Clinical Experience with Magnetic Resonance Imaging in Internal Derangements of the TMJ

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Evaluation of magnetic resonance images of 50 symptomatic temporomandibular joints in 26 individuals indicates that this is a useful modality that can replace the invasive arthrographic method in some cases.

KEY WORDS: • Imaging • Magnetic resonance imaging (MRI) • TMJ •

A growing need for accurate imaging of the soft tissues of the temporomandibular joint has led to further development and increased clinical use of TMJ arthrograms, which were first introduced more than 45 years ago (Westesson 1984, Blaschke et al. 1980, Katzberg et al. 1979, 1980, 1981, Kaplan et al. 1986). The great advances in arthrography since that time have made it a widely accepted imaging technique for gaining information about the dynamics, position, morphology, and integrity of the articular disc and other soft tissues of the TMJ (Kaplan et al. 1986, Manzione et al. 1984).

However, there are limitations and contraindications to the arthrographic approach to soft-tissue imaging. The procedure is invasive, and it is technically difficult (Blaschke et al. 1980, Duffey et al. 1981, Lydiatt et al. 1986, Wilkes et al. 1978). The patient is also exposed to ionizing radiation and varying degrees of pain and discomfort (Harms et al. 1985, Lydiatt et al. 1986).

Magnetic resonance imaging (MRI) is a newer imaging modality only recently added to the medical diagnostic armamentarium. The application of MRI in temporomandibular diagnosis may offer a preferable alternative to soft tissue imaging with arthrography. MRI has no known human biologic hazards, and preliminary evidence suggests that its findings correlate well with arthrographic

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images when evaluating both normal and abnormal TMJ's (Helms et al. 1984, 1986, Katzberg et al. 1985, 1986, Roberts et al. 1985, Paushter et al. 1984). MRI is unique in its capability for "direct" imaging of soft tissues, including the disc, rather than indirect imaging of soft tissues as voids delineated by hard tissues or radiopaque dyes. It has even been suggested that it can reveal evidence of histologic changes (Katzberg et al. 1985).

Arthrography

Toller (1974) described the arthrographic technique that he employed on 146 temporomandibular joints. He linked the clinical evidence of clicking and intermittent locking to hesitation or lag of the disc movement seen arthrographically. He described it as a technically difficult and unpopular technique that required great skill and experience in interpreting.

Wilkes (1978) discussed the diagnostic features provided by arthrography. He related them to the clinical signs and symptoms found to be associated with TMJ disorders. Many other researchers and clinicians have helped establish arthrography as a preferred method to evaluate the integrity of the components of the TMJ (Murphy 1981, Zampese et al. 1983, Kaplan et al. 1986, Hanson et al. 1983, Barrs et al. 1981, Katzberg et al. 1979, 1980, Farrar and McCarty 1979, Westesson 1984).

The renewed interest in arthrography was related to three major factors. These were the development of an image intensifier (Fluoroscope) for help during cannulation of the TMJ and the introduction of the contrast medium, the identification of anterior disc displacement as a source of symptoms that are clinically evident in the patient, and the introduction of various modalities to treat the aberrant soft tissue conditions diagnosed on arthrograms.

The reliability of using arthrography in the diagnosis of TMJ abnormalities can best be appreciated by comparison with surgical findings performed on the same joints at a later time. Delfino and Eppley (1986) performed a prospective study evaluating 236 patients who underwent both procedures.

They found that the incidence of disc displacement, as revealed by inferior space arthrography with fluoroscopy, was nearly identical to that found in actual visualization at surgery. However, the comparative incidence of disc perforations reflected a large number of false positives in arthrographic studies. The exaggerated incidence of perforations may be attributed to iatrogenic effects occurring during cannulation of the joint space for the arthrography.

Bronstein et al. (1981) performed a similar study in which 34 joints were evaluated arthrographically and surgically. They, too, found a very high correlation between the two. In fact, in 33 joints (97%) the finding at surgery correlated with the diagnosis made with the arthrogram. This study not only correlated the position of the disc, but also was used to diagnose adhesions, bilaminar redundancy, and meniscal perforations or tears.

