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DIAGNOSIS OF TEMPOROMANDIBULAR JOINT INTERNAL DERANGEMENT: A COMPARISON BETWEEN AXIOGRAPHY AND MAGNETIC RESONANCE IMAGING.

by

GEORGES ROZENCWEIG

Submitted in partial fulfillment of the requirements

for the Degree of Master of Science in Dentistry.

Department of Orthodontics

School of Dentistry

CASE WESTERN RESERVE UNIVERSITY

May 1990

"DIAGNOSIS OF TEMPOROMANDIBULAR JOINT INTERNAL DERANGEMENT: A COMPARISON BETWEEN AXIOGRAPHY AND MAGNETIC RESONANCE IMAGING."

Abstract by

GEORGES ROZENCWEIG

The purpose of this investigation was to compare the diagnostic information obtained from interpretation of a magnetic resonance image (MRI) with the interpretation of axiographic tracings of the temporomandibular joint in human subjects with or without temporomandibular joint dysfunction. Twenty seven subjects presenting with symptoms of internal derangement and eighteen asymptomatic patients were studied. The patients of both groups underwent a TMJ evaluation consisting of axiography, a sagittal MRI in mouth open and closed position, and a comprehensive clinical examination. Records of all patients were randomized before interpretation. The results of this study indicate that axiography was well correlated with both clinical and MRI examination ($k=0.67$, $p<0.001$ and $k= 0.39$, $p<0.001$ respectively). One important difference between MRI and axiography is that axiography is a dynamic test of condylar motion and MRI is a static examination of joint anatomy. Axiography was found to be more effective identifying slight disc displacements which result in changes in condylar function. Some of these early condylar changes were recorded by the axiograph but not demonstrated with MRI. MRI was found to be most effective in identifying gross anatomic abnormalities of the TMJ such as total displacement of the meniscus without reduction. These results suggest that axiography may be a reliable test for identifying early abnormalities in condylar movement which are most common in the orthodontic age group.

DEDICATED

To my wife Sophie Rozencweig

whose love provided the energy needed to go on

when I felt I could not.

To my parents, Denise and Daniel Rozencweig,

who have lovingly sacrificed to make my education possible.

I wish to cherish my own children as my parents love me.

To my sisters and brothers, Anne, Eve, Patrick and Eric

for being wonderful individuals.

To my parents in law, Claudine and Henri Lustman

for their love and encouragements.

To all my relatives.

To all my friends.

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INTRODUCTION

Clinical symptoms of mandibular dysfunction affect more than three-fourths of a population of young adults in the United States (Solberg et al., 1979). The incidence of malocclusion has been reported in the United States to be as high as forty six percent (Emrich et al., 1965). Therefore, the orthodontist is necessarily involved with patients who will have symptoms of temporomandibular joint (TMJ) dysfunction before, during, or after treatment. In spite of the increasing amount of research devoted to the temporomandibular joint, many of the diagnostic and most of the therapeutic issues remain controversial. However, TMJ dysfunction is no longer considered to be a unique isolated syndrome. TMJ dysfunction has now been well established as a set of symptoms with a multifactorial etiology (Morawa, et al.,1986).

Signs and symptoms classically associated with TMJ dysfunction are classified by their etiology. Symptoms may originate outside of the temporomandibular joint capsule and are refered to as extracapsular. Other symptoms may originate within the joint capsule and are refered to as internal or intracapsular. Internal derangement of the TMJ has been defined as a displacement of the disc associated with a posterosuperior displacement of the condylar head when the teeth are in centric occlusion (Farrar and MacCarty , 1979). Cadaver studies with frozen sections obtained of randomly selected temporomandibular joints in the sagittal and the coronal plane revealed that the disc was displaced medially in 33% of the joints and

anteriorly in 20% of the joints (Liedberg and Westesson, 1987). During mandibular excursions, a reduction-luxation pattern is usually associated with a reciprocal clicking. As the patient opens, the condylar head reduces onto the meniscus, and produces a vibration of the mandible associated with a clicking noise heard over the TMJ. Near the end of the retrusive movement, the condylar head usually luxates off the disc. Depending upon the relative position of condylar head when the luxation or the reduction of the disc occurs, the clicking is called early, intermediate, or late (Farrar,1978). As the reduction-luxation progresses, the condylar head can push the disc more and more anteriorly. The opening reduction then occurs later and later in the opening cycle of the mandible. Eventually, the disc can be permanently displaced anterior to the condylar head and not reduce during mandibular movement. This permanent displacement of the disc can result in limitation of protrusive movements of the mandible. Mandibular movements are restricted because the condylar head is "locked" behind the meniscus. After months or years of internal derangement, osteoarthritic degeneration of the joint can occur (Farrar,1978).

An accurate diagnosis is a key factor for obtaining successful results in treatment of patients with TMJ dysfunction. Internal derangement (ID) of the temporomandibular joint can usually be detected by a careful clinical examination, including an evaluation of the amplitude and path of motion of the lower incisors. Because internal derangement is often associated with symptoms of neuromuscular dysfunction, head and neck muscles should be palpated as well as a complete evaluation of the TMJ. Articular noises can be

evaluated with a stethoscope or recorded with a sonograph (Hutta, et al., 1987; Heffez and Blaustein , 1986; Oster et al., 1984)). Clinical tests may also be performed to study the resiliency of the joint (Slavicek, 1988) or reactions of the patient upon loading or distraction of the TMJ (Azogui and Turlay, 1988).

Movements of the condylar heads within the glenoid fossa can be measured with an axiograph. The axiograph is a pantograph which simultaneously tracks and records the path of the hinge axis of the condylar heads in the horizontal , vertical, and transverse dimensions. When the meniscus is displaced forward or medially, the path of the condylar head is deviated. This deviation is recorded with the pantograph on graph paper. Because of the sensitivity of the condylar head movement along the inferior surface of meniscus, the axiograph is capable of detecting early subclinical discopathies. Axiograph data provides information necessary to substantiate other clinical findings in evaluation of symptomatic temporomandibular joints and can be used to formulate a differential diagnosis. (Slavicek, 1988).

Images of the TMJ may be obtained with various radiologic methods. The disc must be visible to assess the relationship among the condylar head , the disc and the fossa. Considerable effort has been put into finding a reliable, non-invasive technique that will demonstrate clearly the position of the meniscus. Arthroscopy and arthrography are too invasive to be used on a routine basis. Both techniques require the joint space be entered and ,with

arthrography, a dye must be injected into the inferior joint space. Computed tomography (CT) has had limited success in displaying soft tissues with an acceptable contrast resolution. CT can not predictably establish the relationship of the meniscus to the condylar head (Laurell, et al., 1987). The recent application of nuclear magnetic resonance to clinical imaging has produced a new reliable modality for investigating the anatomy and, to some extent, the tissue character of human body components (Katzberg et al.,1985). This application has been termed Magnetic Resonance Imaging (MRI). Many clinical studies of the human TMJ with MRI have been reported. Magnetic resonance imaging is a non-invasive and non-ionizing technique with no known biological hazards documented. Currently, the high price and the limited availability of MRI are major drawbacks to its routine use. Another shortcoming of MRI is the static nature of the image. This is a significant problem as the symptoms of TMJ internal derangement are associated with the dynamics of the relationship between the condylar head and the meniscus. TM joint dynamics may be viewed with the use of fluoroscopy and arthrography, but again these methods are invasive. MRI taken with the mouth closed and fully open may give a reasonable idea of the condyle-meniscus dynamics.

MRI is now considered by practitioners to be superior to any other non invasive technique to diagnose TMJ internal derangement. Sadowsky and Schach (1988) reported that magnetic resonance images can be an extremely useful diagnostic tool in the evaluation of TMJ dysfunction. However, it

remains to be seen whether MRI provides a significant advantage over other techniques in imaging the TMJ , as it has in other tissues of the body. An equilibrium has to be assessed realistically between cost and effectiveness of the MRI with use in TMJ imaging. The ability of this imaging technique to display anatomic details has been studied since 1984 through many anecdotal descriptions of normal and dysfunctional TMJ anatomy. Magnetic resonance images have also been compared with other radiologic techniques, arthroscopic and surgical findings, and autopsy specimens. Information gained from MRI of the TMJ, like many other diagnostic procedures, involves an element of subjective interpretation. The sensitivity and the specificity of the use of MRI assisted diagnosis of TMJ internal derangement has not been established.

Since the most valuable use of MRI of the TMJ is to diagnose internal derangement, it would be useful to compare the results of the interpretation of the MRI with a functional examination of the condylar motion. The pantographic tracings obtained with the axiograph provide significant functional and structural information about the TMJ movements.

The purpose of this investigation is to compare the diagnostic information obtained from interpretation of an MRI with the interpretation of pantographic tracings of the temporomandibular joint in human subjects with and without temporomandibular joint dysfunction.

The literature review contains four sections. First, a brief summary of the functional anatomy of the TMJ. The most recent studies on internal derangement are reviewed in the second part. The diagnosis of internal derangement with a functional pantographic examination is summarized in a third part. The fourth section reviews the current literature about magnetic resonance imaging techniques used to observe the morphology of the hard and soft tissues of the temporomandibular joint.

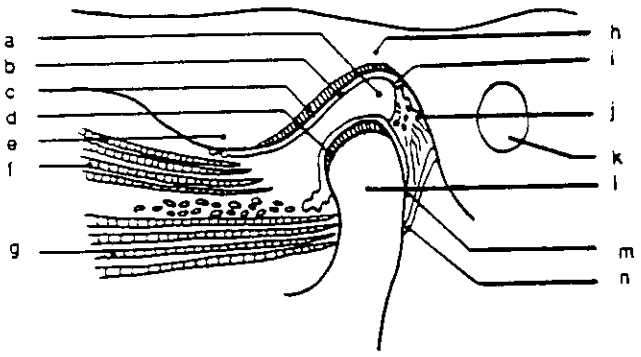
LITERATURE REVIEW

1. Functional anatomy of the TMJ.

The area where craniomandibular articulation occurs is called the temporomandibular joint. The TMJ is a freely movable (Diarthrodial) joint formed by the articulation of the mandibular condylar head with the mandibular fossa of the temporal bone (Okeson, 1989). The condylar head is convex in the frontal plane, and strongly convex in the parasagittal plane. Its medio lateral dimension is about twice its antero posterior dimension. The articular surface of the mandibular fossa and condylar head are lined with dense fibrous connective tissue. The two bones are separated by the articular disc. The articular disc is composed of dense fibrous connective tissue devoid of any blood vessels or nerve fibers. The biconcave shape of the disc accommodates the incongruities which exist between the articular surface of the condylar head and that of the eminence. In the sagittal plane, the articular disc can be divided in three regions according to thickness. The central part is the thinnest and is called intermediate zone. Anterior and posterior to the intermediate zone , the disc becomes thicker. The posterior band is generally thicker than the anterior band (Rees, 1954). The head of the condyle is seated in the intermediate zone (Fig.1). The articular disc is attached anteriorly to the superior head of the lateral pterygoid muscle, laterally to the medial and lateral pole of the condylar head, and posteriorly to the bilaminar zone. This posterior attachment contains two layers of fibers with

Figure 1. Anatomy of the TMJ

a: Meniscus, b: Superior compartment of the joint, c: Articular surface of the glenoid fossa, d: Articular surface of the mandibular condyle, e: Temporal eminentia, f: Superior belly of the lateral pterigoid muscle, g: Inferiorbelly of the lateral pterigoid muscle, h: Glenoid fossa, i: Superior stratum of the bilaminar zone, j: Bilaminar zone, k: External auditory meatus, l: Mandibular condyle, m: Inferior stratum of the bilaminar zone, n : Posterior part of the capsule.


a
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loose fibrous tissue and adipous tissue in between. The superior lamina attaches the disc to the tympanic plate, the inferior lamina to the posterior margin of the articular surface of the condylar head. Unlike the meniscus, the bilaminar zone is highly innervated and vascularized. A rather thin, relatively loose fibrous capsule surrounds the articular surface of the condylar head and blends with the periosteum of the mandibular neck. On the mandible, the articular capsule attaches at the medial and lateral pole of the condylar head. On the temporal bone, the capsule completely surrounds the eminence, being well in front of its crest anteriorly (Mohl, 1982). The articular capsule also attaches to the periphery of the articular disc. The articular capsule is strongly reinforced laterally by the temporomandibular (Lateral) ligament. Between the superior surface of the disc and the dome of the fossa, and between the inferior surface of the disc and the head of the condyle are two different synovial spaces. Upper and lower compartments of the joints are separated from each other and non confluent in the normal healthy joint. Synovial fluid acts as a lubricant to facilitate movement of the disc and condylar head during rotational and translatory movement of the joint. Innervation of the TMJ consists of a dense plexus of unmyelinated fibers that weaves throughout the fibrous capsule and related fibrofatty tissue. The afferent pain fibers enter the regionally related branches of the auriculotemporal, masseteric, deep temporal and lateral pterygoid nerves, to pass into the sensory root and spinal track of the trigeminal nerve. The blood supply to the joint is through the internal maxillary artery principally via its deep auricular branch (Ogus and Toller, 1986).

TMJ are complex joints because they are connected to the sane U-shaped bone (mandible) and therefore must function simultaneously. The range of motion of the TMJ is limited by a third (Dental) articulation. At the beginning of the opening motion, a true rotational movement occurs in the lower compartment of the joint (Lavigne, 1972). Since the disc is tightly bound to the condylar head by the lateral and medial discal ligaments, the only physiologic movement that can occur is a rotation of the disc on the articular surface of the condylar head (Okeson, 1989). As the mouth opens wider, a translation occurs within the upper compartment of the joint, between the superior surface of the articular disc and the mandibular fossa. The articular surfaces of the joint have no structural attachment or union, and contact must be constantly maintained for joint stability (Okeson, 1989). Stability of the joint is maintained by constant activity of the muscles of mastication that pull across the joint, primarily the elevators. The width of the articular disc varies with interarticular pressure. At rest, the disc is wide. Then, when the joint is loaded, the pliability of the articular disc permits constant contact of the articular surfaces. During the second phase of the opening motion, the meniscus and condyle slide on the temporal eminentia. The meniscus is guided anteriorly and medially by the condylar head as the condyle is pulled forward by the inferior head of the lateral pterygoid muscle. It has been postulated that as the articular disc moves forward, the superior retrodiscal lamina is stretched, creating a force to retract the disc during the closing motion (Ogus and Toller, 1986). The sliding component of the opening motion is limited by the temporomandibular ligament. During the lateral excursions of the

mandible, the ipsilateral condylar head rotates with a slight lateral shift. This is known as the Bennett movement. The contralateral condyle translates in a forward and medial direction.

2. Internal derangement of the TMJ.

Internal derangements of the TMJ have been defined as an abnormal relationships between the articular disk and the condyle (Farrar and MacCarty, 1979). These conditions may involve displacement or deformation of the articular disc, alteration of condylar position, osseous remodeling, and joint hypermobility. Clinical signs include clicking and limitation of mandibular movements with locking. Steepness of the articular eminence, morphology of the condyle and the fossa, joint laxity, trauma and bruxism, have been reported as predisposing factors for disc interference disorders (Okeson, 1989).

Nielner (1981) shows that the prevalence of TMJ clicking in a swedish population of youngsters increases gradually with age. TMJ clicking was reported to be present in 13% of children and 17% of adolescents. Solberg (1979), reported an incidence of 28% in a population of young American college students.

Clicking is often a result of anterior displacement of the disc (Farrar,1978; Isberg, 1989). As the condylar head slides under the

temporal eminentia, it pushes the disc forward. The condyle then moves across the posterior border of the disc and reduces onto the thinnest region of the meniscus. Normal condyle-disc function occurs during the remaining opening and closing movement until the closed joint position is approached. Then, the condylar head moves from the intermediate zone to slide under the posterior border of the disc (Okeson, 1989). Clinically, a clicking noise is heard upon opening when the condylar head reduces onto the articular disc, and upon closing when the head of the condyle slides behind the posterior ridge of the meniscus. The opening click is generally louder than the closing click and occurs at a point of more condylar translation (Isberg-Holm and Westesson, 1982). Clicking during mandibular closing will not occur unless preceded by clicking during opening (Isberg, 1982). In patients with unilateral clicking, the mandibular midline deviates toward the side of internal derangement in opening (Farrar and McCarty, 1979). Scapino (1983) studied TMJ histopathology associated with disc displacement. This author concluded that the malposition of the disc provokes a general remodeling of the joint's soft tissues. The anterior part of the posterior attachment becomes fibrotic; The external shape and the internal architecture changes in characteristic ways. The disc appears to overlie more of the lateral pterygoid than is normal. The capsule connecting the anterior band of the disc to the condyle appears to be elongated. Liedberg and Westesson (1988) observed 45 TMJ autopsy specimens from a swedish population of elderly cadavers. Twenty percent of the TMJ showed anterior disc position, 33% medial disc displacement, and 4% lateral disc displacement. It was

concluded that medial disc position is relatively frequent among elderly persons, and that this condition might represent a variant of TMJ internal derangement. When the articular disc is totally anteriorly displaced, the condylar head doesn't reduce anymore into the articular disc in opening. The disc thereby obstructs normal condylar translation, which results in decreased mandibular range of motion. Disc displacement without reduction is clinically characterized by a history of clicking followed by limitation of opening without clicking. Isberg et al.(1985) recorded electromyographic (EMG) activity of the temporalis and the masseter muscles in the mandibular closure cycle of symptomatic TMJ patients. They observed that a disc displacement can produce masticatory muscle activity: the arthrokinetic reflex is generated upon distraction of the articular surfaces. Continuous muscle activity is also produced by disc displacement, and ceases when disc position is normalized. Anterior disc displacement may cause spastic activity of the temporalis muscle on the affected side. This muscular activity is beleived to inhibit the movement of the condylar head necessary to achieve reduction and to contribute to further damage the posterior disc attachment (Isberg et al., 1985).

Farrar and MacCarty (1979), suggest that disc displacement often leads to degenerative disease. Greene and Laskin (1988) followed a group of patients with TMJ internal derangement over a long period of time. The long term evaluation showed that the internal derangement was exacerbated in a very small percentage of the TMJs. Most of the patients adapted to the disc

displacement. Greene and Laskin concluded that the clicking is not a disease, but a symptom.

