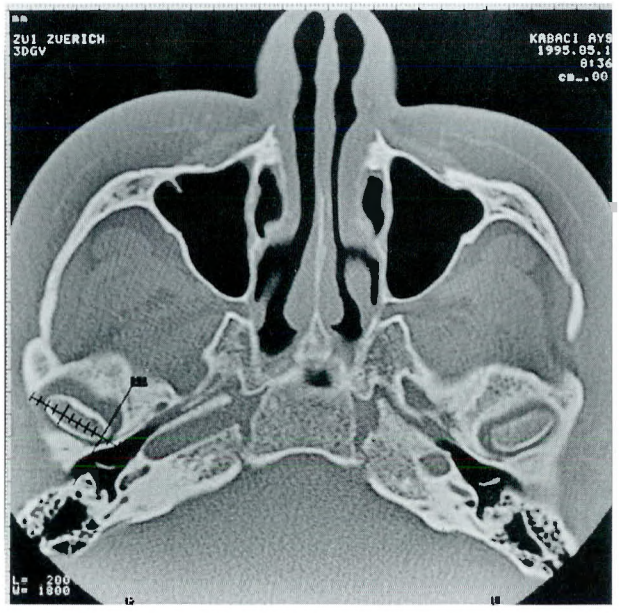


Fig. 1 – Axial CT scan with condylar plane. The line indicates the position of reconstructed sagittal dental scan slices which are perpendicular to the condylar plane.

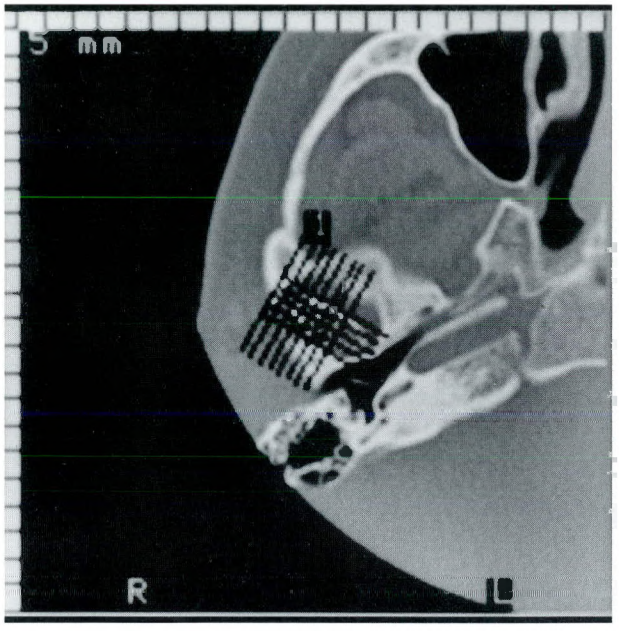


Fig. 2 – Detail of the CT scan of Figure 1 with 13 lines identifying the location of the oblique sagittal and frontal dental scan cuts.

Evaluation

For each patient and each of the three imaging methods, 14 measurements (Table 1) were taken. In the sagittal plane the joint cavity was divided into three parts: anterior, cranial and posterior. Then, the minimum and maximum distances between condyle and fossa were measured in all three parts. In this way, the width of the joint cavity was assessed. Furthermore, 24 qualitative characterizations (Table 2) were performed. All measurements were carried out directly on the CT films with a 0.5 mm ruler and then standardized each to the 5 cm reference scale on each film. As for the linear tomograms, the magnification was calculated and taken into account. The images were independently assessed by two physicians. The direct CT scans were considered to be the most exact method because the mean percentage difference between direct measurements on dried skulls and indirect methods of measurement on CT