Even though it may be accurate in identifying soft tissue abnormalities in the TMJ, arthrography is still an invasive diagnostic procedure with potential complications, contraindications, and side effects. Reported complications vary, with the one frequently encountered being the extravasation of contrast material into surrounding tissues while attempting to infiltrate the joint space (Katzberg et al. 1979, 1980). This can produce pain as the tissue distends.

Other more rare complications include the loss of a cannula tip (Wilkes 1978), an acute hypertensive episode following the intravasation of epinephrine that is added to the contrast material to prolong the opacification (KATZBERG, 1979), hematoma formation, (DOLWICK, 1985), and transient facial nerve palsy following too vigorous infiltration of lidocaine around the joint (KATZBERG 1979, DUFFY 1981). The potential for infection is also present, although none have been reported (ROSS, 1987).

Magnetic Resonance Imaging

The principles on which magnetic resonance imaging are based were developed in 1946 when Felix Bloch of Stanford University and Edward M. Purcell of Harvard University laid the foundations of nuclear magnetic resonance spectroscopy (PARTAIN ET AL. 1983). Recently, the technique has been applied in medicine by radiologists to produce images of the body, using sophisticated electronic instruments to create a visual image.

In medicine, magnetic resonance images are most easily generated from the protons of the hydrogen nuclei (PYKETT 1982). Since these nuclei serve as a major atomic constituent of both the water molecule which makes up approximately 75% of the human body, and of tissues which are known to be altered by many disease states, their imaging potential is significant. By imaging the density of the tissue protons, the density of the water is actually being visualized. This yields anatomic information as well as a sensitive discrimination between healthy and diseased tissues that are not observable when electron densities are compared via ionizing radiation exposure.

The technique is based on the presence of specific magnetic properties found with atomic nuclei containing odd numbers of protons and neutrons; specifically, their inherent property of rotation about their own axes, similar to that of a spinning top (KRAMER 1984). This property causes a small magnetic field to be generated around the electrically charged nuclei, producing a magnetic moment or dipole. When not exposed to a magnetic field, the dipoles are randomly oriented like small magnets without any overall charge (Fig. 1).

When placed within a strong static magnetic field, however, as during MRI, the dipoles orient themselves in response to the field's forces in either a parallel (with the field) or antiparallel (against the field) direction (Fig. 1). There are small energy level differences between these two orientations, so the orientation with lower energy will have a larger number of protons in position. This produces the appearance of an overall slight net magnetization (M) that is aligned with the applied static magnetic field (Bo) in a direction, Z (PYKETT, 1982).

The large number of spinning protons are actually not perfectly aligned. As a result, the magnetic field causes them to precess (wobble) as they spin around its axis of orientation Z. The oscillating magnetic field that is produced can induce an oscillating voltage in a perpendicularly directed receiving coil.

This signal can be amplified, filtered, and recorded as the MR signal. For the signal to be viewed, however, requires that a second signal force be applied to the protons. This is done by radiowaves (RF 1) at a specific resonant frequency that is in harmony with the precessing protons.

The radiowaves are applied perpendicular to the constant magnetic force. This energy is absorbed by some of the lower-energy dipoles and shifts them to the higher antiparallel states. This changes the net magnetization vector from the original one that is aligned with the Z axis to one at an angle with it and with the X-Y plane.