Joint sounds can also occur because of irregularities of the articular surfaces. In contrast to reciprocal clicking, joint sound caused by articular surface irregularities generally occur at the same place during the opening and closing motion (Isberg, 1989). Therefore, the timing of TMJ clicking during mandibular movement is important clinical finding in the differential diagnosis of joint sounds. If the articular surfaces become altered, movement is impaired. Alterations can occur because of insufficient synovial lubrication, or because adhesions develop between the surfaces. Adhesions can occur between the disc and the fossa, or between the disc and the condylar head. If adhesions occur within the upper compartment, the translatory movement is restricted. If adhesion affect the lower compartment, the rotational movement of the condylar head is impaired (Okeson,1989).

Hypermobility may cause a subluxation of the TMJ. At the end of the opening motion, a quick upward leap occurs within the upper compartment of the TMJ. The condylar head - meniscus relationship remains normal.

3. Functional instrumental analysis.

Pantographic tracings were first used to study the mandibular border and functional movements (Preiskel, 1972), and these early works were

primarily directed at the improvement of the stability of dentures. Chick (1953) stressed the importance of recording movements of the mandible at the emergence of the hinge axis to eliminate errors and artifacts resulting from mechanical factors inherent to the measurement procedures. Pantographic tracings where used to adjust the settings on articulators such as the Denar™ and Stuart™. The articulators were used accuratly reproduce mandibular movements during construction of removable dentures or fixed prostheses such as crowns or bridges (Winstanley, 1977; Isaacson, 1958). Recently, the pantograph has been used as a valuable tool to diagnose internal derangement of the TMJ. Farrar (1978) reported that the biomechanical phenomena associated with reciprocal clicking and locking in the TMJ can be observed and measured with a pantograph. He established a graphic classification system illustrating early, intermediate, or late reduction as related to the anatomy of the TMJ. He also delineated the classic reduction-luxation pattern associated with a reciprocal click which he believed progressed to complete anterior displacement of the meniscus without reduction. According to Farrar(1978), degenerative arthritis is a natural consequence of derangement of the anatomical relationship between the disc and the condylar head. Whether degenerative arthritis is a natural consequence of internal derangement is very controversial. Other authors, Dibbets (1977), Dibbets and van de Weele (1987), reported in a 15 year longitudinal study that symptoms associated with TMJ internal derangement such as clicking or flattening of the condylar head, do not result in degenerative arthritis. Greene and Laskin (1988), also reported a long term

evaluation of patients with TMJ clicking and temporomandibular dysfunction symptomatology. One to ten years after the initial examination, the clicking was reported absent in 10% of the patients. Symptoms improved in 41% of the patients. Fourty five percent of the patients were found to have the same clicking pattern, and the clicking within the TMJ was worse in only 10% of the cases. They felt that abnormal disc position does not result in an increase in TMJ symptoms over many years, and that many patients will eventually accomodate to the abnormal anatomical relationship. However, normal position of the disc has been shown to be essential for normal function (Isberg et al.,1985). The occurrence of the articular sounds, reciprocal or unique clicking, have been studied by Isberg, (1982). The mandibular movements of the cadavers and patients were recorded with high speed cinematography. This very interesting series of studies lead to a better understanding of the pathogenesis of TMJ internal derangement. However, tracings were only obtained from the mandibular incisor region, and only in the sagittal plane of reference. Lepera (1967) claimed that only tracings recorded at the level of the hinge axis displayed a true representation of the condylar path and not a combination of movements of both condylar heads. Bates et al., (1986) developed a simple recorder, the Quick set recorder (Whip-Mix corporation, Louisville, Ky.) to trace the path of the condylar head during mandibular excursions, on a sagittal graph paper. The tracing is used to determine the position of the condylar head upon luxation in the closing cycle. This information is used for the fabrication of the therapeutic splint. The quick set recorder is also used to monitor the position of the

meniscus during splint therapy, and to determine whether or not the disc is in the normal anatomic position.

Slavicek (1988) claimed that the two dimensional parasagittal tracings alone are insufficient for a complete evaluation of TMJ internal derangement and have a high potential for misinterpretation. He felt that the axiograph was a much more valuable pantograph because the tracings are recorded close to the emergence of the hinge axis and horizontal pathways in mediotrusion may be computed according to tables based on the intercondylar width . This instrumentation is easy to use and significantly quicker to install than other three dimensional pantographs. Slavicek (1988) reported an extensive review of the different possible tracing patterns found in patients with TMJ internal derangement, and developed for the first time a classification system for a possible differential diagnosis of temporomandibular joint pathology based on axiographic findings. Axiographic tracings can not only reproduce TMJ disc displacements in all three dimensions , but are helpful to interpret possible TMJ internal and extracapsular derangements such as the degree of looseness of the supporting ligaments, muscular hyperactivity, overrotation of the mandible, anterior luxation of the condylar head, muscle splinting, non moving meniscus, and also some anatomical changes in the shape of the condylar head. Sheppard and Sheppard (1965) reported that restricted condylar movement upon opening, particularly condylar rotation within the fossa, is most of the time associated with temporomandibular dysfunction. The range of motion of the condylar heads measured at the emergence of the hinge axis, provides a better

representation of the TMJ dynamics than the range of mandibular motion measured at the lower interincisal midline.

Retarded condylar head movement is often present prior to clicking. The velocity of the condylar head is then increased with the clicking. When there is no internal derangement, left and right condylar movements are synchronized and have equal velocity (Isberg-Holm; and Ivarsson,1980). Slavicek (1988) felt that the operator should record comments about the velocity of the condyle's movement during the axiography. The CADIAX system (Computer Aided Axiograph) eliminates the need for this observation. The CADIAX can record the pathways of both condylar heads at the same time, in four dimensions. Each path of the condylar head can be plotted in the sagittal, frontal and horizontal plane as well as displayed with the computer in relation to time. Accelerations and decelerations of condylar head movement may provide important information for the diagnosis of possible TMJ internal derangement and /or a neuromuscular, extracapsular problem. Transverse problems arising from a medially displaced meniscus may be described in detail by correlating the Y (Transverse) axis movement in space with the velocity of the condylar head at various time intervals (Slavicek, 1988). A customized functional clutch allows the use of the axiograph or the CADIAX without occlusal interference at a minimal vertical dimension. The movements of the condylar heads can therefore be evaluated between centric relation and centric occlusion. The resiliency of the TMJ can also be tested upon vertical loading of the condylar heads when the operator applies a cranial pressure on the mandible during the mandibular motion.

Mongini, (1980) compared the pantographic tracing of the Bennett movement and the tomographic characteristics of the temporal eminentia and the mandibular condylar head to see how the shape of the bony components of the TMJ influences the pantographic tracings of the mandibular movements. A significant correlation was found between the shape of the anatomic components of the TMJ and the pattern of the pathway of the non working condylar head in the horizontal plane. In the patients with rounded condylar heads and convex articular eminences, the pantographic tracings showed curved progressive side shift, a curved vertical protrusive tracings, and occasionally a curved immediate side shift. When the condylar heads and the eminentia were flattened, the tracings were significantly straighter.

Shields et al.,(1978) reported that the reproducibility of the pantographic tracings were negatively correlated with TMJ and muscle dysfunction. Pantographic tracings of mandibular excursions of a patient presenting a neuromuscular dysfunction are not reproducible. These authors suggested that the pantographic reproducibility index (PRI) which measures the discrepancy between two consecutive pantographic tracings could be an aid to the detection of TMJ dysfunction and muscular incoordination. However, the PRI does not make any evaluation between different degrees of temporomandibular dysfunction. Also, the experiment was not designed to sort out the patients with internal derangement from the patients with myofacial pain dysfunction syndrome.

Kotowicz et al., (1970) tested the reproducibility of pantographic recordings on seven patients, over an extended period of time. They concluded that reproducibility is a practical quality of excursive movements of the condylar heads which are representative of the patient's jaw movements at any given time, and for any experimental conditions. This extremely small study did not report if the patients had neuromuscular problems, internal derangement of the TMJ, or no TMJ symptomatology.

The patient's neuromuscular state is an important factor in registering the lateral side shift of the mandible as the amplitude of the Bennett movement increases after splint therapy and occlusal equilibration (Simonet and Clayton, 1981; Mongini and Capurso, 1982). Therefore, a flat Bennett movement may be a sign of neuromuscular dysfunction. For Simonet and Clayton (1981), the Bennett movement can be affected by neuromuscular activity. To record the total border movements of a given subject, induced pantographic surveys after relaxation may be preferred over voluntary recordings. Mongini and Capurso (1982) point out that both articular and neuromuscular factors influence the tracings. The neuromuscular factor can be dramatically improved by relaxation with biofeedback. Therefore, the relaxation method allows the clinician to sort out extracapsular influences on the TMJ such as neuromuscular factors and allows for more complete evaluation of TMJ internal derangement.

Farrar and McCarty, (1979), correlated pantographic tracings with

arthrography of the inferior joint space in 34 patients with 44 symptomatic joints. The authors reported that the correlation of TMJ arthrography and pantography provides conclusive evidence that most patients with TMJ pain or dysfunction have suffered from an anteriorly displaced meniscus associated with a posterior displacement of the condylar head. However, the study provided no statistical tests to substantiate the findings that arthrography of the inferior joint space and pantographic tracings were correlated.

4. Magnetic resonance imaging of the temporomandibular joint.

The principles of nuclear magnetic resonance (NMR) were discovered in 1946 by Edward M. Purcell and Felix Bloch whose research on the resonance properties of atomic nuclei within a magnetic field earned them the Nobel prize for physics in 1952. NMR has since been useful as an analytical tool in physics and chemistry. In 1973, Lauterbur was the first to show that the magnetic resonance signal can be used to form images by a reconstruction method (Helms et al., 1984).

The application of nuclear magnetic resonance in biomedicine is refered to as Magnetic Resonance Imaging (MRI) . Unlike conventional radiologic techniques, MRI is not based on electron density but is dependent on a tissue's proton density. Each water hydrogen atom within tissues has a magnetic moment dependent upon the spin of its protons. These magnetic

moments of the hydrogen nuclei are normally randomly aligned. When they are placed in a strong magnetic field, the hydrogen nuclei align themselves along the axis of this magnetic field. When a radiofrequency (RF1) is applied perpendicularly to the main magnetic field , the protons begin to wobble, rotate, or resonate. When the radiofrequency is removed, the protons emit energy that they have acquired. This energy is detected as a second radiofrequency pulse (RF2) that can be localized and quantified to give a signal. The period of time from termination of the radiofrequency (RF1) to its repetition is called repetition time (TR). The relaxation time is characteristic of the time required for the spins of the protons to realign with the external magnetic field. T1 is the longitudinal relaxation time, T2 is the transverse relaxation time. By varying the conditions under which the radiofrequencies are applied, one can emphasize T1 or T2 weighting, and so produce images of different appearance and information content. An image is generated based on the spatial difference of the emitted radiofrequency signals (Sadowsky and Schach, 1988; Manzione at al., 1986; Helms et al., 1984). Magnetic resonance images produce a map of tissue proton density differences, primarily due to differences in water content.

MRI studies provide information concerning deep soft tissue structures without being invasive, or subjecting the patient to any form of ionizing irradiation. MRI is not known to produce any significant human hazards (Helms et al, 1984; Manzione et al, 1986). Studies are currently underway to test for possible metabolic and mutagenic effect of radiowaves

and strong magnetic fields at the cellular level (Schach and Sadowsky, 1988).

Magnetic resonance images of the TMJ have been reported in the literature since 1984 (Helms et al., 1984). Since this early publication, many attempts to improve the quality of the images have been reported. Laurell et al.(1987) recommended the use of a cephalostat, along with an axial scout image to localize and orient the long axis of the condylar head. The cephalostat prevents most of the motion artifacts, and produces images with superimposable reproducibility. The axial scout image is made by using a partial saturation pulse sequence which provides a low but acceptable resolution image with a reduced acquisition time. The orientation of the scanning image perpendicular to the long axis of the condylar head is now a standard in obtaining good images of the TMJ. Large variations of condylar orientation among individuals makes the arbitrary positioning of the scan in reference to the skin surface or the sagittal plane unreliable. Utilization of a surface coil improves the signal to noise ratio, so that high resolution is achieved when thin sections are imaged. (Harms et al., 1985). Schellhas et al., (1988) proposed the use of partial flip angle images to produce images with an acquisition time as short as three seconds and provide in most cases, reliable information on disc position, morphology, and intrinsic signal. Because of the extremely short acquisition time, sequential scans during incremental degrees of mouth opening can be obtained, along with high resolution T1 weighted images in closed position. Together these images can

cartilages emit a low signal intensity. Cortical bone is seen as smooth and well delineated because of its contrast with the surrounding soft tissues.

The fibrocartilaginous meniscus produces a low signal intensity and therefore appears dark on the MRI. The meniscus has the configuration of a biconcave lens with a thick posterior band, a thin central section, and a thick anterior band. The posterior band of the normally positioned disc is at the twelve o'clock position relative to the condylar head when the mandible is in the closed position (Katzberg et al., 1985; Kaplan et al., 1987). The bilaminar zone and lateral pterygoid muscle appear intermediate in density and there is a clear demarcation between the posterior band of the meniscus and the bilaminar zone because of a greater fat and water content within the bilaminar zone tissues. The inferior belly of the lateral pterygoid muscle is attached to the neck of the condyle and the superior belly is connected to the anterior band of the meniscus. The posterior band of the meniscus is not consistently observed because the low signal intensity of the cortical bone of the mandibular fossa and condylar head blends with the low signal intensity of the posterior band of the disc (Kaplan et al., 1987). The lateral pterygoid fat pad is seen as a high signal intensity structure between the superior and the inferior belly of the lateral pterygoid muscle, just in front of the anterior band of the disc.

Open mouth views of a normal TMJ should show the meniscus remaining on top of the condylar head. The thinnest portion of the meniscus is positioned

above the superior pole of the meniscus (Manzione et al., 1986).

4.2 MRI findings in abnormal TMJ's.

The crucial landmark for determining the location of the meniscus is the posterior band. In an anatomically normal TMJ, the junction between the posterior band of the meniscus (low signal) and the posterior attachment (intermediate signal intensity) should be on top of the condylar head. An anteriorly displaced meniscus can usually be seen as a well demarcated low signal intensity structure located in front of the condylar head. The disc is visualized in the space formed by the anterior-superior surface of the condylar head and the posterior-inferior surface of the articular eminence. The anteriorly displaced meniscus may displace the pterygoid musculature and the lateral pterygoid fat pad from this area (Manzione et al., 1986). Katzberg et al. (1986) and Laurel et al. (1987) observed a thickening of the fascial plane between the superior and inferior bellies of the lateral pterygoid. If the condyle-disc relationship is normal in open mouth view, but displaced in the closed mouth view, a radiographic diagnosis of anterior displaced meniscus with reduction is reported. Protrusion of the posterior band in front of the condylar head is seen in the mouth open position when the disc is not reducing (Kreipke et al., 1985). In some cases of meniscal displacement, the MRI shows poor demarcation between the posterior edge of the meniscus and the bilaminar zone. This finding suggests possible histologic changes within the posterior band of the disk (Manzione et al., 1986; Katzberg et al., 1985). In a study of cadavers, Scapino (1983) reported that

the fiber pattern of the chronically anteriorly displaced meniscus is modified by the neomorphic addition of transverse fibers. The shape of a chronically anteriorly displaced disc is variable (Kirk, 1989). The disc can be normally shaped, folded, or thickened with various degrees of hyperplasia of the inferior surface. The posterior portion of the disc can also show remarkable thinning. In some cases, the chronically displaced meniscus is large and has an upward flexure in its thinnest region. Medial and lateral disc displacement can be determined directly from frontal views, or inferred by examination of the meniscus relative to internal bony and soft tissue landmarks on multiple sagittal images (Katzberg et al., 1986). Adhesions can be seen on the MR images as low density material connecting the condylar head to the fossa or bridging the condylar head with the meniscus. However, adhesions may be difficult to observe (Kirk, 1989; Harms et al., 1985). When the disc is displaced anteriorly, the condylar head is usually displaced posteriorly and is eccentric within the glenoid fossa (Avrahami et al., 1986).

Roberts et al., (1987) reported that the MRI study is very sensitive in disclosing degenerative joint disease despite the lack of cortical bone imaging. Osteophytes can be observed on the surface of the cortical bone (Laurel et al., 1987). Intraarticular effusions can be identified by a characteristic increase of intensity between T1 and T2 weighted images (Helms et al., 1986). Some authors have reported the observation of disc perforations (Walter et al., 1988; Westesson et al., 1987; Harms et al.,

1985). Helms et al., (1986) , are more skeptical about the ability for MRI's to identify perforations, unless the fragments are widely separated.

Many authors have tried to compare Magnetic resonance images to other techniques or sources of information. Dolon and Moron, (1987) compared the MRI's of twelve symptomatic patients with arthrotomographic results, surgical examination, and clinical findings. They showed that the MRI is as accurate as arthrotomography in confirming disc displacement. However, MRI evaluation failed to detect disc displacement in three joints with an early click. The MRI was found to be more accurate in disclosing gross arthrosis than tomography, however, four perforations were diagnosed by arthrotomography, but were not visible on the MRI study. Roberts et al.(1984) evaluated 28 temporomandibular joints and reported a perfect correlation of the anatomic description of the disc's anterior recess with MRI and with arthrography. Sadowsky and Schach (1988), and Kirk (1989), compared the same two techniques, and concluded that a good correlation exists, but no specific information and no statistic analysis were given as to the reliability of MRI as a diagnostic test.