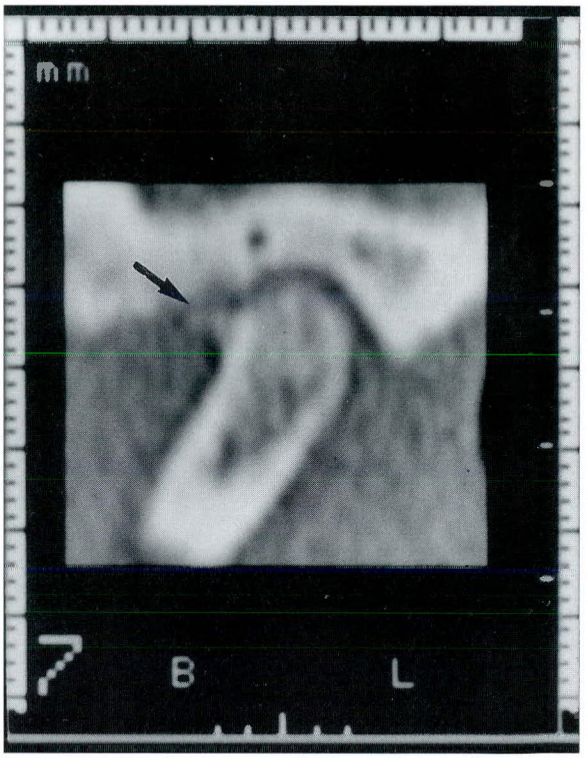
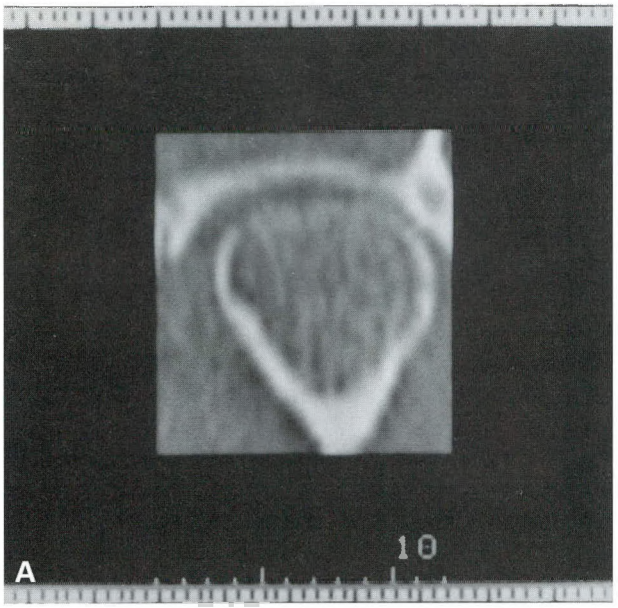


Fig. 3 – Sagittal reconstruction of axial CT scans: exostosis in the anterior part of the condyle (arrow), very small joint space (1.0 mm).



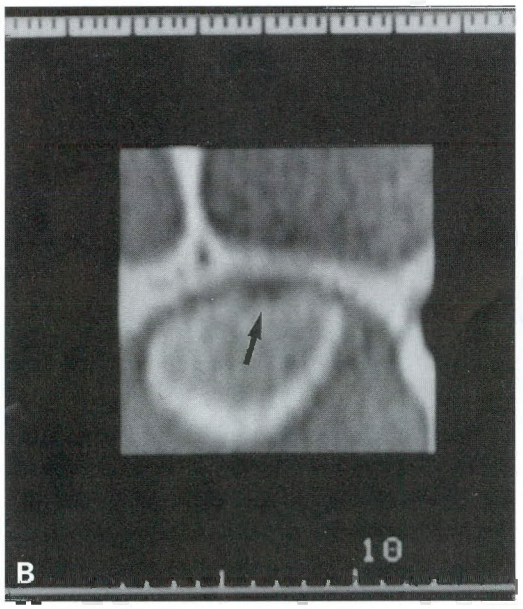


Fig. 4 – Coronal reconstructions of axial CT scans: (A) Representation of a condyle (18 year-old patient) without pathological signs. In this cut the joint space is smaller in the lateral part (1.0 mm) than in the cranial part (2.0 mm) and in the medial portion (2.5 mm). (B) Interruption of the cranial cortex of the condyle (arrow), small joint space (1.0 mm), no difference between lateral and medial part.

films was shown to be less than 1% (*Waitzman* et al., 1992).

Patients

Eleven patients (1 male, 10 female) with an average age of 30 years (range 18–43 years) were included in this study. The patients showed different clinical signs and symptoms, e.g. closed lock with or without pain, pain of unknown origin and friction murmur. They had been referred for investigation of osteoarthrotic changes in the TMJs.

RESULTS

The averaged results of the measurements (with standard deviation) in 11 patients are given in Table 1. All parameters for the three imaging methods are shown.

The average reading of the measurements was 3.1 mm. There were no significant differences in width between the anterior, cranial and posterior part of the joint space (Fig. 3). In the coronal cuts, there was a tendency towards a somewhat smaller lateral joint space compared with the medial part of the joint space (Fig. 4a).

It was assumed that the direct sagittal scans presented the exact distances. The overall measurement error was 1.4 mm (45%) for the linear tomograms, and 0.7 mm (23%) for the sagittal reconstructions of the axial CT slices (Table 2).

With respect to the qualitative findings, the incidence of error was 34.1% for the linear tomograms, and 15.9% for the sagittal dental scan reconstructions, assuming again that the direct sagittal scans show 100% of the pathological bony changes.