The degree of tilt is dependent on the intensity of the constant magnetic field and the length of time that the second signal force is applied. On termination of

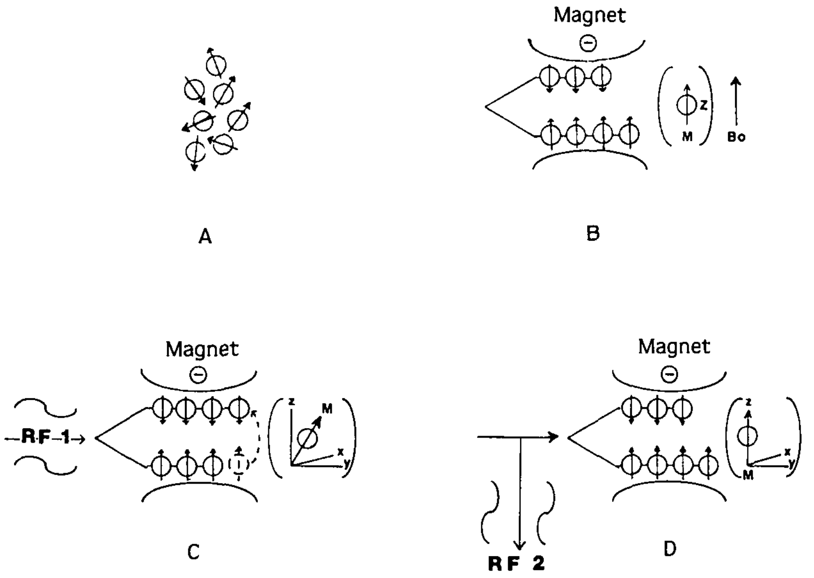

Fig. 1 Diagrammatic representation of the principles of MRI.
- A Dipoles in a random pattern with no external magnetic field.
- B Dipoles in constant magnetic field, Bo, produced by the magnet and aligned in direction Z. More dipoles are in the lower than higher energy state, and contribute to the net magnetic moment, M., also in the Z direction.
- C Dipole in the lower energy state is excited by RF 1 to the higher state. RF 1 is applied perpendicular to the static magnetic field, Bo, and must be of a specific resonant frequency. A shift in the magnetic moment, M, occurs toward the X-Y plane. The degree of shift is dependent on the strength of the magnetic field, Bo, and the length of time that RF 1 is applied.
- D Relaxation over time allows the dipoles to shift toward equilibrium, with the release of energy as a second radiowave RF 2. These radiowaves are detected and processed to produce the magnetic resonance image.

RF 1, the energized dipoles will tend to return to equilibrium within the original force field at a rate determined by their tissue-specific T1 and T2 relaxation times. As they do, a second radio frequency signal (RF 2) is emitted, which can also be picked up by a receiver coil antenna (Fig. 1).

The magnitude or intensity of the voltage is related to the concentration of the nuclei in the site being imaged. To produce the images, signals are interpreted for density and spatial relationship.

The period of time from termination of RF 1 to its repetition is termed the repetition time, TR. The relaxation time, T1, (spin-lattice relaxation time or longitudinal relaxation time) is characteristic of the time required for the spins of the protons to realign with the external magnetic field. T2 (spin-spin or transverse relaxation time) is the other component

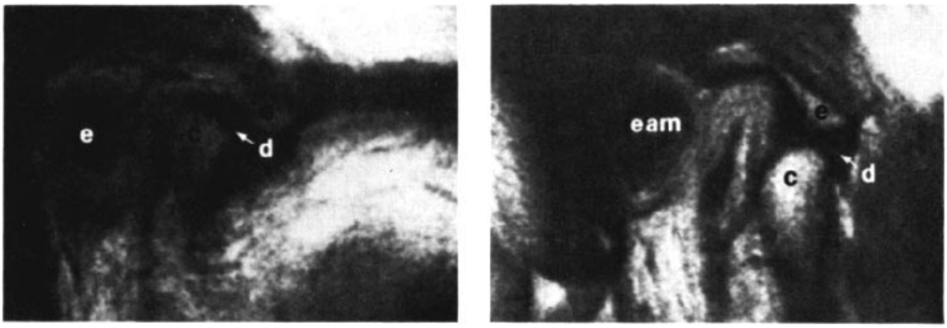

Fig. 2 MRI of a normal TMJ. The external auditory meatus (eam) appears as a relatively large black area. The central area of the condyle (C), is directly anterior to the meatus and appears white because of the fatty bone marrow contained within it. The periphery of the condyle is covered by articular cartilage and cortical bone on sagittal view. Both are relatively devoid of water, emit a low signal intensity, and appear as black bands. The articular eminence (e) and the black fibrocartilagenous disc (d) can also be seen.