Laurell et al., (1987), evaluated the ability of MRI studies to detect specific components of cadaver TMJ anatomy at standardized planes by using laminographic, anatomic, and histologic sections. They concluded that MRI studies can image osseous, muscular and fibrous components of the TMJ anatomy with a high degree of contrast resolution relative to conventional

radiographic techniques. Also, the presence of a thickened fascia in the inferior lateral pterygoid muscle was detectable using MRI and may be an indicator of anterior disc displacement. Westesson et al., (1987), studied 15 fresh autopsy specimens of the TMJ and compared the magnetic resonance imaging findings with the corresponding sagittal cryosection. The MRI study correctly delineated the position of the disc in 11 (73%) joints. Medial or lateral displacement of the meniscus was present in all the joints where the sagittal disc position was incorrectly assessed. Perforations were detected in the cryosections of 5 joints , but were not observed in any of the MRI views. The MRI-based analysis of osseous anatomy was correct in nine (60%) joints. In most of the joints where the demarcation between the disc and the posterior attachment was not visible, the cryosection revealed either large perforations or a fibrotic posterior attachment. The inability to differentiate the disc from the anterior attachment in four joints resulted from the presence of large perforations. This last study is the only attempt , among numerous publications, to try to measure the sensitivity and the specificity of the magnetic resonance image based diagnosis. However, the very small number of joints observed (15) gives little significance to the statistical results.

Zemer (1985), wrote that new techniques go through a four stage evolutionary process during their development. The method is first evaluated anecdotally and soon believed to be a breakthrough discovery superior to all other techniques by the second stage. The inconveniences are slowly

discovered during the third phase , and finally, as the technical improvement reaches a plateau, an equilibrium is established and the cost effectiveness of the technique as a diagnostic tool is assessed realistically. The fate of magnetic resonance imaging may be no different (Sadowsky and Schach, 1988).

Because magnetic resonance imaging is non-invasive and non-hazardous, the technique may be used for evaluation of human subjects with and without TMJ internal derangement. This allows MRI results to be compared to evaluations done on the same patients with other non-hazardous non- invasive tests such as axiography and clinical examination.

The purpose of this investigation is to compare the diagnostic information obtained from interpretation of an MRI with the interpretation of pantographic tracings of the temporomandibular joint in human subjects with and without temporomandibular joint dysfunction.

MATERIALS AND METHOD.

1.-Experimental design.

The study consisted of 45 patients divided in two groups. The first group (Group A) consisted of 27 subjects with one or more of the following symptoms of TMJ internal derangement :

1). Pain localized in the TMJ area upon intrameatal or antetragal palpation.

2). Articular noises: clicking or popping during mandibular excursions.

3). Articular dysfunction: limited range of motion, deviation of the mandible on opening or protrusion.

One or both joints of Group A's patients were symptomatic. A total of twenty seven symptomatic joints were examined. The second group (Group B) consisted of 26 asymptomatic adolescent patients. Teenagers comprised the asymptomatic group for three reasons:

1. Children between the age of 7 and 15 were readily available through the orthodontic clinic. The MRI studies of these patients was funded by a grant from the American association of orthodontists (AAO Grant# 4833-100).

2. The incidence of internal derangement increases gradually with age. The frequency of clicking within the TMJ has been reported to be significantly higher among 15-18 year olds as compared to a group of 7-14 year olds (Nilner, 1981,1985)

3. The age and sex of the control group patients have little bearing on the amplitude and the direction of the condylar path (Isaacson, 1959). The amplitude of the protrusion and mediotrusion path do not vary with age after

8 years of age. The maximum opening path increases slightly but not significantly after age 10 (Ingervall, 1972).

The subjects of both groups underwent a TMJ evaluation consisting of an axiography, a clinical examination, and a MRI study of both joints.

2. Method of Axiography.

2.1. Patient position.

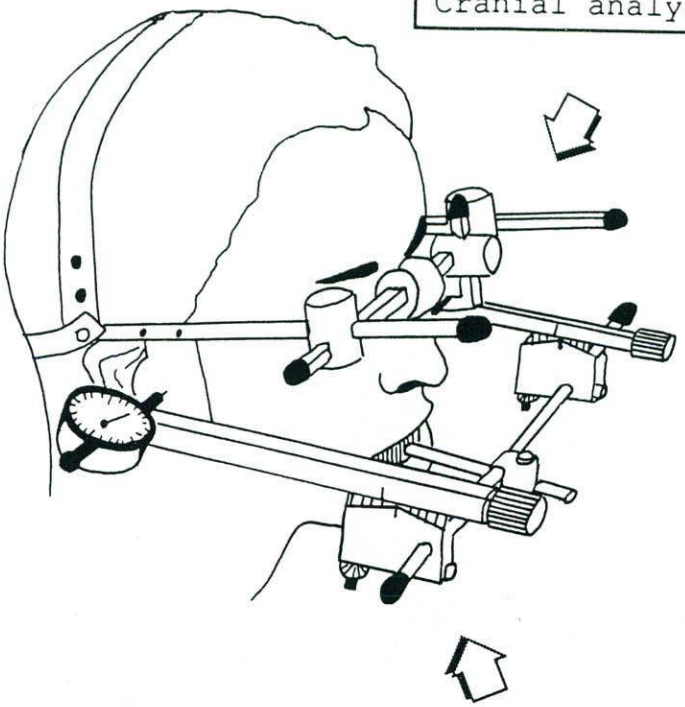
The patient is seated in an orthostatic position in the dental chair, with a balanced tension between the head and neck muscles.

2.2. Fixation of the clutch.

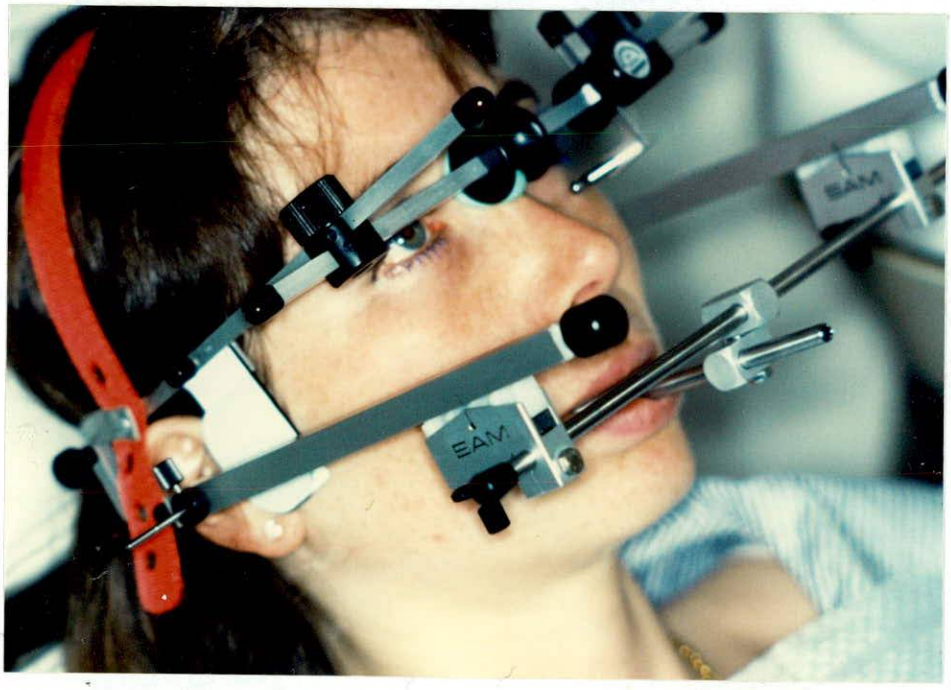
The clutch is a fork designed to support the arms of the pantograph (Mandibular recording bow) (Fig 2). A suitable clutch is chosen for the lower arch. A stick of periphery wax (Modern Materials ™) is placed on the incisal edge and across the clutch to facilitate its removal at the end of the procedure. The clutch is partially filled in with a fast setting plaster (Kerr #2 plaster, Great Lakes Orthodontics). The clutch is placed on the lower teeth and the handle of the clutch is centered in the mid-sagittal plane. The patient is asked to bite on the clutch to minimize any change in the vertical dimension of occlusion so as not to alter the location of the hinge axis. According to Lavigne (1972), a true rotational movement of the condyle can only occur within an average of 12 degrees of vertical opening (Range 4.9 to 17.25). This corresponds to 6 to 25 millimeters of bite opening, measured between the central incisors. Having the clutch set at a minimal increase in vertical

Figure 2. The axiograph.

Cranial analyser bow



Mandibular recording bow



dimension is also critical to be able to detect early opening clicks. For early detection of disc displacement, Slavicek (1988) suggests using a casted functional clutch that doesn't interfere with the occlusion. When the plaster is set, the clearance of the clutch with the upper posterior teeth is checked in lateral and protrusive excursions.

2.3. Fixation of the analyzer bow (cranial bow).

The double cone shaped nasal support is adjusted to fit the soft tissues over the nasal bridge. To relief the pressure of the elastic strap, a piece of silicone putty material (Citricon, KERR) is placed between the sella of the nose and the nasal support of the cranial bow. The two lateral arms are secured in contact with the skin. The posterior end of the sagittal flags are adjusted to lie just in front of the tragus. The cranial flag bow is stabilized with an occipital elastic, and a parietal adjustable strap (Fig 2).

The interflag distance is measured between the inner surface of the cranial bow's arms. This value represents intercondylar distance and is used to compute the Bennett movement. Orbitale point is located by palpation of the anterior border of the orbit and the vertical position of orbitale is recorded on the ruler fixed on the orbitale pointer. Orbitale point, along with the position of the emergence of the hinge axis on both sides, will define a reference plane used to measure and compare the right and left condylar paths.

2.4. Fixation of the mandibular bow (Recording bow).

The mandibular bow is designed to be connected to the mandible. Its adjustable lateral arms support the instruments necessary to draw and measure the movements of the condyles (Fig 2). The mandibular bow is placed flat on a table to be initialized. The lateral arms are adjusted to a neutral position. The mandibular bow is then placed on the shaft of the clutch. The lateral arms are positioned against the flags, and the patient is asked to hold the lateral arms in place while the parallelism of the transverse bar with the cranial bow is visually checked in the frontal plane by observing the bar from the front, and in the coronal plane by observing the bar position from above. The posterior end of the arms of the mandibular bow must coincide with the posterior border of the flags. Before the mandibular bow is secured to the clutch, the remaining stresses in the joints of the mandibular bow are relieved by spinning the transverse bar. The lateral arms of the mandibular bow are pulled away from the flags, and secured on the transverse bar at a distance set by spacers.

2.5.Location of the hinge axis(Rotational Center of the Condyle).

The hinge axis is located with the mandible positioned in centric relation (CR) by guiding the mandible in minor opening and closing movements. To obtain a pure rotational movement of the condylar heads, the amount of vertical opening must be minimized. The stylus on the mandibular

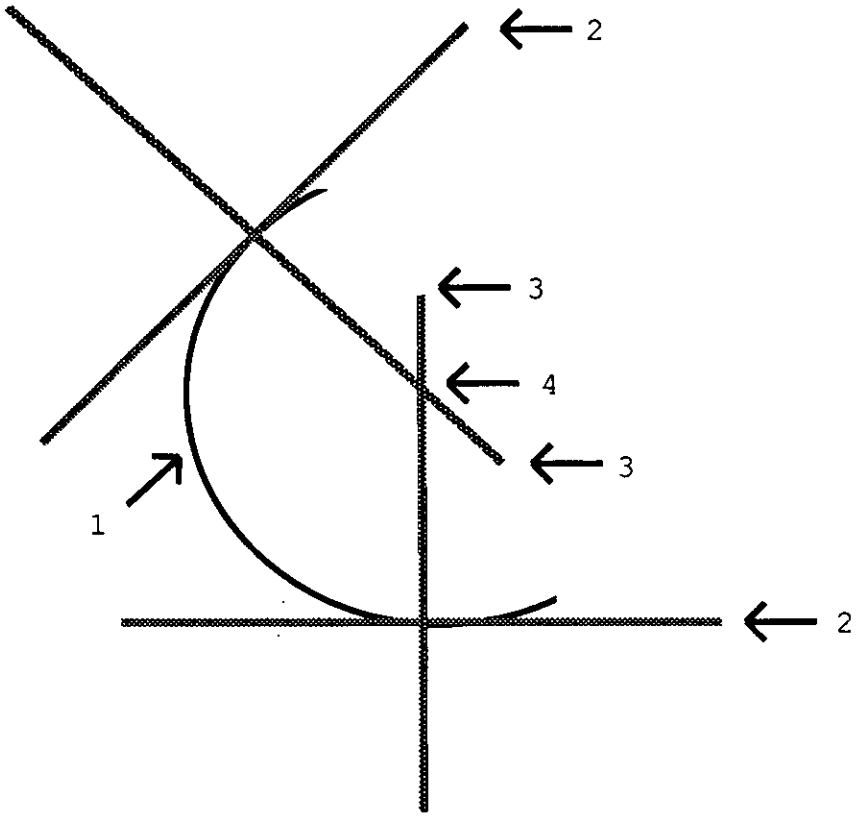
bow displays an arch and two imaginary perpendicular lines of two tangents to this arc intersect at the point of emergence of the hinge axis (See fig. 3). Using a trial and error method, the operator finds the location of this point by examining at the arc with a magnifier and adjusting the position of the stylus. The stylus spins around it's greatest axis when it is located over the hinge axis.

2.6. Axiographic tracings.

A black retractable pen is mounted on the arm of the mandibular bow to record the centric relation reference position. To trace this point, the patient is guided to an unstrained retro border position. Four tracings are recorded : 1. Opening/Closing,(traced in black); 2. Protrusion/Retrusion, (traced in red); 3. Mediotrusion / Medioretrusion, (traced in blue). The use of different colors permits an accurate identification of the intricate tracings. Two sets of tracings are recorded for each condyle. One is used for the interpretation of the sagittal recordings, and another one is overlaid with a transparent millimeter grid and used as a guide for recording transverse movements. The transverse movements of the condyles are then recorded with the dial gauge in protrusion, opening, guided mediotrusion, and unguided mediotrusion. A value is read on the dial for each millimeter of sagittal movement, and recorded. Further calculations, using conversion charts, will enable the tracing of the Bennett movement in an horizontal plane.

Figure 3.

Location of the hinge axis.



1. The stylus traces an arc.
2. Imaginary tangents.
3. Perpendicular lines to the tangents.
4. Point of the emergence of the hinge axis.

Observations about the timing of the tracings are recorded on a tape recorder during the procedure. Changes in speed of the mandibular condyles movement are important information for the diagnosis of internal derangement (Slavicek, 1988). Joint noises, such as popping or clicking, are also documented during the axiography.

2.7. Orientation of the tracings.

The Axis Orbital Plane marker is clipped onto the ball of the orbitale pointer. The flexible arms are clamped so that they bisect the centric relation reference point bilaterally. The reference line is drawn on the left and right graph papers.

The tracings are enlarged 6 times with a photocopy machine and the angle of the condylar slope to the reference line is measured at each intersection of the condylar path in opening and protrusion with the millimeter overlay ruler. These values are entered and directly plotted with a computer (Macintosh Plus, Apple Computer) using a chart-spreadsheet program (Microsoft™ Excel 1.5). Left and right condylar slopes are superimposed for comparison.

2.8. Drawing the pathway of the condyles in the horizontal plane.

The relative values obtained from the dial gauge are converted into

millimeters and can be directly plotted on a graph for the opening and protrusion motion. However, in laterotrusion, these values must be converted as the data obtained from the dial gauge depend on the width of the subject's head (interflag distance). Conversion tables are available for each centimeter of interflag distance. The computer automatically chooses the table corresponding to the interflag distance, calculates the relative values from the data obtained from the dial gauge, converts the values according to the table, and plots the trajectory of the Bennett movement.

3. Interpretation of the axiographic tracings.

3.1. Introduction

Axiographic findings consist of the tracings of the mandibular border movements in the horizontal and sagittal plane, and timing of the condylar motions. The four mandibular border movements are 1. opening / closing, 2. guided mediotrusion / guided medioretrusion, 3. unguided mediotrusion / unguided medioretrusion, and 4. protrusion / retrusion. The tracings drawn on the parasagittal graph paper represent the pathways of the mandibular condyles projected on the vertical (X/Z) plane. Normally, all axiographic tracings in this plane should be superimposed for the first 8 to 10 mm (Slavicek, 1988). The protrusive motion typically produces a shorter path (8 to 10mm) because this movement is limited by the stylomandibular ligament. The mediotrusive path should be around 12mm, and the opening movement is the longest at about 14mm. The final phase of the opening

tracing usually has a smaller radius, directed cranially as the condyle moves up the eminence (Fig.4). Bilateral tracings of each movement should be symmetrical and of similar dimensions. Length, shape, regularity and reproducibility of axiographic tracings all provide information about possible neuromuscular or intracapsular problems. Superimposition of the right and left tracings along with spacial relationships between the axiographic tracings of the same TMJ, provide information concerning the anatomy and the kinesiology of the TMJ.

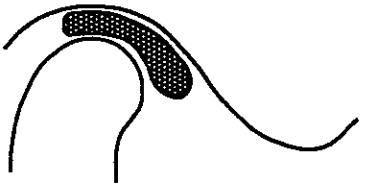
The pathway of the condyles in the transverse dimension (Y) is recorded during the same four movements with a dial gauge. A value is read on the gauge for each millimeter of condylar movement. The computer draws a chart for the four condylar border movements projected in an horizontal plane (X/Y).

