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Ultrasound Imaging of Condylar Motion: A Preliminary Report

Stanley Braun, DDS, MME;[a] J. Shaun Hicken, DDS, MS[b]

ABSTRACT

Studies of condylar motion within the temporomandibular joint have been going on for some time. These studies have used techniques that included direct viewing via x-rays, magnetic resonance imaging, and arthroscopy, as well as indirect measurements using axiographs, kinesiographs, photocells, and light-emitting diodes. These viewing and measuring methods have important disadvantages and shortcomings. Recent advances in ultrasound technology, used extensively in medicine, have been adapted to dynamic imaging of the temporomandibular joint in the near-sagittal plane. Preliminary results strongly suggest that condylar motion is curvilinear throughout its range of motion. No evidence was seen to support the notion that condylar motion occurs about a fixed axis or point at any time during movement. Additional improvements in ultrasound technology may allow further definitive studies, and it may become usable in diagnosing temporomandibular dysfunction and disease states in the near future.

KEY WORDS: Ultrasound imaging, TMJ, Condylar motion, Curvilinear.

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INTRODUCTION Return to TOC

Imaging of the temporomandibular joint in an effort to understand normal and abnormal function continues to be a challenge. The principal methods currently used to image the joint in the sagittal view are x-rays, magnetic resonance imaging, and arthroscopy. The main disadvantage of x-rays is that they provide a static view while exposing the surrounding structures to radiation. With magnetic resonance imaging, the patient's head position is abnormal, which can influence mandibular motion. It is a costly procedure and often requires the patient to travel to a special facility. Arthroscopy involves surgical invasion of the joint with attendant surgical risks as well as the significant likelihood of altering normal function by its presence.

Ultrasound imaging has been recognized for some time as having several important advantages[1,2]: it does not require special facilities and thus has the potential to become available in an orthodontic office, and it can be used to view the joint in a continuum without invasion, discomfort, alteration of the patient's normal head posture, or interference with condylar motion.

Audio frequencies greater than 1600 Hz (cycles per second) are considered ultrasonic. An ultrasonic sound wave passing through tissue will have a portion of the sound wave reflected on transiting dissimilar tissues. This reflected energy is returned to the ultrasonic emitting device (transducer) where the location of the interface is determined, and an appropriate image is produced representing the interface contours.

In earlier studies, ultrasonic transducers have been placed at various parts of the skin surfaces related to the temporomandibular joint area. This produced nonconventional images of the joint from the frontal, superior, or both aspects.[1–7] Recently Hirt and Knupfer[8] obtained images of the temporomandibular joint in the more conventional sagittal plane. These were images of the joints of cadavers. Until now, obtaining conventional (sagittal) images of the temporomandibular joint via sonography has been limited for several reasons. Ultrasound is unable to penetrate the relatively large mass of bone overlying the joint, and the size of the transducer has prevented its strategic placement in order to produce conventional sagittal images.

Condylar motion has been studied directly by using arthroscopy,[5] serial radiography,[9–11] and magnetic resonance imaging[5,12] and indirectly by using axiographs,[13] kinesiographs,[14,15] light-emitting diodes,[16] and photocells.[17,18] These methods have led to differing views of condylar motion. Posselt[19] suggested that during border movements, the mandible rotates as a hinge on an intercondylar axis. Others[13,20] have supported this view and have applied this thinking to describe jaw movement as an initial rotation of the condyle followed by translation. It is interesting to note that a majority of dental articulators employ a hinge axis design. Other investigators have suggested that condylar motion is described by rotation about a point that is constantly changing.[14,15,21] In engineering parlance, this is defined as curvilinear motion.[22]

It is the purpose of this article to report the initial findings regarding condylar motion by use of newly developed sonographic equipment which does not interfere with condylar motion or require abnormal positioning of the head and produces a dynamic, continuous, near-sagittal view of the temporomandibular joint.

MATERIALS AND METHODS Return to TOC

Two adult male subjects free of any current or past signs or symptoms of temporomandibular joint disorders, including clicking or popping, were used in this initial study. Imaging was done at the Indiana University Medical Center, Department of Medicine, Division of Cardiology. The ultrasound instrumentation used was the Hewlett-Packard Sonos 5500 (Andover, Mass) fitted with an S-12 transducer, one of the smallest presently available (Figures 1 and 2). The instrument, having an output of 12 MHz, was set at a penetrating depth of 4 cm with a sampling rate of 49 Hz. The transducer is approximately 2 cm at its widest dimension (at the emitting surface) and 10 cm in length. This size, unlike earlier transducers, permits its placement $1\frac{1}{2}$ – 2 cm into the external auditory canal (Figure 3). The orientation of the transducer was 25° to the sagittal plane and parallel to the Frankfort horizontal. This provided the best diagnostic near-sagittal view of the joint. A gel (Aquasonic #100, Parker Inc, Orange, NJ) was used on the transducer portion in contact with the tissues of the external auditory canal. This provides a satisfactory surface-to-surface continuum without a significant loss of sonic energy. A continuous ultrasound image is thus obtained that is similar to the conventional sagittal view of the temporomandibular joint. With the transducer in place, each subject repeatedly opened and closed his mandible in a normal manner for 2 minutes. The images obtained were continuously recorded on VHS videotape in the standard play mode.