Left Normal temporomandibular joint in the closed position.

Right On opening, the condyle (c) translates downward and forward toward the apex of the eminence (e). The disc (arrow) maintains its position between the condyle and the eminence.

occurring during relaxation and/or decay of the transverse X-Y component of magnetization, produced by the interactions among the dipoles themselves.

By varying the conditions under which the radio frequency pulses are applied, one can emphasize T1 or T2 weighting, and so produce images of different appearances and informational content (Pykett 1982, Easton et al. 1986).

When MR images are displayed for viewing, intense signals are displayed as white, weak ones as black, and intermediate signals appear as shades of gray. Remembering that the intensity of the signal is related to the density of protons and water within a sample helps indicate the expected intensity.

In interpreting a magnetic resonance image of the TMJ, two locations are especially helpful to note for orientation; these are the external auditory meatus and the condyle of the mandible (Fig. 2). The auditory meatus appears as a relatively large black area, and the central area of the condyle, directly anterior to it, appears white because of the fatty bone marrow within it.

The periphery of the condyle is covered by articular cartilage and cortical bone on sagittal view. Both are relatively devoid of water, emit a low signal intensity, and appear as black bands. The central area of the articular eminence also contains fatty bone marrow, so its image is also white. The perimeter of the articular eminence, like the condyle, is covered by cartilage that appears black. The muscles and the bilaminar zone of the disc appear intermediate in intensity. The fibrocartilagenous disc produces a low signal intensity that appears black.

Complications and Contraindications of MRI

The magnetic forces and radiowaves that are used in the technique of magnetic resonance imaging are not known to produce any biologic side effects or complications in man (HELMS ET AL. 1984, SAUNDERS ET AL. 1984, MANZIONE ET AL. 1986). It is a noninvasive technique that can be used on most patients. The cardiac pacemaker is a notable exception, because of the possible interference with the pacemaker's operation (PAVLICEK 1983).

Because of strong magnetic force fields generated by the apparatus, however, and the attractive force between any ferromagnetic material and such a static magnetic field, ferromagnetic substances should also be eliminated.

Because of the potential for ferromagnetic materials to move under the influence of a magnetic field, the application of MR imaging may be restricted in those patients who are connected to support systems containing such materials, and those patients harboring ferromagnetic foreign bodies. Examples of patients necessarily excluded for these reasons include those on respiratory assistance, those with metal shavings embedded within their eyes, and those with surgically implanted metallic aneurysm clamps.

NEW ET AL. (1984) explored the potential hazards of imaging various surgical devices. They found that the ferromagnetic properties of the devices varied considerably with their alloy composition. They also noted that the ferromagnetic objects had the potential to generate force under the influence of the magnetic field. These objects therefore have the potential for producing hemorrhage or cerebral injury.

Such alloys also tended to produce regional artifacts on the images, proportional to the mass of the alloys and to their degree of magnetization. Sometimes these artifacts extended to distant areas of the image. Large amounts of dental amalgam and gold produced no detectable artifacts in the images, although dental stainless steels found in prosthethic devices and orthodontic braces created substantial ones that tended to obliterate imaging details found in the facial areas, but not necessarily in the TMJ areas of those tested (EASTON ET AL. 1986).

MRI Versus Arthrography

With the advent of MRI and its clinical application to image soft tissues of the body, its potential in the area of the TMJ has been met with great anticipation by both the radiologist and the patient. Compared to arthrography, MRI offers several major advantages.

For the patient, the greatest single advantage may be the elimination of the need to insert the needle and catheter while introducing the contrast material. Both the psychologic and real pain experienced by the patient undergoing such a procedure can be severe. Other potential hazards of invasive procedures are also avoided. Of course, the elimination of ionizing radiation is welcomed by the patient, technician, and radiologist.