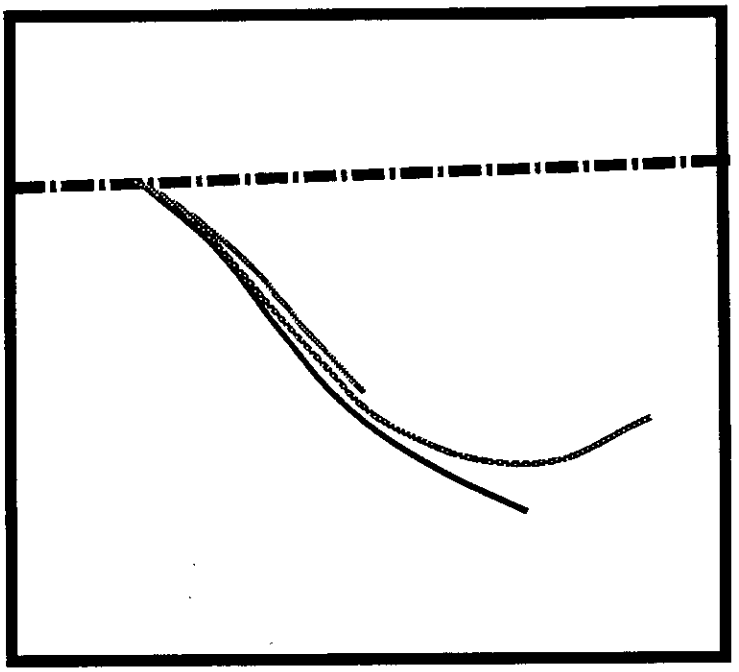
Timing of the mandibular movements is the fourth dimension of the axiography. The timing of condylar head movement is automatically recorded and can be plotted against any tracing when the axiograph is directly interfaced with a computer (CADIAX, Gamma Institute). This study uses a regular axiograph and abnormal acceleration or deceleration are simply carefully recorded by the operator during the axiography.

Figure 4.

Normal tracings in the sagittal plane.

OPENING
PROTRUSION
MEDIOTRUSION





3.2. Opening Closing.

Axiographic tracings can be affected by four factors:

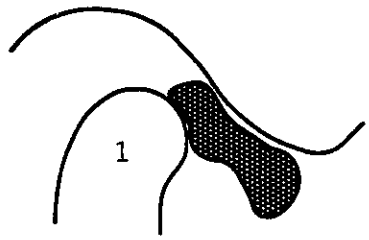
1. Anatomical variations of joint structures such as a modification of the shape of the mandibular condyle or the anterior slope of the eminentia.
2. Anatomical changes in the position of the meniscus,such as anterior or medial displacement.
3. Anatomical changes in the ligamentous support of the joint, such as increased looseness of the ligaments.
4. Muscular incoordination, such as spasm of the lateral pterygoid, which can be significant in conditions like myofacial pain syndrome.

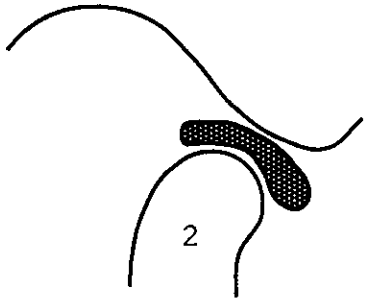
If the patient presents with a reciprocal click, the condyles demonstrate characteristic axiographic tracings. Figure 5 illustrates the path of the condyle during a reciprocal click (Bates et al., 1986; Farrar, 1978). At the beginning of the opening movement, the mandibular condyle is displaced posteriorly and superiorly and the disk is displaced anteriorly. The condyle then slides over the posterior ridge of the meniscus and the condylar head reduces into the thinnest portion of the meniscus. When the condyle reduces, an acceleration of the condyle is noticeable, and the tracing shows a cranial jump. Reciprocal clicking can be classified as early, intermediate or late (Farrar, 1978) based on the position of the condylar head when the reduction occurs. As the reciprocal clicking becomes more chronic, the.

Figure 5.

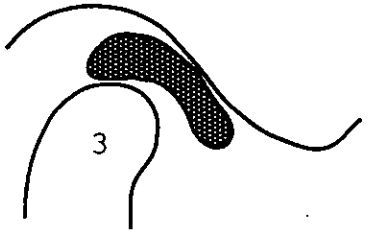
Anteriorly displaced meniscus with reduction.

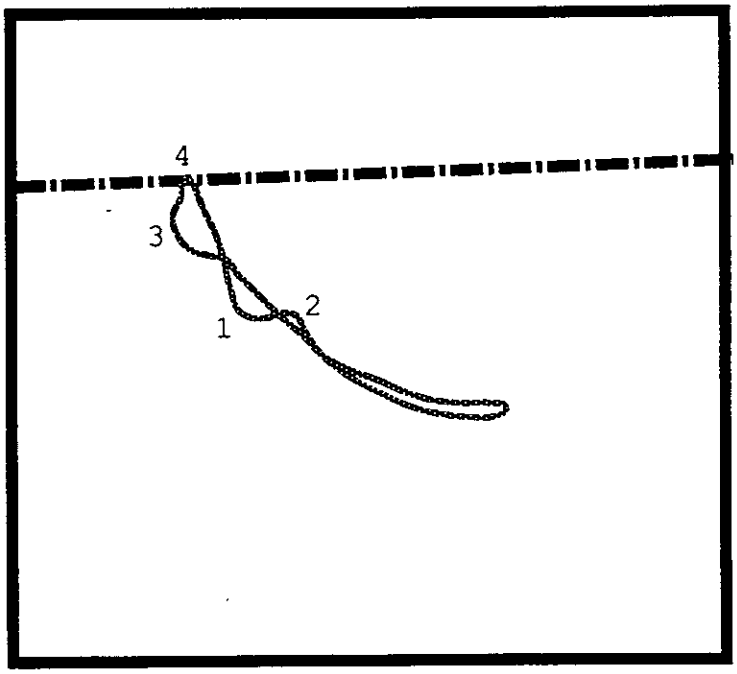
Sagittal axiographic tracing.











from Slavicek

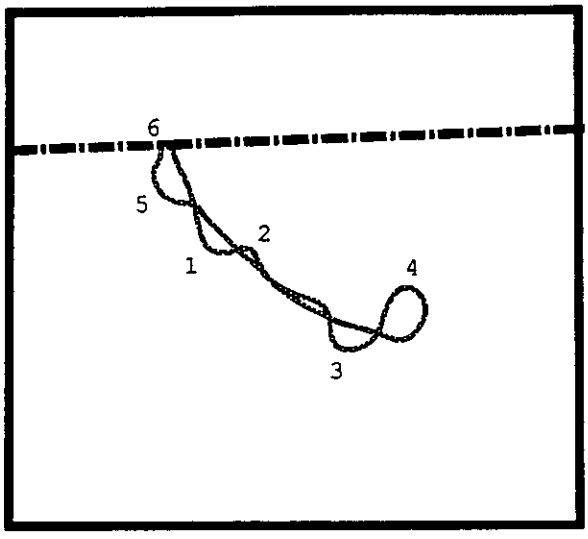
clicking occurs at a point farther removed from the centric relation condylar position. Sometimes, the disk remains dislocated throughout the functional range of motion and does not reduce(Farrar, 1978). As the condylar head approaches the end of the closing path, it suddenly deviates upward and backward (Fig.5). The position of this condylar dislocation along the closing movement reflects the amount of muscular tension of the temporalis, masseter, and pterygoid muscles. The earlier in the closing movement the luxation occurs, the more tension present in the joint. The elevator muscles on the ipsilateral side produce an increased compression of the disk. The friction in the TMJ's upper compartment slows down the motion of the meniscus and the mandibular condyle snaps behind the disk. Slavicek (1988) reported that a cranial loading of the joint increases the amplitude of the vibration during reduction. The reduction is also further removed from the centric relation reference point. The luxation generally occurs closer to the beginning of the excursive movement. In some cases, the mandibular condyle comes off the disc at the end of the mandibular opening movement when the condyle passes the apex of the eminence. The condyle reduces onto the meniscus at the beginning of the closing movement (Fig.6). This anterior luxation of the condylar head (anterior outway) is a dangerous situation because it may often lead to an open lock (Slavicek,1988). The anterior outway may (Fig.6) or may not (Fig.7) be associated with a reciprocal clicking (Vinot and Orthlieb, 1989).

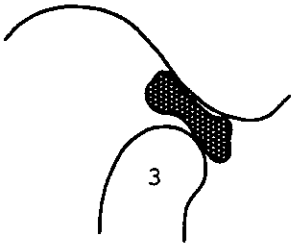
Figure 6.

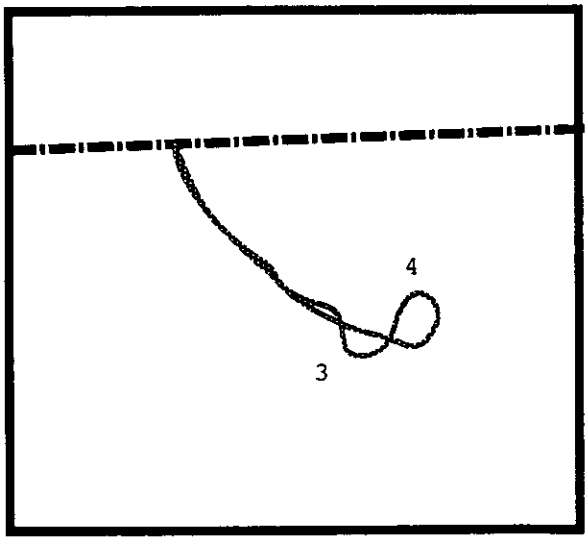
Anterior outway with double luxation-reduction pattern. Sagittal plane tracing.

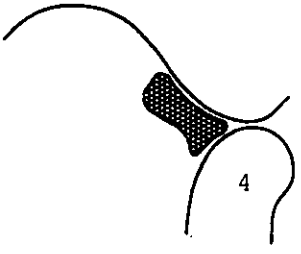
Figure 7.

Anterior outway. Sagittal plane tracing.









from Slavicek

If the meniscus is completely dislocated anteriorly without reduction, the joint doesn't produce a clicking noise. The condylar path is relatively steep, short and divergent with the condylar path in protrusion and mediotrusion on the axiographic tracings(Fig.8). Usually, reciprocal clicking precedes locking of the joint (Farrar, 1988). When the anterior dislocation of the disc becomes a chronic situation, the path of the condyle gets longer because the condyle pushes the disk farther forward and stretches the posterior attachment of the meniscus (Farrar, 1978; Slavicek, 1988; Isberg, 1989).

Isberg-Holm and Westesson (1982), showed that a deviation in form of the articular surface can cause a deviation in the condylar path. A functional bulge occurs along the excursive and incursive movement at the same place on the axiographic tracing. An irregularity of the articular surfaces of the lower compartment of the TMJ can produce a clicking noise during the rotation of the mandible at the beginning of the opening motion and can be detected by the axiograph (Slavicek, 1988). As opposed to the functional bulges, the anatomic irregularities cannot be modified in place and amplitude by manipulation.

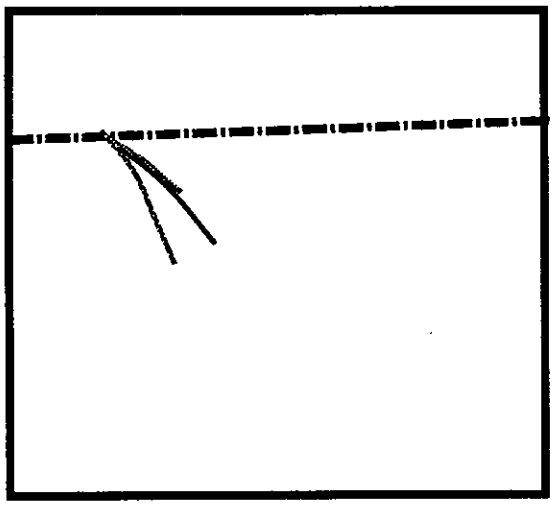
There is usually no transverse translation of the condylar head during the opening movement (Fig.9) but a movement of 0.2 or 0.3 mm is acceptable. Any movement exceeding 1 or 2 mm may be considered as a sign of

Figure 8.

Locked joint. Sagittal plane tracing.

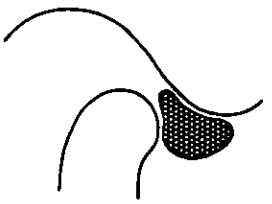
Anteriorly displaced meniscus without reduction.

OPENING
PROTRUSION
MEDIOTRUSION





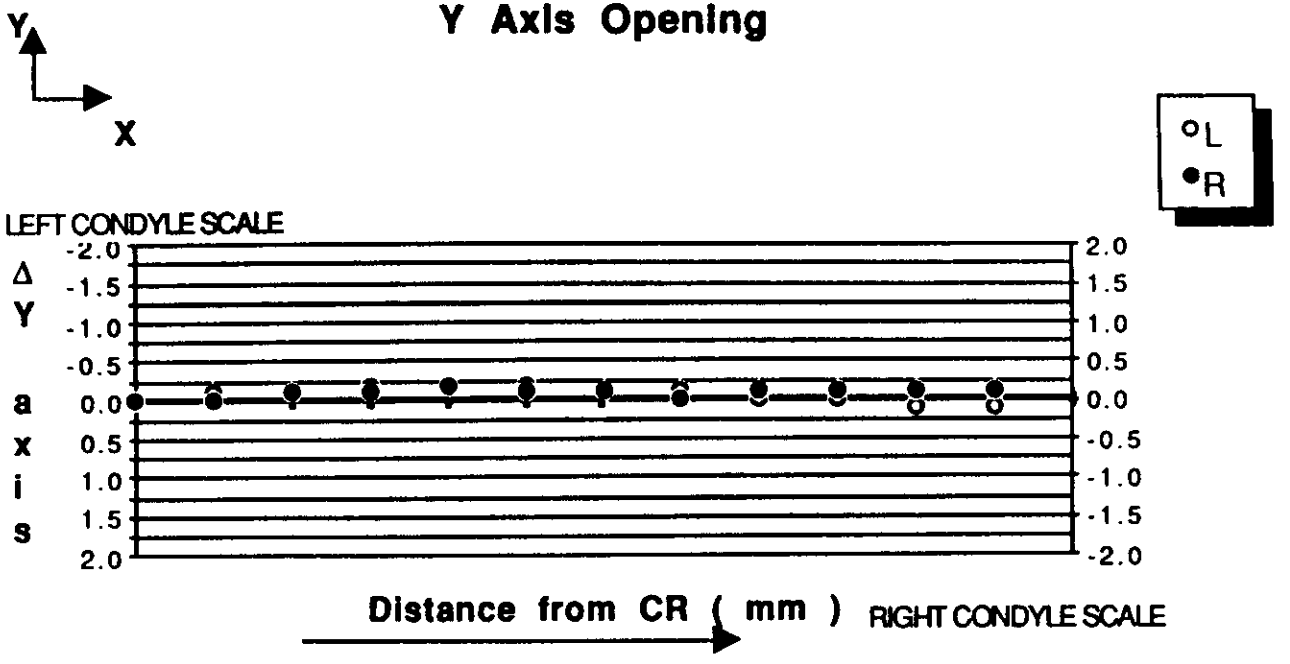




from Slavicek

Figure 9.

Pathway of the right and left condyles in the horizontal plane.


Y Axis Opening
Y
X
L
R
LEFT CONDYLE SCALE
Δ Y a x i s
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
Distance from CR (mm)
RIGHT CONDYLE SCALE

a medially displaced disk (Slavicek, 1988) or muscular incoordination. If the disc is displaced medially in one TMJ, the condyle usually deviates laterally upon opening in the same TMJ. A displaced disc generally causes the condyle to slide laterally at the beginning of the opening movement of the mandibule. In contrast, muscle incoordination is more likely to provoke a deviation toward the end of condylar tracing. The anteriorly displaced meniscus often causes lateral movement of the condyle, as well as the medially displaced disc (Slavicek, 1988).

The left and right condylar slopes are compared and should be symmetrical upon opening. The computer provides a superimposition of the pathways (Fig.10). If one slope is significantly steeper than the other, the possibility of an anatomical discrepancy, such as condylar remodeling, or a functional problem, such as disc displacement, should be investigated.

If the mandible is overrotated at the end of the opening motion (Fig.11), the tracing becomes very irregular because the uncurbed portion of the condylar head is exposed to the meniscus (Slavicek, 1988).

Comparison of the tracings of the condylar path on opening with the path in protrusion and mediotrusion provide information concerning the morphology of the head of the condyle. Protrusion and mediotrusion occur mainly in the upper compartment of the joint. The head of the condyle,

Figure 10.

Superimpositions of the right and left opening path in the sagittal plane.

X/Z Axis Opening

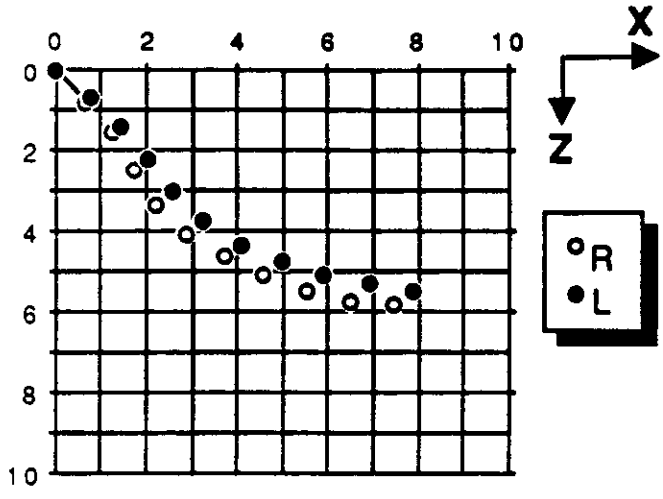
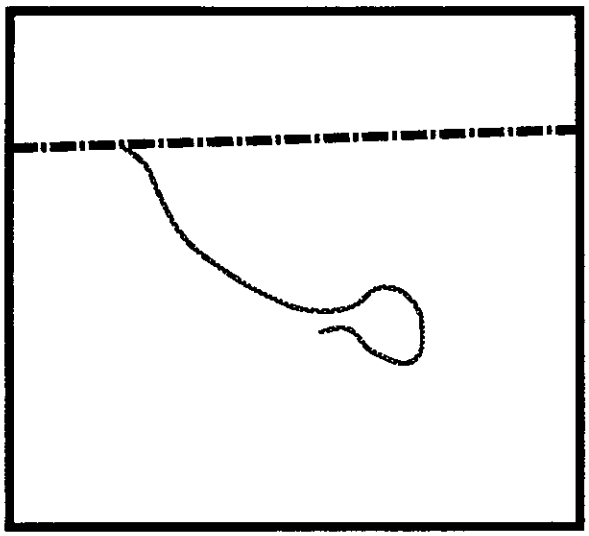
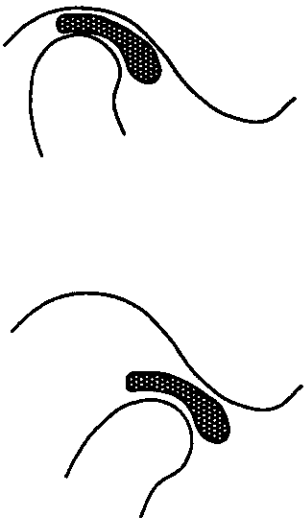


Figure 11.