DISCUSSION

Although linear tomograms of the TMJ were considered to be a precise evaluation method (*Engelke* and *Colla*, 1991), computed tomography has been improved to such an extent, in respect of quality and

Table 1 – The average (standard deviation) of the distances (in mm) within the TMJ measured bilaterally on the films of three imaging methods

	Linear tomography	Reconstructed sagittal images of axial CT	Direct sagittal CT
Maximum sagittal diameter of the condyle	8.6 (±1.5)	8.0 (±1.3)	8.7 (±2.0)
Maximum width of the anterior joint cavity	3.0 (±1.3)	2.9 (±1.2)	2.9 (±1.5)
Minimum width of the anterior joint cavity	1.4 (±1.0)	1.0 (±0.6)	1.2 (±0.6)
Maximum width of the cranial joint cavity	3.0 (±1.1)	3.1 (±1.0)	3.3 (±0.8)
Minimum width of the cranial joint cavity	1.2 (±0.6)	0.9 (±0.5)	1.1 (±0.5)
Maximum width of the posterior joint cavity	3.0 (±0.8)	3.0 (±0.6)	3.2 (±1.1)
Minimum width of the posterior joint cavity	1.7 (±0.9)	1.5 (±0.8)	1.4 (±0.9)

Table 2 – Frequency of qualitative findings of the TMJ of three imaging methods (22 TMJs of 11 patients)

	Linear tomography	Reconstructed sagittal images of axial CT	Direct sagittal CT
Rough surface structure of the condyle	6 (27.3%)	8 (36.4%)	9 (40.9%)
Exostosis of the condyle	6 (27.3%)	7 (31.8%)	8 (36.4%)
Sclerotic changes in the condyle	5 (22.7%)	6 (27.3%)	7 (31.9%)
Interruption of the cortex of the condyle	4 (18.2%)	5 (22.7%)	6 (27.3%)
Subcortical cyst within the condyle	2 (9.1%)	5 (22.7%)	6 (27.3%)
Sclerotic changes in the glenoid fossa	3 (13.7%)	3 (13.7%)	4 (18.2%)
Interruption of the cortex of the glenoid fossa	3 (13.7%)	2 (9.1%)	3 (13.7%)
Calcified fragments within the joint cavity	0	1 (4.5%)	1 (4.5%)
Exostosis of the glenoid fossa	0	0	0
Subcortical cyst within the glenoid fossa	0	0	0
Demineralization of the glenoid fossa	0	0	0
Demineralization of the condyle	0	0	0
Total number of findings	29 (65.9%)	37 (84.1%)	44 (100.0%)*

* It is assumed that direct sagittal scans presented all pathological findings, i.e. 100%.

radiation exposure, that in our clinic CT is increasingly used. On the other hand, indications for conventional tomography have diminished. Both linear tomography and computed tomography were performed in the Clinic for Maxillofacial Imaging within the Department of Maxillofacial Surgery. This study showed that lateral linear tomograms are less precise than sagittal reconstructions of axial CT scans. Direct sagittal CT slices are even more accurate. However, there are some disadvantages of direct sagittal scanning: there is an increase in the radiation dose to the thyroid gland and to the eye lenses. In addition, some patients are not able to extend their necks sufficiently (*Dula* et al., 1994).

Bone structures are better visualized by multiplanar CT than by conventional tomography (*Larheim* and *Kolbenstvedt*, 1990). Oblique sagittal images which are perpendicular to the line between medial and lateral pole of the condyle (i.e. the condylar plane) demonstrate the anatomy better than straight sagittal planes. When direct sagittal scans are performed, it is sometimes difficult even for the experienced maxillofacial radiologist to locate this plane precisely. This holds especially true when movement artefacts due to the patient's discomfort during sagittal scanning occur. During axial scanning, the patient is in a comfortable supine position and therefore rarely moves during the examination. Furthermore, it is very simple to determine the oblique sagittal planes with the dental scan software in a way that they are perpendicular to the condylar plane. In this way all measurements of the joint cavity are also defined exactly. The method presented here allows the medial and lateral pole of the condyle and the surrounding tissues to be assessed in frontal reconstructions as well.

The most notable inconvenience of frontal and sagittal reconstructions of axial CT scans is the poor vertical resolution of about 1 mm. It is foreseeable that this problem will be solved in the future with thinner CT slices, smaller table advancement and improved software packages.

With respect to the diagnosis of internal derangement, especially disc pathology, magnetic resonance imaging has proven to be superior to CT scanning (*Larheim*, 1995).

As for the interpretation of the examinations, there are still some difficulties to be overcome. A normal condyle position has not yet been defined. In volunteers with normal joints and with normal superior disc position, the condyles were almost randomly distributed in anterior, centric and posterior positions in the glenoid fossa (*Ren* et al., 1995). A further issue is the reported increasingly larger condylar angle in TMJs with more advanced pathological changes related to internal derangement and degenerative disease (*Westesson* et al., 1991). Is the larger condylar angle the cause or the consequence of TMJ disorders? Longitudinal investigations on that question should be carried out.

With respect to the future, there is a call for comprehensive assessment of the TMJ along with increased patient throughput and reduced costs (*Katzberg*, 1991).

In conclusion, we found in this study that reconstructions of axial CT slices of the TMJ using the dental scan software show several advantages over linear tomograms. They allow qualitative as well as quantitative evaluation of the temporomandibular joint. The quantitative evaluation by dental scan is accomplished rapidly because images are given on a 1 : 1-scale. In comparison with direct coronal and sagittal scans, they show reduced radiation dose, time and cost.

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