Although a complex technological marvel, the actual operation of the MRI system is not complex, and it is much less stressful and technically easier to perform than the arthrogram.

Many workers have reported positively on the use of MRI for the study of both normal TMJ's and those with symptoms (ROBERTS ET AL. 1985, KATZBERG ET AL. 1985, 1986, HELMS 1984, 1985, 1986, MANZIONE 1986).

The purpose of the present study is to gain further insight into magnetic resonance imaging and to evaluate its status for the diagnosis of internal derangements of the TMJ.

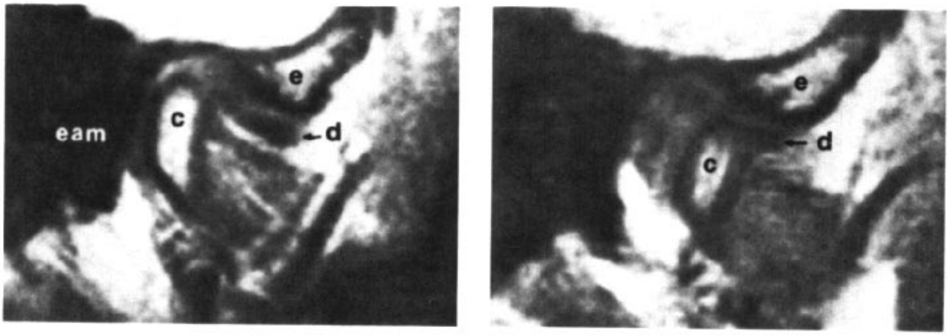

Fig. 3 MRI of anterior disc displacement with reduction.

Left Closed position. The anteriorly displaced disc (arrow) is seen as a black structure located below the articular eminence (e) and anterior to the condyle (c).

Right Open position. The disc (arrow) is reduced on opening. It is interposed between the condyle and the articular eminence. Translation is less than normal in this image. On maximum opening, the condyle should reach the apex of the articular eminence.

— Material and Methods —

Fifty temporomandibular joint MR images from 26 symptomatic individuals were evaluated. They were divided into four groups:

Group A — joints in which no previous temporomandibular surgery had been performed.
  A-1 — bilaterally imaged patients.
  A-2 — unilaterally imaged patients.

Group B — joints in which surgery had been performed.
  B-1 — bilaterally imaged patients.
  B-2 — unilaterally imaged patients.

Of the 26 patients imaged, 25 were female and one was male. They ranged in age from 16 to 60 years, with an average age of 35 years.

The MR images were evaluated in the following order: right closed, right open, left closed, and left open positions.

In closure, the relationship of the disc to the condyle and eminence was noted, as well as any apparent morphologic variations in either the condyle, disc, or eminence. In the open position, the location of the disc was estimated and categorized as being either reduced, nonreduced, partially reduced, or questionable/undiagnosable.

Abnormalities in morphology of the disc were noted, and an evaluation of the range of mobility of the lower jaw was made with "normal mobility" being recorded when the condyle reached the apex of the articular eminence. Examples of MR images demonostrating three different diagnoses are shown in Figs. 3-5. Within the group screened, 40 TM joints from 21 patients had not been subjected to surgery, and 12 of the imaged joints had undergone surgical procedures.

As part of this study, a small number of patients (3 patients, 5 joints) who had both MRI and arthrography procedures