Overrotation of the mandible in the sagittal plane.

Opening





from Slavicek

covered by the meniscus, slides under the eminentia, and the tracings reflect the morphology of the upper compartment. The opening motion is a combination of a rotation and translation movement. If the condylar head is flattened between the superior pole and the anterior pole, the center of rotation of the condyle will move inferiorly as the condyle rotates because of a geometric concentric cam effect (Fig.12). The path of the condyle in opening will not coincide with the path in protrusion and mediotrusion (Fig.13). A curved opening tracing can be observed below a flat protrusive and mediotrusive path.

Laxity in the ligaments that support the joint also produces non-coincident tracings. The condylar path for opening and closing motions are not superimposed (Fig.14). The tracing is usually superior in opening and inferior in closing. A TMJ with loose suspensitory ligaments allows the disk to move and change position over the condyle. A manipulation of the mandible can confirm this diagnosis: the operator guide the mandible by applying a force at the gonial angle in an upward (cranial) direction. Laxity is observed when the tracing of a free opening motion is not coincident with the path of a cranially loaded opening movement. Inability to reach the reference position at the end of the closing movement is also a sign of stretched ligaments (Fig.15).

Muscle hyperactivity also produces abnormal axiographic recordings. Tracings ending anterior to the reference position are frequently evidence of

Figure 12.

Geometric concentric cam effect.

The hinge axis is lowered when the flattened condylar head rotates.

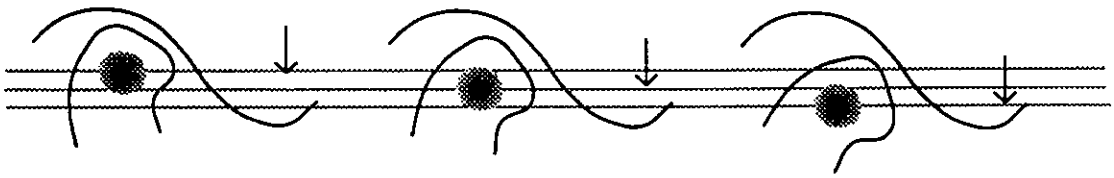
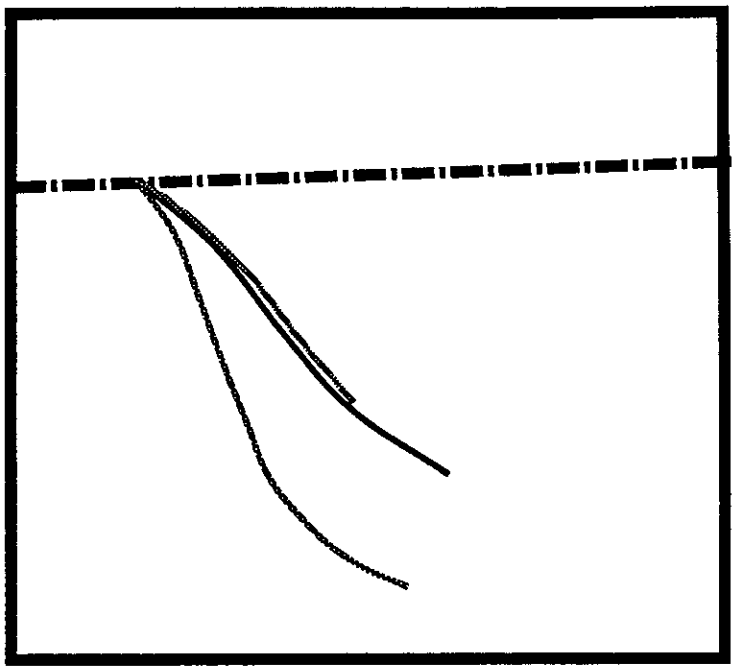


Figure 13.

Flattened condylar head.

Axiographic opening tracing is not superimposed with the tracings in protrusion and mediotrusion in the sagittal plane.

OPENING
PROTRUSION
MEDIOTRUSION

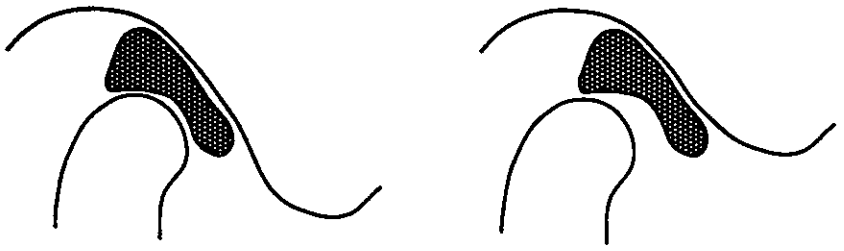


from Slavicek

Figure 14.

Ligamentous laxity of the TMJ.

Incursive and excursive movements are not superimposed. Sagittal plane tracing.



OPENING CLOSING

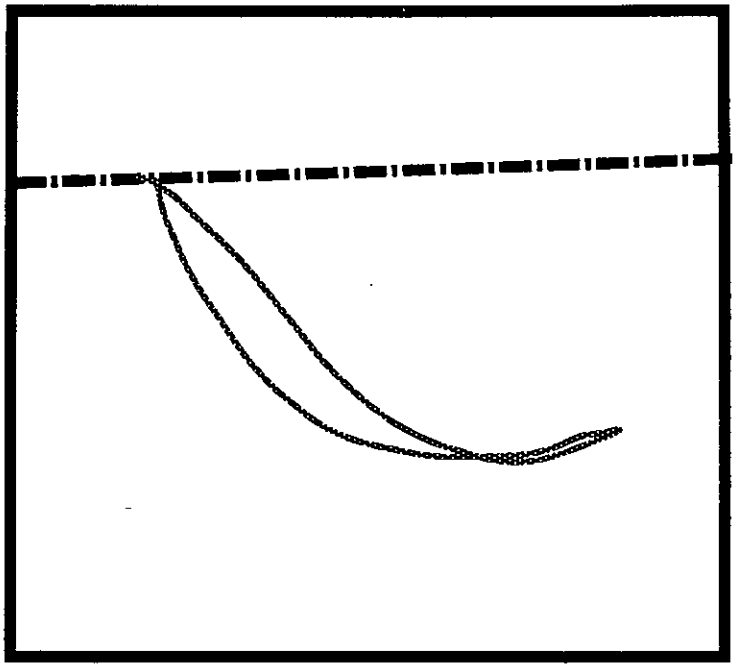
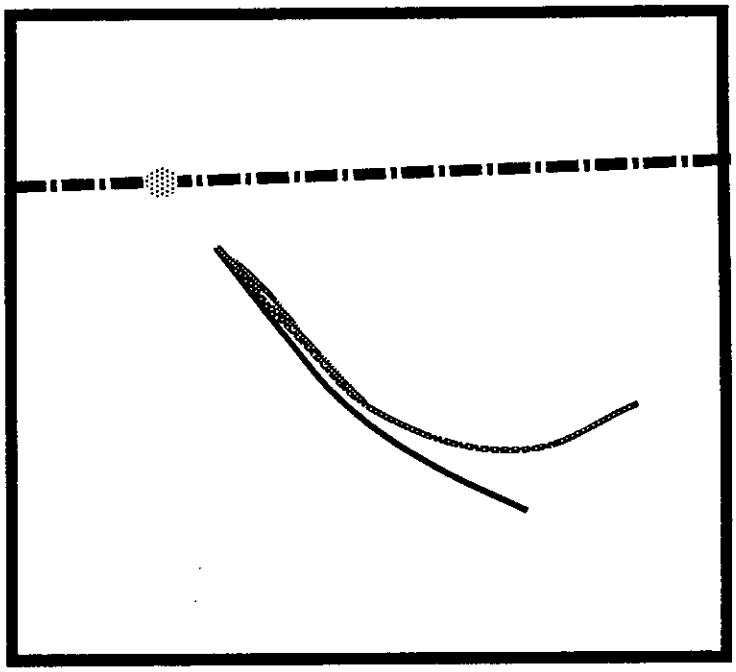


Figure 15.

Inability to reach the reference point during the incursive motions. Sagittal plane tracings.



from Slavicek

hyperactivity of the opening muscles (Fig.16). If the tracing terminates below and behind the reference point, a hyperactive temporalis is suspected. The degree of hyperactivity of the temporalis muscle is measured by the amount of subluxation taking place as the hinge axis pathway moves in an arc when the condylar head goes posteriorly and inferiorly, following the morphology of the posterior band of the meniscus (Fig.17)(Slavicek, 1988).

3.3. Protrusion-retrusion.

The protrusive tracings should coincide with the tracings generated during opening, and mediotrusive movements. Non-coincident tracings may indicate, loose joint ligaments, flattening of the condylar head, or muscular incoordination. The differential diagnosis is the same as described for the opening motion. The typical pattern of reduction-luxation with the two characteristic bulges of the condyle can be observed in protrusion-retrusion and mediotrusion-medioretrusion, as well as in opening-closing (Fig.5).

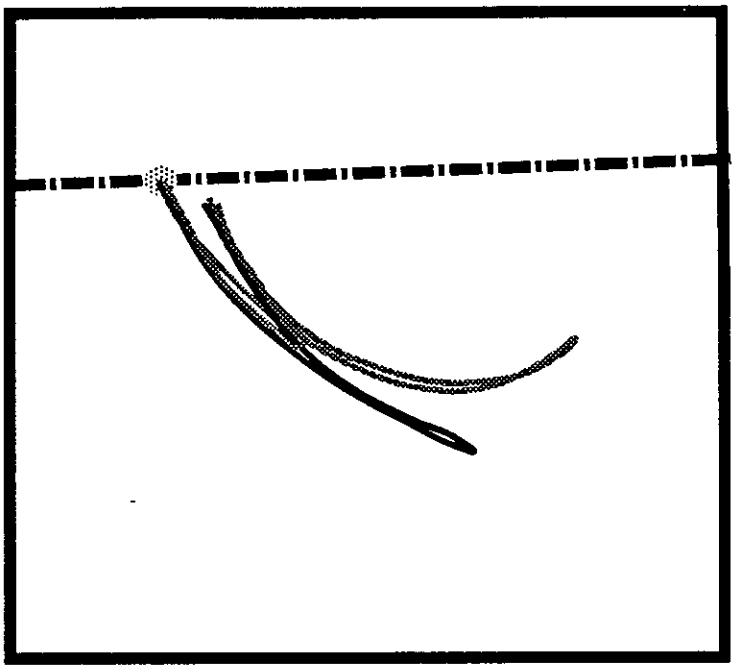
The normal amplitude of the axiographic tracing in protrusion is 10mm and a movement smaller than 8mm is considered abnormal (Slavicek, 1988). However, in some cases where the malocclusion limits mandibular excursions (Class II division 2), the movement is restricted because the muscles are unaccustomed to function in protrusion.

Asymmetrical timing of protrusive motion is due to an incoordination between the medial pterygoid muscle and the inferior head of the lateral.

Figure 16.

Hyperactivity of the opening muscles.

Sagittal plane tracings.

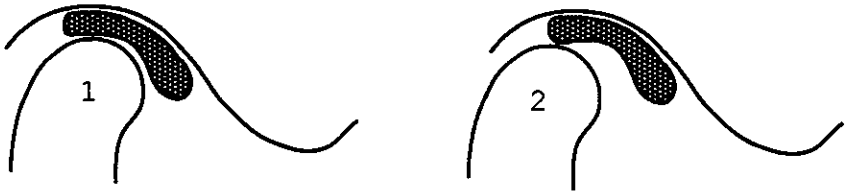


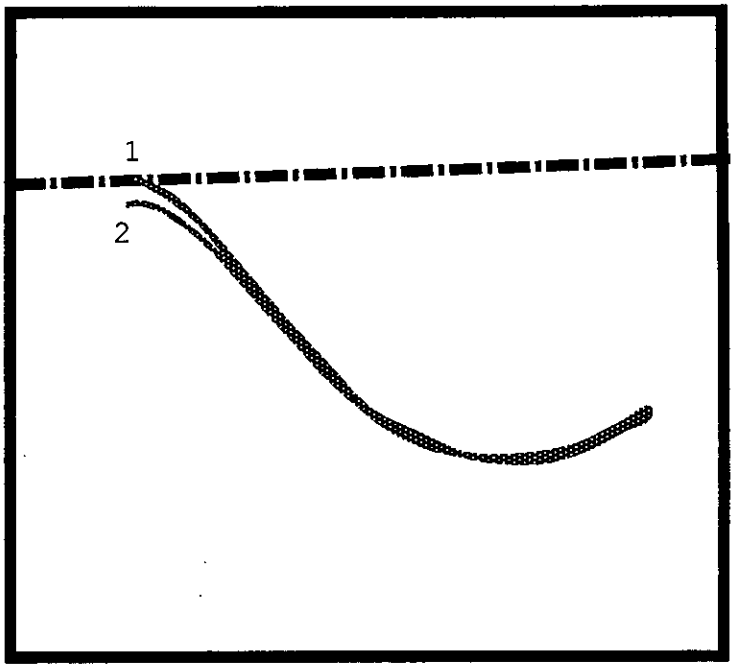
from Slavicek

Figure 17.

Hyperactivity of the temporalis muscle.

Sagittal plane tracings.





from Slavicek

pterygoid muscle. This incoordination can also produce a transverse movement detected on the horizontal (X/Y) graph (Fig.18). The tracing in protrusion should normally occur in a straight forward direction, without any transverse deviation. More than 1 or 2mm of transverse movement can be due to a muscular incoordination or to a displaced disk. The differential diagnosis is usually based on a clinical examination of the pterygoid muscles and the axiographic interpretation of the sagittal tracings. If the transverse displacement of the condylar heads is different for the left and right recordings, a muscle incoordination is be suspected.

3.4. Mediotrusion - Medioretrusion.

A normal mediotrusive path is about 12 mm(Slavicek, 1988). The differential diagnosis of anteriorly displaced disk, medially displaced disk, loose ligaments, luxation, subluxation, locked joint, muscles hyperactivity or incoordination, follow the same guidelines as for the opening and protrusive movements.

A medially displaced meniscus is an obstacle in the mediotrusive translation of the condylar head. As the lateral pterygoid pulls the condyle anteriorly and medially, the condylar head is forced downward (Fig.19). The Fisher angle is described as the angle between the path of the balancing condyle during a lateral border movement and the path along which it travels when a symmetrical protrusion is made (Preiskel, 1972). The Fisher angle is actually an artifact (LePera, 1967). In most of the pantographs, the recording vertical flags are far removed from the condyles. With the

Figure 18.

Deviation of the protrusive motion of the right and left condylar heads due to a muscular incoordination. Horizontal plane record.

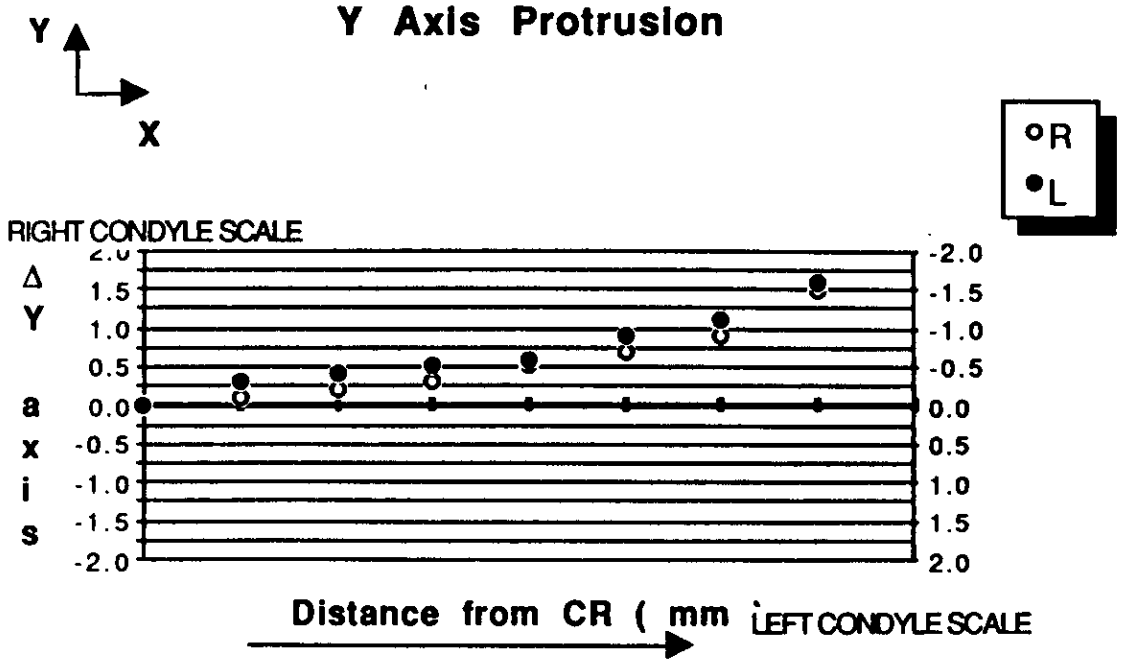
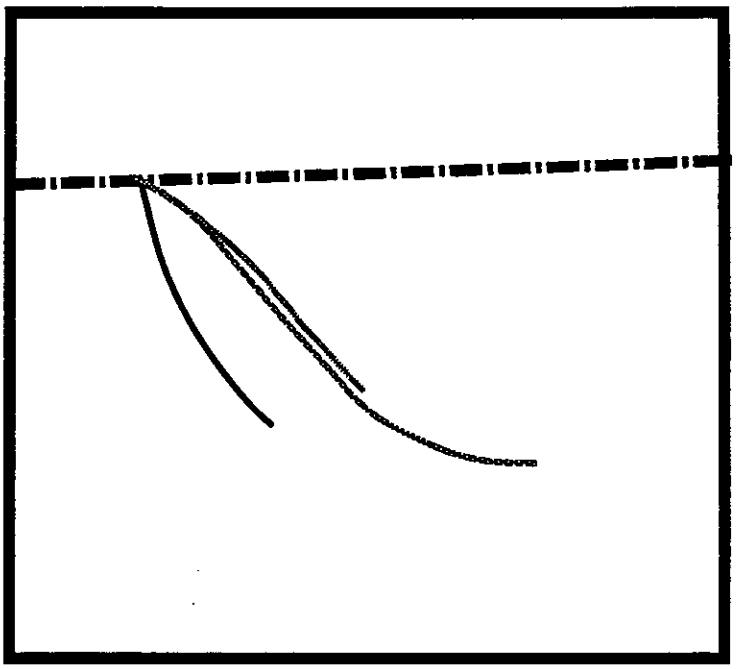

Y Axis Protrusion
Y
X
R
L
RIGHT CONDYLE SCALE
Δ Y axis
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Distance from CR (mm
LEFT CONDYLE SCALE

Figure 19.