The images were subsequently transferred to an IBM computer by using a videotape player/recorder interface with a resolution of 640 × 480 pixels and analyzed by using Microsoft (Redmond, Wa.) Paint for Windows 95. The sequential ultrasound images were then transferred to a bitmap image, enlarged, and graphed by using the left border of the Hewlett-Packard Sonos screen as a vertical (y) axis. The superior border of the tracking line seen inferior to the ultrasound image was used as the horizontal (x) axis. Contrast was set at 100% and brightness to 90–92%. A discreet single point at the geometric center of the condylar head outline was identified, and sequential images were then compiled as a representation of condylar motion in the near-sagittal plane.

RESULTS Return to TOC

Composite images of the single point on the condyles of each subject are shown in Figures 4 and 5. Regression analysis of the data points on each figure yielded a fourth-order polynomial with a correlation coefficient of $r = .992$ for one subject and $r = .994$ for the other subject. The motion in each figure is curvilinear.

DISCUSSION AND CONCLUSIONS Return to TOC

The individual static, sequential images that were analyzed in this initial study did not capture all that is truly seen when examining the joint images in motion. At the posterior aspect of the moving condyle, one can observe soft tissues that either stretch and recoil or relax and contract coincidentally with motion. Additionally, an outline of the articular eminence is seen. It is somewhat faint and is lost in the individual, static images. The articular disk is not seen, although previous investigators have reported viewing the meniscus with ultrasound imaging.[4,23]

It is noted that the images are not truly sagittal, but rather near-sagittal, because of the 25° angular displacement of the transducer relative to the true sagittal plane. This offset is required by the current size of the transducer used. As new transducers, presently under development, become available, this offset may be eliminated.

This study of condylar motion does not support the belief of many clinicians that the condyle first rotates open and then moves anteriorly and downward, following the surface of the articular eminence. No rotation is seen on initial mandibular opening. Rather, motion is of a curvilinear nature, where the condyle moves in a continuum of motion, which is not separable into 2 entities of rotation and translation. This is seen in the graphs in Figures 4 and 5.

Ultrasound images are affected by inherent noise accompanying the signal returned to the transducer. This makes interpretation of the static images, and sometimes the dynamic ones as well, difficult. A nonmoving object will vary in appearance because of this noise. Thus the authors believe that it is premature to consider ultrasound imaging as a viable tool in diagnosing temporomandibular dysfunction or disease. However, the use of ultrasound technology for imaging the temporomandibular joint does appear promising. The technique is relatively easy, it provides real-time dynamic imaging that may be recorded and studied at a later time, it is noninvasive, and it does not interfere with normal function. Technical improvements are needed to reduce the size of the transducer, reduce signal noise, and more easily manipulate sonic energy output to visualize the various structures of the joint, including the meniscus. This may then allow ultrasound imaging of the temporomandibular joint to be used as a diagnostic tool in the future.

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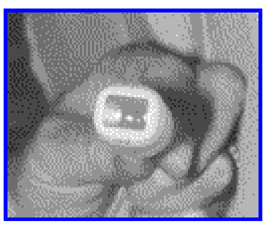
FIGURES Return to TOC

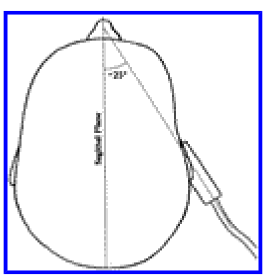
Click on thumbnail for full-sized image.

FIGURE 1. The Hewlett-Packard Sonos 5500 Ultrasonic Machine



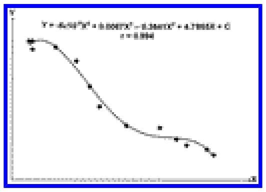
Click on thumbnail for full-sized image.

FIGURE 2. End view of the hand-held Hewlett-Packard S-12 transducer



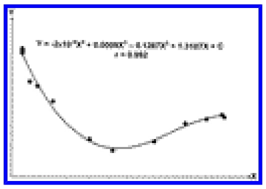
Click on thumbnail for full-sized image.

FIGURE 3. Illustration showing the orientation of the transducer to the sagittal plane in contact with the tissues of the external auditory canal



Click on thumbnail for full-sized image.

FIGURE 4. Graph of condyle point motion of subject A during mandibular opening



Click on thumbnail for full-sized image.

FIGURE 5. Graph of condyle point motion of subject B during mandibular opening

[a]Clinical Professor of Orthodontics, Vanderbilt University Medical Center, Nashville, Tenn, and St Louis University, St Louis, Mo.

[b]Private practice, Edina, Minn.

Corresponding author: Dr Stanley Braun, 7940 Dean Road, Indianapolis, IN 56240 (E-mail: Ortho.braun@juno.com).