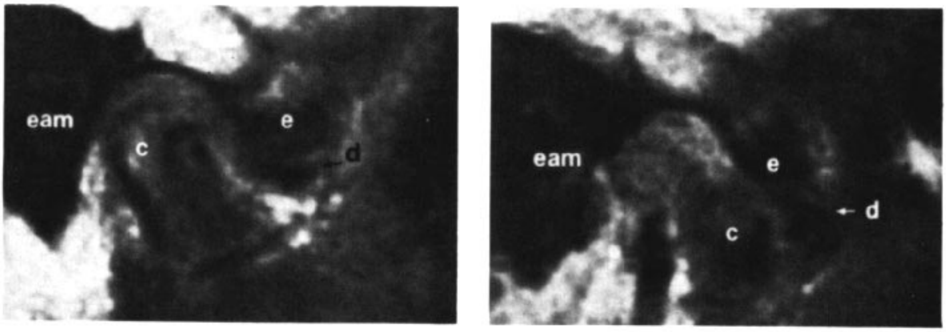

Fig. 4 MRI of anterior disc displacement without reduction. Condyle (c) and eminence (e) are seen as intermediate intensity or gray structures, due to partial image sectioning through both cortical bone and marrow.

Left Closed position. The anteriorly displaced disc (arrow) is seen as an irregular black structure located below the apex of the articular eminence (e) and anterior to the condyle (c).

Right Open position. Disc (arrow) is seen as a > shaped structure located anterior to the apex of the eminence. It has been folded and further displaced anteriorly by the condyle (c) on the mandibular opening. It is not reduced.

performed on their joints were questioned on their experiences in order to gain further insight into patient acceptance and comparison of their response to the two procedures.

— Results and Conclusions —

1. The radiologists' report indicated that they were satisfied with the MRI diagnosis of the disc/condyle relationship in 34 (89.5%) of the nonsurgical joints reviewed.

2. In contrast to other studies of this size, no adhesions, perforations, or histologic changes of the discs were found with MRI imaging. This may have been due to many factors.

3. Morphologic variations in the eminence and condyle were more clearly evident in the arthrograms than the MR images in the small sample of patients who underwent both procedures.

4. With MRI, soft tissue variations were more easily evident than were osseous abnormalities.

5. Surgery performed previously on the TMJ increased the number of MRI artifacts and negatively affected the ability to diagnose soft tissues and their relationship to osseous tissues. Magnetic resonance imaging cannot be relied upon as a diagnostic tool following surgery of the TMJ.

6. The intraoral presence of limited orthodontic appliances (one patient) did not adversely affect magnetic resonance imaging of the temporomandibular joint area. More comprehensive fixed orthodontic appliances (one patient), however, produced signal changes.

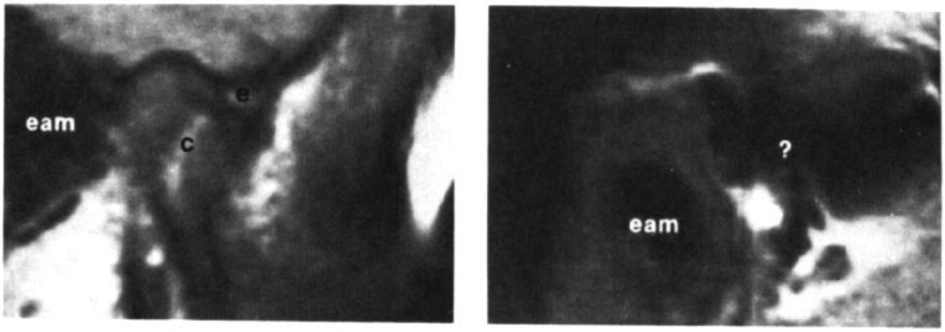

Fig. 5 Magnetic resonance images of undiagnosable temporomandibular joints.

Left This image is from an undiagnosable MRI that was made on a patient who had not had TMJ surgery. A diagnosis was not possible in either the open or closed positions.

Right Total signal drop specific to the TMJ areas was exhibited bilaterally in this patient. She had undergone previous bilateral arthroplasty procedures and was still symptomatic. No implant material was reported to have been incorporated. Fluoroscopy imaging was negative. The signal drop appears to involve a greater area then the immediate incision area. A definitive explanation could not be found for this anomaly, but it was suspected that it was related to the earlier surgery.

7. All patients in the small sample undergoing both arthrography and MRI procedures preferred the MRI procedure.

8. In the small sample imaged by both arthrography and MRI, there was complete agreement between the disc/condyle relationships found with both diagnostic procedures.