Medially displaced meniscus. Sagittal recording showing that the tracing in mediotrusion is not superimposed with the other tracings.

OPENING
PROTRUSION
MEDIOTRUSION



from Slavicek

axiograph, the graph paper lies close to the skin, and there is normally no Fisher angle. The presence of a Fisher angle is a sign of medial displacement of the meniscus (Slavicek, 1988).

The Bennett movement is a translation of the condylar head toward the contralateral side, measured along the Y Axis. The Bennett movement can be divided in two different portions. The condylar head normally first travels medially along straight line (8-12 degrees from the X axis). This movement is called immediate side shift (ISS) . The second part of the motion is the progressive side shift (PSS) in which the condylar head moves mostly forward and slightly medially (Fig.20). A negative Bennett movement is a sign of an anteriorly and/or medially displaced disk (Slavicek, 1988). The anteriorly displaced disk usually produces a very irregular Bennett pattern (Fig.21) as the displaced disk disrupts the normal mediotrusive pathway. An absence of a transverse movement can be also due to a muscle controlled avoidance reflex (Slavicek, 1988). The amount of side shift is usually correlated with the extent of muscular dysfunction (Simonet and Clayton, 1981). Both components of the Bennett movement can be classified as curved (Type A) or straight (Type B). Type A and type B tracings are usually related to the shape of the mandibular condylar heads, but may be due, to a lesser extent, to the muscular pattern. Rounded condylar heads and convex articular eminences produce mostly type A tracings. Type B pathways tend to be generated by the flattened condylar heads and straight articular eminences.

Figure 20.

Normal tracing pattern in mediotrusion.

Orientation in the horizontal plane.

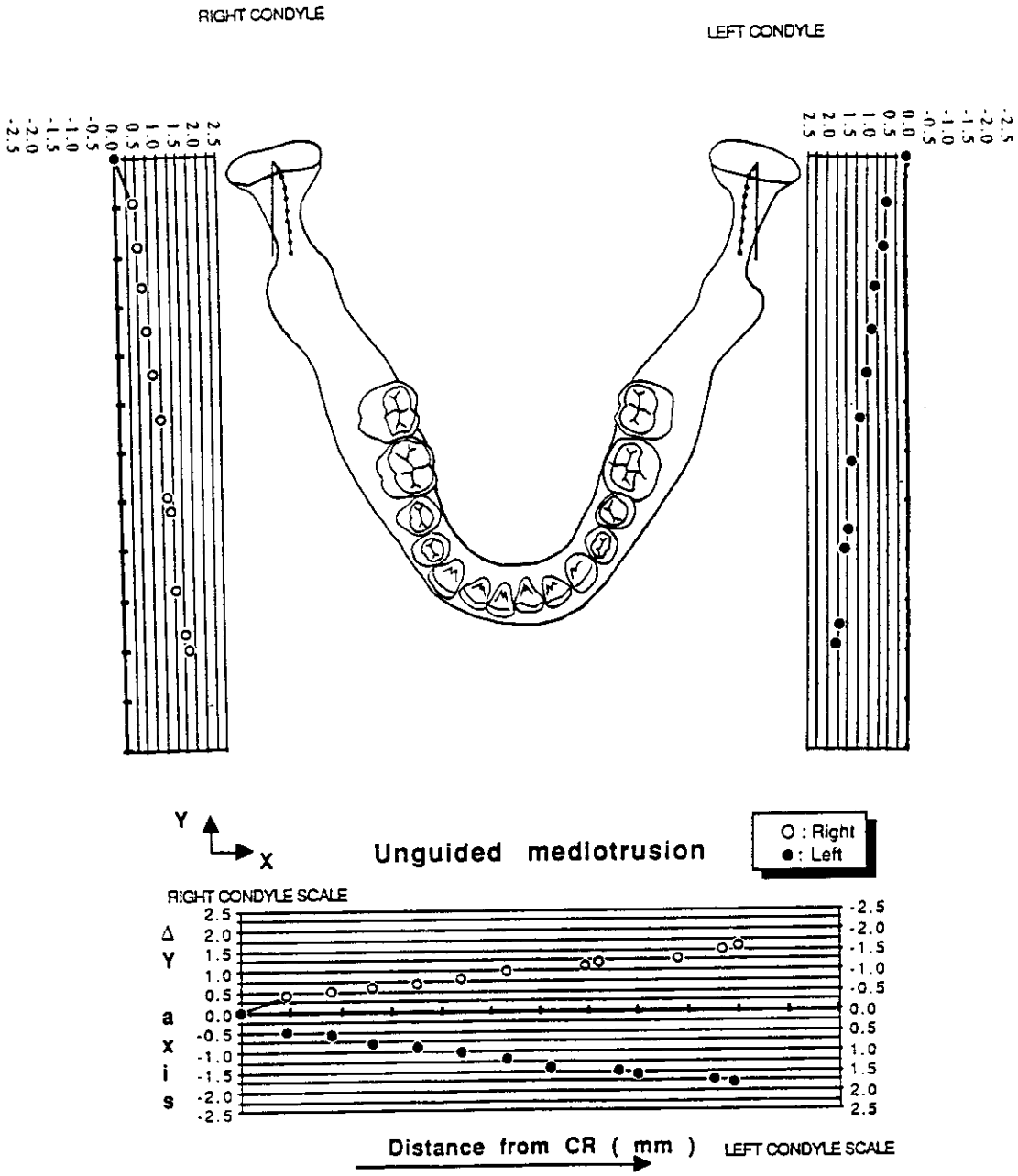
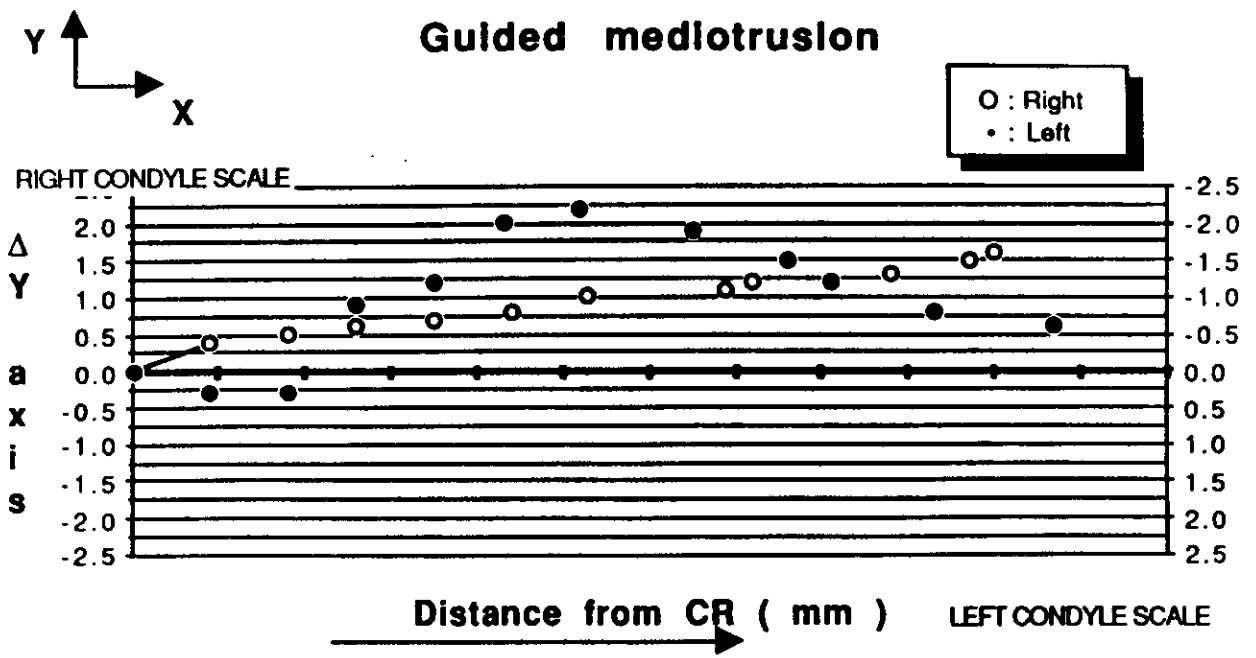

RIGHT CONDYLE
LEFT CONDYLE
Y
X
Unguided mediotrusion
O : Right
● : Left
RIGHT CONDYLE SCALE
Δ Y axis
2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5 -2.0 -2.5
-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5
Distance from CR (mm)
LEFT CONDYLE SCALE

Figure 21.

Abnormal mediotrusive excursion due to a medially displaced meniscus within the left TMJ.


Guided mediotrusion
Y
X
O : Right
• : Left
RIGHT CONDYLE SCALE
Δ Y axis
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
Distance from CR (mm)
LEFT CONDYLE SCALE

With muscular relaxation, type A tracings are sometimes more rounded (Mongini,1980).

The comparison of the guided and unguided mediotrusion pathway is also interesting. If there is a looseness of the joint, the amplitude of the Bennett guided movement should be significantly greater than the unguided side shift movement. In contrast, muscles spasms and contractures cause the amplitude of the unguided movement to be greater than the amplitude of the guided pathway.

3.5. General interpretation rules.

The timing of the condylar extrusions provides some information but its evaluation requires some experience with the axiographic procedure. If the joint presents some early signs of derangement, the affected side will move more slowly, or may be momentarily stopped by obstruction or adherence (Slavicek, 1988). Isberg-Holm and Ivarson (1980) reported that prior to condylar reduction, a retarded movement is often present and that the clicking is usually associated with an increased condylar velocity. Muscular incoordination may also affect the timing of mandibular movements. Slavicek (1988), reports a case with a loud clicking, but no evidence of a disc displacement on the parasagittal graphs. Observation of the velocity of the condylar heads confirmed the clinical diagnosis of a ligamentous problem.

The axiographic diagnosis must be closely correlated to the clinical

examination. Each abnormal axiographic finding has several different possible interpretations. A differential diagnosis, based on the clinical examination, is often necessary to rule out some of these possibilities.

Any movement of more than 4 millimeters, but less than 10 mm (e.g.7 mm in protrusion) is considered limited. A complete examination must be done to distinguish a muscular from a structural limitation. If limitation of movement is muscular in origin, the amplitude is increased when the movement is guided. Unlike a ligamentous limitation, restriction caused by a muscle splinting reflex may be improved after several manipulations. Limitations caused by a meniscus or ligamentous problem are generally less painful than muscular limitations. Muscular limitations are usually more easily detected in opening than in protrusion. A condylar path of only several millimeters is a sign of a disc displacement without reduction. In closed lock, one might suspect an anteriorly displaced meniscus, tumor, hyperfluid levels, adhesions, and arthritic disease (Slavicek,1988). If the tracing is short, but with a normal concave configuration, the possibility of an anteriorly displaced meniscus can be ruled out. If the tracing is short and also abnormal in shape (forced downward), one might suspect an anteriorly displaced meniscus without reduction. Limitation of mandibular movement due to a lack of synovial fluid produces axiographic tracings in which the mediotrusive and protrusive pathways are usually more limited than the opening tracing. The type of limitation can usually be improved by

manipulation. When there are adhesions between the disc and an articular surface, all movements of the condylar head are generally limited.

Both articular and neuromuscular factors significantly influence the tracing patterns of the mandibular border movements (Mongini and Capurso, 1982 ; Shields et al., 1978) . Occlusal splints and biofeedback therapy may improve the shape of the condylar paths (Simonet and Clayton, 1981). Chemical relaxation using sedatives and tranquilizers may also decrease muscular tension and incoordination. These therapeutic tools may be useful when the neuromuscular dysfunction is so active that a proper diagnosis of the anatomical changes within the joint cannot be made. Such modalities may also be utilized when it is not possible to consistently locate centric relation.

4. Summary of the axiographic findings.

The findings are recapitulated on an axiographic data spreadsheet presented in appendix(A). The measure of the length of the drawings and fourteen variables characterize the tracings on each side. Muscular incoordination is also graded.

4.1 Sagittal tracings (X/Z). Length.

The length of the three excursive tracings in the sagittal plane are measured with the overlay ruler using a magnifier (Peak™,2.5X). Limitations improved by manipulation are reported.

4.2 Diagnosis of disc displacement.

The diagnosis of disc displacement, observed in the sagittal and the horizontal plane is recorded in the first two cells.

4.3 Reduction - Luxation.

The distance from the reference point to the luxation or the reduction point is reported in the following six cells. The luxation or reduction point are defined on the tracings as the highest point behind the bulge when the condylar head luxates and in front of the bulge when the condylar head reduces. This corresponds to the point where the articular surfaces of the bony components of the joints are the closest to each other. Isberg (1989) proposed that it is probably at this point that the clicking occurs.

4.4 Subluxation in opening.

When there is a luxation of the condylar head in front of the temporal eminentia, a characteristic bulge is observed on the axiographic tracings, and reported in the chart.

4.5 Irregular surface of the eminentia.

Irregularities in the surface of the eminentia cause a deviation of the excursive and incursive movements at the same place.

4.6 Flat condylar head.

A flat condylar head causes the tracing of the condylar movement in opening to be not superimposed with the protrusive and mediotrusive tracings.

4.7 Muscular hyperactivity.

When the incursive tracing ends in front of the reference point, the opening muscles may be hyperactive. When the temporalis muscle is hyperactive, the incursive tracing is ending behind and below the reference point (Slavicek, 1988).

4.8 Laxity of the TMJ.

The symptoms of TMJ ligamentous looseness, i.e. the vertical discrepancy between the incursive and excursive movements, the occurrence of overotation and subluxation of the condylar head, and the inability to reach the reference position at the end of the incursive movement, are graded on a five points scale.

4.8 Muscular incoordination score.

This grade is based on the observation of the tracings in the horizontal plane. Muscular incoordination usually cause non-reproducible tracings, asymmetries between the right and left pathways, and progressive transverse

deviation of the condylar heads in opening and protrusion.

4.9 Protocol.

The axiographic tracings were recorded by the same operator between july 1989 and february 1990. Interpretation of the axiographic recordings was done by two orthodontists and one oral and maxillofacial surgeon. The axiographic recordings of the symptomatic and non symptomatic patients were randomized to prevent bias. The investigator with the greatest experience in interpretation of the axiographic findings is considered as the expert for the axiography. His findings are used as a reference in the results analysis.

5. History and clinical examination.

5.1. History.

The questionnaire designed by Slavicek (1988) is used for this study (See appendix B). The questionnaire is completed by the investigator. Ten questions about TMJ symptoms such as pain, dysfunction, noises are graded from 0 to 3 :

0 = No symptoms.

1 = Slight symptom.

2 = Moderate symptom.

3 = Severe symptom.

The scores are added to give an index of dysfunction. The dysfunction index is a subjective finding and does not reflect a gradation in the development of the TMJ syndrome (Dibbets and Van der Weele, 1986), but gives an idea of the degree of impairment of the masticatory function as reported by the patient. If the dysfunction index is less than 5, the problem is probably minimal. If the index is greater than 10, the problem needs to be more accurately outlined and the practitioner needs more information concerning any history of trauma, parafunctional activities, previous treatments, and the impact of TMJ functional difficulties in the subject's life (Slavicek,1988).

5.2 Clinical examination.

The clinical examination is summarized on a dedicated chart (See appendix B). The same operator did all the examinations, before doing the axiography.

5.2.1 Palpation of the head and neck muscles.

Myofacial pain is evaluated by palpation of the head and neck musculature. Skeletal muscles, tendons and ligaments may be tender upon palpation. The patient should be seated in a comfortable orthostatic position and bilateral muscles palpated at the same time. Digital pressure should be low to begin with and increased gradually. Pain elicited with minimal pressure is graded 3. A grade of 3 is also recorded if the palpation produces a

clear reaction from the patient: i.e., a palpebral response, or an avoidance reflex. Pain triggered by moderate pressure is graded 2 and minimal pain is graded 1; The patient may have difficulty in distinguishing the difference between the sensation of pain and the sensitivity caused by the palpation. No pain elicited under a significant amount of digital pressure is graded zero.

The patient is asked to bite forcefully into centric occlusion to outline the anatomy of the temporal and masseteric muscles (Rozencweig, 1984). The temporalis muscle is palpated between the external corner of the eye and the superoposterior region of the ear. The three bellies are palpated and graded separately. The superficial masseteric muscle is palpated along the inferior insertion, at the antegonial angle. Insertions of the deep fibers are palpated through the superficial fibers about three millimeters under the zygomatic arch. Only one grade is given for the entire evaluation of the masseter muscle. The lateral pterygoid is too deep to be felt directly by palpation, however, when applying pressure behind the maxillary tuberosity, the underlying tissues can transmit pressure to the inferior border of the lateral pterygoid's inferior belly and elicit a painful stimulus if the muscle is traumatized. The medial pterygoid is easier to reach. External and intraoral palpation is made at the inner face of the gonial angle. The anterior belly of the digastric muscle is palpated externally under the floor of the mandible. Only one grade is given for the entire palpation of the neck muscles, Sternocleidomastoid and upper trapezius.

