Ultrasonic imaging of the temporomandibular joint: A clinical trial for diagnosis of internal derangement

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(Received 30 January and accepted 1 May 1998)

Abstract: Kinematic imaging of the temporomandibular joint (TMJ) was applied for diagnosis of TMJ disorders using an ultrasonic diagnostic imaging system. Patients with a normal TMJ (male, 24 y 1 mon) and a symptomatic TMJ (female, 20 y 2 mon) were selected for imaging. The transducer must be placed in a specific location in order to propagate ultrasound through soft tissue because it is difficult for ultrasound to penetrate bone such as the condyle and the eminence. Therefore the ultrasonic images were not taken in sagittal cross-section, as is the case with magnetic resonance images. The ultrasonic diagnostic imaging system showed a transverse cross-section and no hard tissue images. It was difficult to become accustomed to these images, thus making it difficult to find differences between the normal TMJ and the symptomatic TMJ on the basis of static ultrasonic images alone. However a difference between the kinematic images of the normal and symptomatic TMJ was observed during jaw opening. Irregularity in the striated pattern of the soft tissue surrounding the condyle was observed in the image of the symptomatic TMJ. In order to make a precise diagnosis using ultrasonic imaging, it may be useful to understand the kinematics of the soft tissue surrounding the TMJ during jaw opening and closing. (J. Oral Sci. 40, 89-94, 1998)

Key words: TMJ; articular disc; ultrasonic; diagnosis; jaw movement; kinematic image.

Introduction

In order to make a precise diagnosis of abnormalities of the temporomandibular joint (TMJ), advances in diagnostic equipment and techniques have become necessary.

Ultrasonic echography has been developed for application in medical fields for studying the central nervous system, cardiovascular organs, respiratory organs, muscles, tendons, articular ligaments, and so on (1-3). Ultrasonic echography is also regarded as a useful diagnostic technique for closed observation of internal structures in optional areas, and some researchers have applied it into the diagnosis of parotid tumors (4), temporomandibular ganglions (5) and many kinds of oral disease (1,6,7). Spranger (8) has applied ultrasonic diagnostic imaging to the TMJ. However, ultrasonic diagnosis is not widely used for the TMJ at present. It is difficult to perform because ultrasound does not easily penetrate the complex anatomical structures surrounding the TMJ. This is related to the supradirectivity and poor permeability of bone to ultrasound.

An ultrasonic diagnostic imaging system using high frequencies and a large caliber annular-array transducer (Toshiba, SSA-250A) has been developed in recent years. The ultrasonic sound generated from the transducer may penetrate even a small gap between the articular fossa and the condyle.

This study was an attempt to apply the ultrasonic diagnostic imaging system for static and kinematic imaging of the TMJ and for clinical diagnosis of TMJ disorders.

Materials and Methods

Two subjects were selected on the basis of the findings of physical examination. One of them (male, 24 y 1 mon, Case 1) had had no previous clinical signs and symptoms of TMJ disturbance. The other subject (female, 20 y 2 mon, Case 2) had TMJ sound and pain during mastication. The conditions of the TMJ discs in these subjects were examined using magnetic resonance imaging (MRI). The MRI was carried out on a MRHS00AD scanner (Hitachi Medical Corp., Tokyo, Japan). The scans were T1-weighted (TR500, TE25) with a 15 cm field of view. A pair of two-turn flat coils 15 cm in diameter was used for TMJ imaging.

The ultrasonic diagnostic imaging system (Toshiba, SSA-250A) employed is shown in Fig. 1. The specifications of the newly developed transducer are shown in Table 1. This annular-array transducer features a low side-lobe level, deep focus depth and narrow slice thickness.

Ultrasound goes straight in to the media from the source, as its directional characteristics are sharp. If there are heterogeneous objects in its path, reflected waves are detected. Ultrasound is easily propagated through water and homogeneous objects, but becomes attenuated in air.
The degree of attenuation depends on the type of object interposed. When ultrasound is emitted from the surface of human skin and directed into a body, a boundary surface between different organs reflects part of the incidence wave. The ultrasonic diagnostic imaging system receives this reflected wave, calculates the information, and forms images.

The bone surface reflects two-thirds of the entire ultrasound input, and thus one-third alone can propagate through the interior. The transducer must be placed in a specific location in order to propagate ultrasound through soft tissue lying between the condyle and the eminence. For this reason the section was fixed, as shown in Fig. 2. The inclination of the section was defined utilizing the sagittal condylar path angle derived from the computer-aided axiograph (SAM, CADIAX). Pulse-echo B-mode

Table 1 Specification of a newly developed annular-array transducer

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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<tr>
<td>Type of transducer</td>
<td>Spherical curved annular-array</td>
</tr>
<tr>
<td>Piezoelectric material</td>
<td>Polymer film P (VDF-TrFE)</td>
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<tr>
<td>Center frequency</td>
<td>7.5 MHz</td>
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<tr>
<td>Aperture</td>
<td>36 mm in diameter</td>
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<tr>
<td>Radius of curvature</td>
<td>60 mm</td>
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<tr>
<td>Number of elements</td>
<td>12</td>
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<tr>
<td>Effective focal range</td>
<td>45-90 mm</td>
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</table>

Fig. 1 The ultrasonic diagnostic imaging system. (Toshiba, SSA-250A)

Fig. 2 Angle of incidence for the ultrasound.
   a. Frontal view of the angle of incidence, θ depends on anatomical morphology; 5-10 degrees.
   b. Lateral view of the slice line for the imaging, θ' is defined by referring to axiographic tracing; approximately 60 degrees.
images were used in this study. Fig. 3 shows the way of placing the transducer on a subject at the chair side. \( \theta \) is approximately 60 degrees and \( \theta' \) ranges from 5 to 10 degrees, although these angles vary as the need arises in order to obtain the clearest image of the soft tissue.