9. The incidence of aborting MRI procedures is small (42 of the 1638 patients imaged for all purposes at the University). Claustrophobia was the leading cause, accounting for 26 (62%) of the patients not completing MRI diagnostic procedures. Although some imaged TMJ patients did experience claustrophobia, it was not severe enough in any of the patients in this study to cause termination of the procedure.

— Discussion —

According to Zemer (1985), new modalities go through an evolutionary process of four stages. In the earliest phase, the method is evaluated anecdotally. As the modality becomes established, it enters its second phase and it soon becomes touted as being superior to all other methodologies. The shortcomings become understood during the third stage, and a blacklash effect occurs. Finally, as the technical development of the technique reaches a plateau, an equilibrium is established in the literature and its cost effectiveness and impact on patient care are finally assessed realistically.

The fate of magnetic resonance imaging may be no different. Its final impact on patient care is yet to be realized, although it has already been described as "one of the most sophisticated imaging tools of all time that possesses perhaps the greatest potential of all radiologic technologies" (ALFIDI ET AL. 1984). Studies are currently under way to test for metabolic and mutagenic effects of radiowaves and strong magnetic fields at the cellular level. Since none have been identified at this time, MRI still appears to offer a clear safety advantage over other imaging methods.

Of concern to the orthodontist is the possible effect of orthodontic appliances in the patient's mouth on magnetic resonance imaging of the head. It has been shown that such appliances can produce signal loss and artifacts on imaging (NEW ET AL. 1983) (ALSO SEE PAGE).

Two patients in the present study were known to have undergone MRI while wearing orthodontic appliances. The first was wearing only two lower first molar bands. No adverse affects were noted on the images that were produced. The second patient was wearing a full multibanded appliance. Total signal drop was observed in the oral cavity region, and associated imaging artifacts were noted.

While these artifacts appear to have been restricted to the lower face, it is interesting to note that this patient was the only one of the 21 nonsurgical patients imaged whose discs were not interpretable on MRI. Further investigation of the effects of full banded orthodontic cases on TMJ magnetic resonance imaging may be warranted in the light of these findings.

In the present study, the images made earlier were not of the same caliber as those made later on, which is not surprising with a new procedure. However, we have still been unable to define all of the changes documented elsewhere in the literature (PAUSHTER 1984, KATZBERG 1986). Greater experience in MRI of the TMJ may account for these differences.

Furthermore, diagnostic procedures involve an element of subjective interpretation. The information gained from magnetic resonance imaging and arthrography in this study is no exception. At times, we can be sure of what we see, but our interpretations of what is actually occurring on viewing the image may still be in doubt. Doubt may exist because of our uncertainty of the anatomy seen, or because of uncertainty following a procedure that may influence the assessment.

One shortcoming of MRI compared to arthrography is in the ability to identify ligamental tears and perforations that can be readily witnessed during the infusion of contrast material into either joint space during arthrography. Similarly, MRI does not show the dynamics of the soft tissues of the joint. This shortcoming may be quite significant, because it is during function that the symptoms and signs usually occur.

While the dynamics may be difficult to interpret from an arthrogram on some occasions, witnessing the dynamics of the joint gives a better idea of the overall status of the joint, including the timing of reduction during opening. A more convincing disc "capture" can be noted with arthrography than with MRI, especially if it occurs on early opening and when normal translation after "recapture" occurs.

In some instances, arthrography has failed in that the radiologist has been unable to visualize the joint spaces. Reasons for this failure may include fibrosis, adhesions, or anatomic variation. Magnetic resonance imaging may serve in such circumstances. Furthermore, when ankylosis is suspected, the joint may be difficult to infuse, and MRI might be useful in identifying scar tissue (KATZBERG 1986).

It is our opinion that MRI can be an extremely useful diagnostic tool. It remains to be seen whether it provides as great an advantage in imaging of the TMJ as it obviously has in other areas of the body.

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