5.2.2 TMJ palpation.

Palpation of the skin anterior to the tragus reveals a capsulitis of the external pole. Compression pain of the posterior part of the capsule is diagnosed by palpation within the external auditory meatus with the little finger when the patient is instructed to close.

5.2.3 Auscultation of the TMJ sounds.

A stethoscope is used to amplify and differentiate the TMJ sounds. Auscultation is made with every excursive and incursive movement. Early, intermediate and late clicking are noted at 1,2, or 3 fingers of opening. Upon closing, the grading is the same, but the scale is inverted : i.e., three fingers is an early click and one finger is a late click. Articular noises with protrusion-retrusion and mediotrusion-medioretrusion movements are also carefully recorded. Crepitus (a "grating noise" suggestive of degeneration of joint integrity) is noted upon opening and closing.

5.2.4 Range of motion.

Measurement of the horizontal and vertical movement of the mandible is particularly important for clinical diagnosis. All measures are recorded with a ruler and all movements are voluntary and unguided. When there is limited range of motion, the amplitude of the guided movements is also measured.

Overjet and overbite are measured with the posterior teeth in maximum intercuspidation. Maximum vertical opening is determined by adding the amount of separation between the incisal edges of the upper and lower central incisors to the amount of vertical overbite with the posterior teeth in occlusion. Similarly, the amount of overjet is added to the measurement of maximal protrusion. A vertical line corresponding to the maxillary dental midline is traced on the facial surface of the lower incisor. The range of motion in laterotrusion is measured between this landmark and the upper incisor midline. The motion index is computed as the amplitude of the opening divided by the sum of the amplitude of the protrusion and the right and left mediotrusion (Rozencweig, 1982). This index underlines the limitations of excursive movements most affected by internal derangement: Lateral excursions and protrusion.

5.2.5 Occlusal examination.

The mandible is placed in centric relation (CR) and the first contact is recorded. The patient is then instructed to slide to maximum intercuspidation. The direction and amplitude of CR-MIC shift is evaluated. When the shift is asymmetrical, a midline deviation is observed in the frontal plane. Working and balancing interferences are also noted.

5.2.6 Provocation test.

A wooden stick, five millimeters thick, is inserted between the

posterior teeth on one side. The patient is instructed to bite heavily for 30 seconds. Any pain developing in the opposite TMJ suggests internal compression. Relief of the pain in the TMJ on the same side (stick) is a sign of ipsilateral compression within that TMJ.

5.2.7 Deviation of the mandibular motion in protrusion and opening.

Opening and protrusive paths of the lower midline should be evaluated on the sagittal plane. A deviation of the lower midline can appear at any time during the mandibular motion. Any condylar luxation, reduction or locking may provoke a deviation. A marked ruler is placed along the facial midline and the lower midline is observed during the entire opening motion. In protrusion, the amount of deviation is measured in the end to end and maximal protrusive positions. Deviations may also be due to a muscular incoordination. This possibility can often be ruled out during the clinical muscular examination.

5.2.8 Resistance test.

Muscular involvement in myofacial pain dysfunction can be more precisely defined when muscular activity is stressed. The patient is instructed to open, close, protrude and go sideways while the operator applies a resistive force in the opposite direction. Opening and closing tests are done at two different vertical dimensions. Pain is graded on the same 0 to 3 scale

used for the muscle palpation.

5.2.9 Resiliency test.

This test has been described by Slavicek (1988). A piece of tin foil (Dentaurum™) 0.3mm thick is placed between the first molars on one side. The operator checks if there is a contact in the opposite side with an 8 micron piece of thick mylar shimstock. The patient is then asked to bite heavily. If the mylar paper resists removal, a second layer of tin foil is added. If the joint is resilient enough to hold the shimstock with 0.6mm, the test is done with 3 layers (0.9mm) (Slavicek, 1988). A child should hold at least 0.9mm, an adult 0.6mm. A lack of resiliency reflects a decreased histologic quality of the TMJ's soft tissue components (Slavicek, 1988).

6. Magnetic resonance imaging.

All scans are made with surface coils located over the TMJ area. The use of this small receiver coil enhances image quality by decreasing the distance and maximizing the signal/ noise ratio (Harms et al., 1985).

6.1. Group A.

In this experiment, symptomatic patients had magnetic resonance image studies done at different facilities, with different scanners. All the scanned joints are examined in the mouth closed and fully opened positions.

Magnetic resonance imaging data of 15 of the 22 patients was done at Marymount Hospital (Garfield Hts,OH). All of these scans were done with a General Electric imager (GR MR Max 0.5 Tesla). A coronal scout image is first used to locate the mandibular condylar head and orient the parasagittal plane. This first image is acquired in 48 seconds with a spin echo sequence, an echo time (TE) of 30 ms, and a repetition time (TR) of 300 ms. A spin echo sequence is also used to obtain the sagittal images with TE = 25 ms and TR = 500 ms on a 224*224 acquisition matrix. The slice thickness was 3mm and the acquisition time was 7 minutes 28 seconds on each side.

Four patients had their MRI studies done at Westlake Hospital (Westlake, OH). Angulation of the parasagittal slices is oriented with a coronal scout image, following the same protocol. The imager has a high (1.5 Tesla) magnetic field strength. All the images are obtained on a 256*256 acquisition matrix, using a spin echo technique, with a relaxation time of 500 and 800 ms, and an echo time of 25 and 20 ms. Slice thickness is 3mm.

Three other symptomatic patients have their MRI taken at 3 other different hospitals (Cleveland Clinic, University Hospital, Northern Ohio Imaging) with 1.5 and 0.5 tesla imagers.

6.2 Group B . Non symptomatic patients.

All the patients were examined in mouth closed position only. One

patient iwas examined at Picker International headquarters with a 0.5 tesla Vista imager. A spin echo sequence is used with TR = 350 ms and TE = 20 ms. Four millimeters thick slices are obtained on a 192*256 matrix in 9 minutes. The same protocol of orientation is used as described for the symptomatic patients.

All the other patients were imaged at Metro Health Hospital (Cleveland, OH), with a Picker vista 1.5 tesla imager. A spin echo scout scan was performed with a repetition time of 300 ms and an echo time of 30 ms. A 20mm slice was obtained in 38 seconds and displayed on a 128*256 matrix. Parasagittal oriented images were acquired in 6.4 minutes on a 192*256 matrix, with TR = 500 ms and TE = 26 ms. The slice thickness was 3mm.

6.3 Protocol.

The MRI studies of the 41 patients are examined by 3 different practitioners including one radiologist, one orthodontist and one oral and maxillofacial surgeon. Each one interpretates all the images. To avoid bias, the MRI of the symptomatic and non symptomatic patients are randomized, and the examiners are also unaware of the clinical examination and of the axiographic results. The radiologist is considered as the expert investigator for the MRI study. His findings are used as a reference in the results analysis.

Magnetic resonance images are depicted with 12 variables for each joint.

6.3.1 Resolution.

This variable grades the quality of the MRI, regardless of the normal and abnormal morphology of the TMJ. A clearly delineated MRI, with a condylar head, a temporal eminentia, and a meniscus sharply defined is graded 2. Grade 1 is given to a MRI presenting a lack of resolution, but with identifiable articular structures. A non-readable image is graded zero.

6.3.2 Disc displacement.

6.3.2.1 Meniscal posterior landmark.

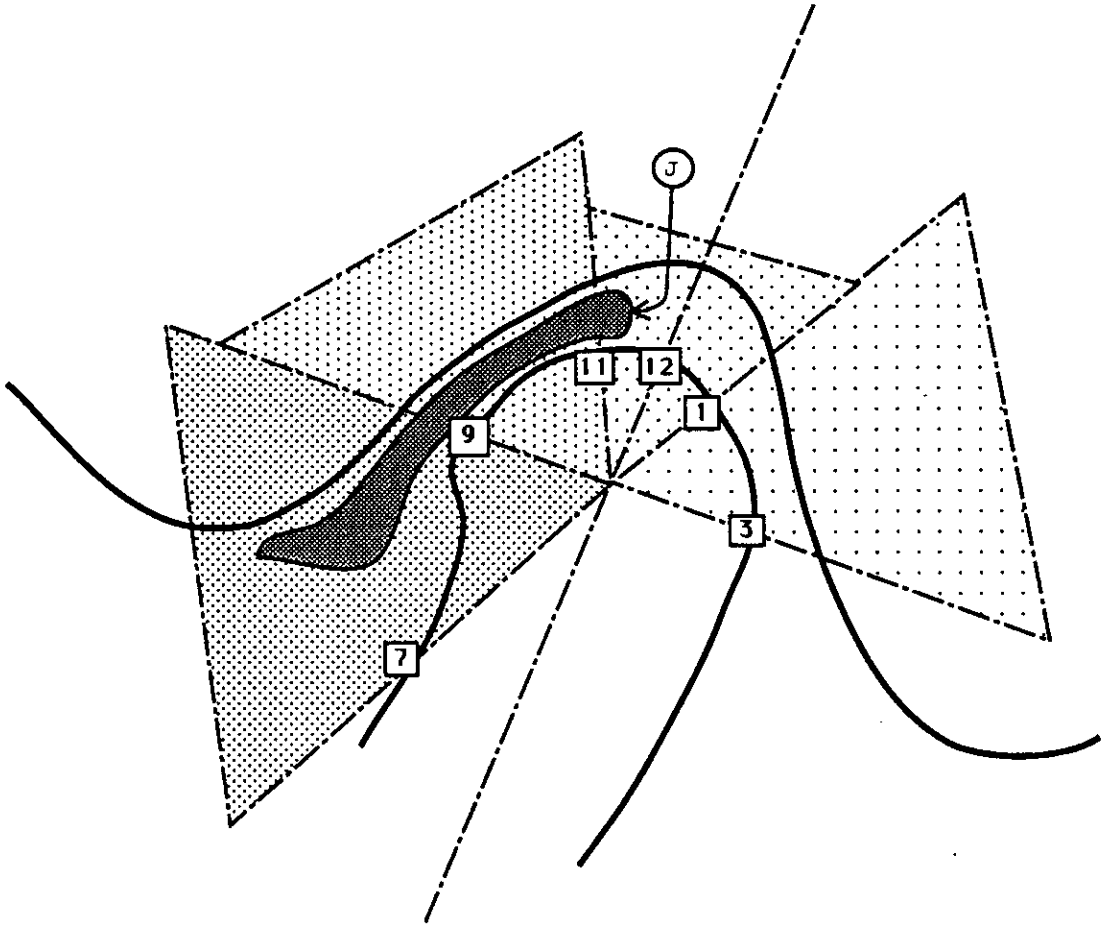
Point "J" is defined as the junction of the posterior band of the meniscus with the bilaminar zone (Figure 22): This variable is graded 1 if there is a clear delineation between the two structure; If not, the grade is zero.

6.3.2.2 Sagittal position of the disc. Mouth closed.

An imaginary line is drawn along the long axis of the condylar head. The center of the condylar head represents the center of a clock system with the long axis of the condylar head running through the 6 and 12 o'clock landmark (Fig. 22). The meniscus is considered to be normally positioned if J point is located between 11and 1 o'clock. The disc is considered partially anteriorly displaced between 9 and 11 o'clock, and completely anteriorly positioned between 7 and 9. When J point is after the 1 o'clock landmark, the

Figure 22.

Classification of the condyle-disc relationships in the sagittal plane.



Posteriorly displaced meniscus

Normally positionned meniscus

Meniscus partially displaced anteriorly

Meniscus totally displaced anteriorly

disc is posteriorly displaced.

6.3.2.3 Sagittal position of the disc. Opened mouth position.

The same clock system is used to grade the position of the meniscus when the mouth is in the fully extended position. The meniscus is considered anteriorly displaced if the condylar head is not in relation to the thinnest portion of the articular disc, and when the posterior band of the meniscus remains anterior to the condylar head. Figure 23 shows the right TMJ of a patient with a normal condylar head-meniscus relationship in mouth closed and mouth opened position. The corresponding axiographic tracing (Fig. 24) in the sagittal plane demonstrates smooth tracings for the three excursive movements. Figure 25 shows the MRI study of a left TMJ with anterior displacement of the meniscus in mouth closed position and reduction of the condylar head in mouth opened position. A bulge in the second third of the opening, protrusive, and mediotrusive tracing (reduction) and at the end of the incursive movements (luxation) is observed on the corresponding axiographic tracing (Fig. 26). Figure 27 presents the MRI study of a right TMJ with a meniscus remaining displaced throughout the entire range of motion. The corresponding pantographic tracing demonstrates short opening and protrusive tracings (Fig. 28).

Figure 24.

Axiographic tracings. Right TMJ with normal condylar head-meniscus relationship.

Red = protrusion / retrusion

Black = opening / closing

Blue = mediotrusion / mediotrusion

Figure 23.

MRI of the right TMJ.

Normal condylar head-meniscus relationship.

Mouth closed.

Mouth opened.

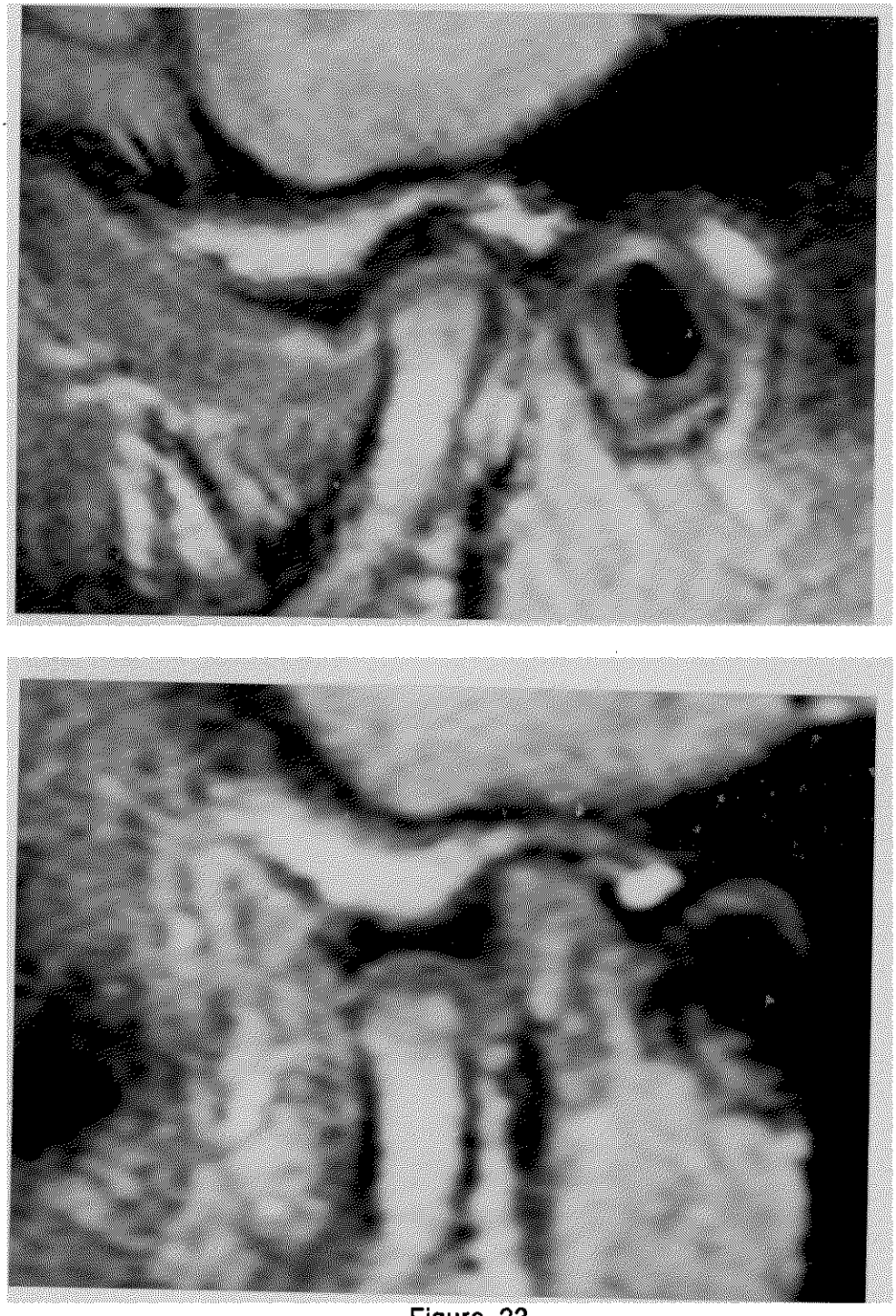


Figure 23.

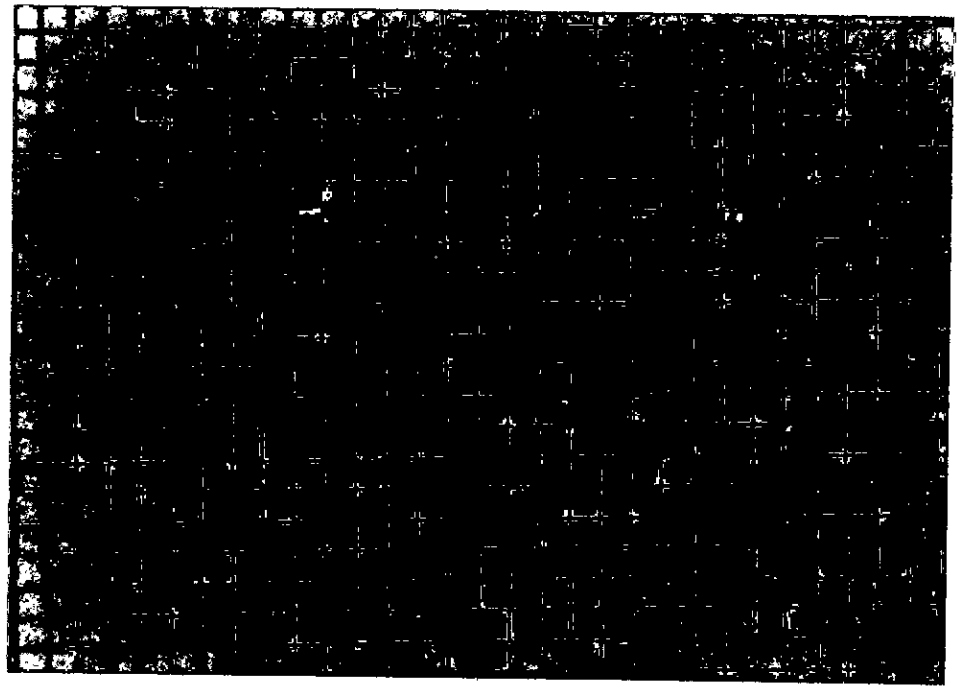


Figure 24.