**Results**

MRI images of closed-mouth views of the TMJ of a male (Case 1) without any symptoms of TMJ disturbances and a female (Case 2) having TMJ sound and pain during mastication are shown in Fig. 4. The normal TMJ meniscus in Case 1 (Fig. 4a) is located anterior and superior to the condyle. The magnetic resonance image in Case 2 (Fig. 4b, c) shows anterior disc displacement without reduction.

The ultrasonic images, closed-mouth views of the normal TMJ and the TMJ with articular disc displacement are shown in Figs. 5 and 6, respectively. It is difficult to distinguish the symptomatic from the normal TMJ on the basis of the static images alone.

The ultrasonic images, open-mouth views of the normal TMJ and the TMJ with articular disc displacement are shown in Fig. 7a, b. Tissues around the condyle with articular disc displacement showed irregularity of the striated pattern in the image during mouth opening, in comparison with the normal TMJ, which showed uniform extensibility.

**Discussion**

The present ultrasonic diagnostic imaging system (Toshiba, SSA-250A) can obtain clear images of minute structures within a wide range of focus and has high
resolution. In order to visualize the soft tissue surrounding the TMJ using ultrasound, no hard tissue must be interposed in its way. The annular-array transducer of the SSA-250A features deep focus depth and narrow slice thickness. The ultrasound generated from the transducer pass through a very small gap between the articular fossa and the condyle. This is why we think this system is well suited to clinical diagnosis of TMJ disorders.

Before referring to ultrasonic imaging, it is necessary to gain experience in reading the images because multi-reflection of ultrasound produces unreal images. In order to avoid misjudgment, anatomical information and kinematic images of the TMJ must be considered. A stock of knowledge about MRI interpretation is of no practical use for reading ultrasonic images.

Kinematic schemata of the condyle and the articular disc are shown in Fig. 8a. At the initial movement of the condyle, less than 8 mm on average, the articular disc remains still. When condylar movement exceeds 8 mm, the disc begins moving (9). This knowledge is useful for reading ultrasonic images showing real-time kinematic behavior.

Considering the ultrasonic images obtained in the closed-mouth view (Figs. 5, 6), it was not easy to find a difference between the normal and the symptomatic TMJ. Static ultrasonic images may therefore not be useful for the diagnosis of TMJ showing articular disc displacement.

The most advantageous feature of ultrasonic imaging is its ability to obtain real-time images of internal structures in fluid conditions without exposure to radiation. Ultrasonic imaging is useful for reading kinematic images in real time for diagnosis of disc displacement.

Considering the ultrasonic images in open-mouth view (Fig. 7a, b), although these figures are also static images, a difference was found between the normal TMJ and disc
displacement. In the ultrasonic image of the normal TMJ, a striated pattern maintained its regularity during jaw opening (Fig. 7a). In contrast, characteristic images in the case of disc displacement were observed during mandibular movement (Fig. 7b, shown with white arrows). Irregularity of the striated pattern was identified in this area, unlike the regular pattern of lines seen in the normal TMJ. Though kinematic images can’t be illustrated in this article, it was easy to distinguish this difference when we observed kinematic images on the display of the ultrasound imaging system. A general idea of the movements of the articular discs is shown in Fig. 8 a, b. In a structurally normal TMJ, the intermediate zone of the disc maintains tension during opening movements, as the extension of the ligament is in harmony with condylar movement (Fig. 8a). In the structurally abnormal TMJ, the intermediate zone shows irregular compression (Fig. 8b). The condyle presses the posterior band of the disc forward during jaw opening because the posterior band is displaced to the anterior of the condyle. This compression of the soft tissue surrounding the condyle may appear as an irregularity in ultrasonic kinematic images.

Limitations and future prospects
It is difficult to distinguish the disc from the soft tissue surrounding the condyle using the ultrasonic imaging system. However, a marked difference in kinematic images between the normal and symptomatic TMJ was observed. In the future, ultrasonic imaging of the TMJ may be useful for screening TMJ disorders. Clinical application will become a reality once clinicians have improved their knowledge of TMJ kinematics and anatomy, and gained more experience of reading images in a larger number of subjects.

Conclusion
This study applied an ultrasonic diagnostic imaging system to both static and kinematic imaging of the TMJ and to the diagnosis of TMJ disorders. The following conclusions were reached:
Different kinematic images were obtained between the normal TMJ and that with disc displacement when we studied the display of the ultrasonic imaging system. Irregularity in the striated pattern of the images was observed during mandibular movement in the case of disc displacement. The ultrasonic imaging system can visualize structural abnormality in the TMJ, and is useful for providing data on TMJ disorders based on TMJ movements.

Acknowledgments
I wish to thank Prof. H. Shinoda and the staff of the Department of Radiology, Nihon University School of Dentistry, for suggesting this study. This study was supported by a grant for Advanced Instrument Equipment from Nihon University School of Dentistry.

References