Figure 25.

MRI of the left TMJ.

Mouth closed.

Anterior displacement of the meniscus.

Mouth opened.

The condylar head is reduced into the meniscus.

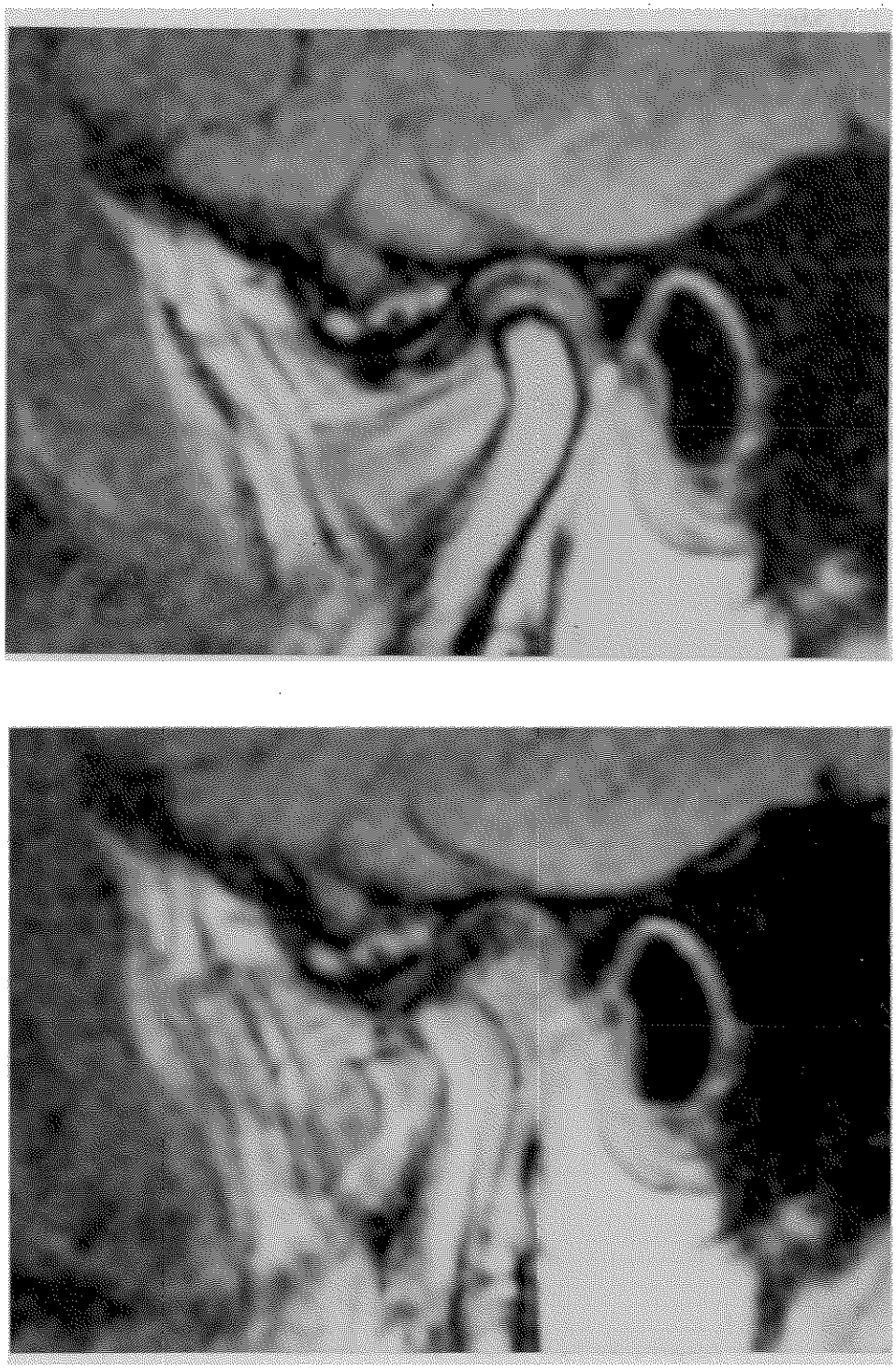


Figure 25.

Figure 26.

Axiographic tracing. Left TMJ. Anterior disc displacement with reduction in the second third of the excursive tracings.

Red = protrusion / retrusion

Black = opening / closing

Blue = mediotrusion / mediotrusion

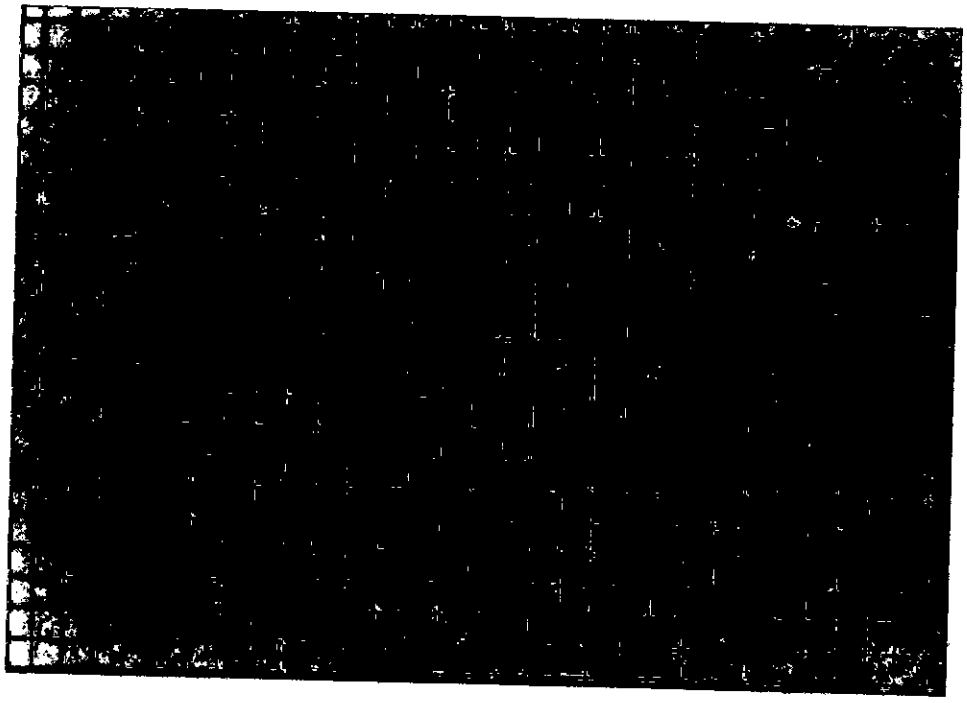


Figure 26.

Figure 27.

MRI of the right TMJ.

Anterior disc displacement in the mouth closed position.

Anterior disc displacement in the mouth opened position.



Figure 27.

Figure 28.

Axiographic tracings. Right TMJ.

Non reducing anteriorly displaced meniscus.

Short tracings in opening and protrusion.

Red = protrusion / retrusion

Black = opening / closing

Blue = mediotrusion / mediotrusion

6.3.2.4 Frontal position of the meniscus.

Medial and lateral disc displacement are determined indirectly from sagittal views or directly from frontal views when available. The meniscus is observed in relation to internal bony and soft tissue landmarks on multiple sagittal images.

6.3.3 Morphology.

6.3.3.1 Morphology of the condylar head.

The mandibular condylar head is graded as "flattened" when a line joining the superior and anterior pole is straight for at least two third of its length.

6.3.3.2 Morphology of the meniscus.

This field can contain up to four different variables. Grade zero is given to a normal biconcave meniscus. Grade 1 characterizes a biconvex meniscus. Grade 2 to 5 depict abnormal thickness of the anterior and the posterior band. A folded disc is graded 6. A meniscus with an even thickness from the anterior to the posterior band is graded 7. Grade 8 is given to an MRI with a low resolution, where the shape of the meniscus cannot be clearly defined. Grade 9 is used to indicate fatty degeneration of the meniscus. The rupture of the meniscus (perforation) into two distinct parts is graded 10.

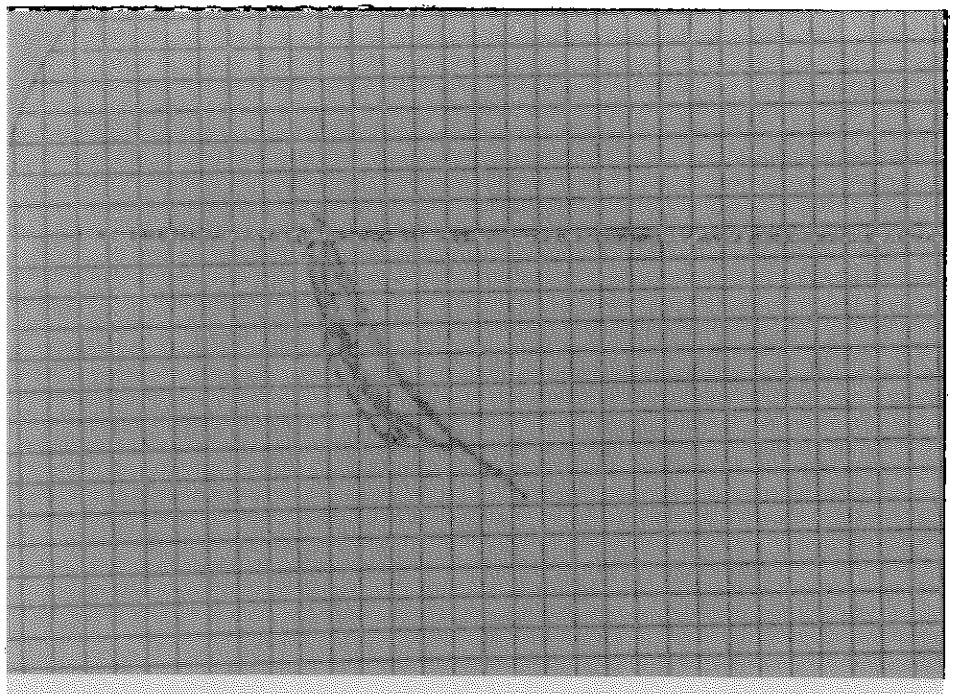


Figure 28..

6.3.4 Degenerative joint disease symptoms.

6.3.4.1 Cortical bone.

The quality of the delineation of the cortical bone with the surrounding tissues is graded zero if normal, and one if there is no clear continuity of the image of the cortical bone.

6.3.4.2 Erosion.

This variable characterizes the anatomic integrity of the bony structures. An erosion of the condyle or the temporal eminentia is graded 1.

6.3.4.3 Concavity/Lacuna.

This variable characterizes the resorption signs of a low grade degenerative process: i.e., the presence of a concavity or a subchondral lacuna.

6.3.4.4 Osteophyte.

Osteophytic bone growth on the condylar cortical bone is graded 1.Absence of osteophytes is graded 0.

6.3.5 Adhesions.

The joint space is sometimes filled with a low density material adherent to join the condylar head to the posterior slope of the eminentia. If

this is present a grade of 1 is used. A grade of 0 is used if no adhesions are present.

RESULTS

1. Final sample.

Twenty five patients with an history of internal derangement of the TMJ and twenty asymptomatic patients were studied. Among the 25 symptomatic patients, 15 presented with a history of unilateral internal derangement and 10 reported a bilateral problem. A thorough clinical examination was done to correlate the clinical findings with the history. Twenty-seven patients were found clinically to have internal derangement, unilateral for 11 patients, and bilateral for 8 patients.

All patients were axiographed after the clinical examination. axiographic symptoms on internal derangement were found bilaterally in 7 patients, and unilaterally in 10 patients.

Four symptomatic patients were financially unable to have an MRI study done. A MRI examination was conducted for 41 patients. A total of 79 joints were included in the study as three of the films were considered unreadable by the radiologist. Twelve patients were found to have an unilateral derangement and seven subjects were found to have a bilateral internal derangement as diagnosed with the MRI study. A total of 26 symptomatic and 53 asymptomatic joints were studied with the MRI. The sample is described in table I.

Table I

Summary of the sample description.

History - Chief complaint N=45

Symptomatic			Asymptomatic		
25			20		
Unilateral		Bilateral	Unilateral		Bilateral
15		10			

Clinical examination N=45

Symptomatic			Asymptomatic		
27			18		
Unilateral		Bilateral	Unilateral		Bilateral
11		8			

Axiographic examination N=45

Symptomatic			Asymptomatic		
24			21		
Unilateral		Bilateral	Unilateral		Bilateral
10		7			

MRI examination N=41

Symptomatic			Asymptomatic		
26			15		
Unilateral		Bilateral	Unilateral		Bilateral
12		7			

The results of this study will be presented in 8 sections :

1. Comparisons between axiographic and MRI results.
2. Comparisons between MRI and clinical results.
3. Comparisons between axiographic and clinical results.
4. Comparisons between different MRI variables.
5. Comparisons between different axiographic variables.
6. Comparisons between different clinical variables.
7. Comparisons between examiners.
8. Summary of the most significant results.

Only the results of the expert examiners will be studied in the first six sections. Section seven analyzes the variability of the results among investigators and the time related consistency of the axiographic reading for the same investigator. Section eight outlines the most significant results.

Most of the results are presented in this chapter in the format of two-way tables. Figure 29 describes the arrangement of the two-variables table with three categories.

2. Comparisons between axiographic and MRI results.

2.1 Displacement of the meniscus.

TMJ disc displacement was rated "0" if there was no disc displacement; "1" if there was a disc displacement with reduction of the condylar head in

Figure 29.

General description of the two-way result tables.

			Variable X Category 0 ↑	Variable X Category 1 ↑	Variable X Category 2 ↑
			0	1	2
Variable Y Category 0	←	0	Agreement	Disagreement	Disagreement
Variable Y Category 1	←	1	Disagreement	Agreement	Disagreement
Variable Y Category 2	←	2	Disagreement	Disagreement	Agreement

The values found in the diagonal of the table represent the count of the individuals with matching categories for both variables (X and Y).

In the shaded areas are counted the individuals with a category discrepancy between the row variable and the column variable.

Example :
Relation between the Axiographic and MRI classification of internal derangement.

			AXIOGRAPHY: No internal derangement ↑	Disc displacement with reduction ↑	Disc displacement without reduction ↑
MRI ↓			0	1	2
No internal derangement	←	0	46	7	0
Disc displacement with reduction	←	1	7	4	0
Disc displacement without reduction	←	2	6	2	7

Examples:
Cell 0\0 : 46 patients had no internal derangement diagnosed with MRI and Axiography.
Cell 2\0 : 6 patients had no internal derangement diagnosed with axiography, but a displaced meniscus without reduction diagnosed with the MRI.

open position; and "2" if there was a disc displacement without reduction in the mouth open position. This same classification was used for the axiographic and the MRI findings (table II). The Kappa test (Fleiss, 1981) was used to analyze the correlation between the axiographic and the MRI diagnosis of internal derangement. Kappa is a measure of consistency of the two categorical variables. Fleiss suggests that values of kappa less than 0.40 reflect poor agreement. With kappa between 0.40 and 0.75, agreement is fair to good. Values of Kappa above 0.75 indicate excellent agreement beyond chance. In this study, kappa (= 0.394) illustrates a fair agreement between the two methods of diagnosis. The overall value of Kappa is highly significant and the null hypothesis stating that there is no agreement between the MRI and the axiography when diagnosing internal derangement can be rejected ($p<0.01$). The McNemar test was used to measure the symmetry of the findings around the diagonal of the table (Fleiss, 1981). The McNemar statistic method tests the equality of frequencies in all pairs of cells that are symmetric around the diagonal of the table as shown in figure 29. In this study, a simple observation of the table indicates an asymmetry in the category 2. Six cases were diagnosed as "normal TMJ" (0) with the axiography and diagnosed as "disc displacement without reduction" (2) using the MRI study. In contrast, there were an equal number of disagreements for the diagnosis of disc displacement with reduction. Seven patients were diagnosed by axiography as having anteriorly displaced discs with reduction (1) when the MRI resulted in a diagnosis of normal condyle disc relationship (0), and seven patients were diagnosed by MRI as having anterior

Table II

Diagnosis of internal derangement.
Comparison of the axiographic and the MRI findings.

Axiography → / MRI ↑	0	1	2
0	46	7	0
1	7	4	0
2	6	2	7

	Value	d.f.	p
Kappa	0.394	∞	<0.01
McNemar	8	3	<0.05

displacement with reduction (1) when the axiography gave a diagnosis of normal condyle disc relationship (0). The overall McNemar test indicates no significant departure from symmetry in this table ($p<0.05$). A test of the disparity between the MRI and the axiographic classification of internal derangement was also done to correlate the ability of the examiner to detect the posterior disc landmark in the MRI study (table III). The accurate identification of the junction between the posterior band of the meniscus and the bilaminar zone is important to radiograpically diagnose the degree of TMJ internal derangement. This variable was graded "1" when there was no agreement between the axiographic and the MRI diagnoses, and "0" when the evaluations were alike. The disc posterior landmark was rated "0" when clearly visible, and "1" for any other situation. The kappa test indicates a poor correlation between the two variables ($k=0.11$). Therefore, the null hypothesis that the difference between the axiographic and MRI diagnosis is dependent on the visibility of the posterior band of the meniscus cannot be rejected ($p>0.20$). In other words, the visibility of the disc posterior landmark was not a significant factor of disagreement between the axiographic and MRI diagnoses.

2.2 Morphology of the condyle.

Table IV shows the relationship between the diagnosis of a flat condyle (Grade 1) and a normal rounded condyle (Grade 0) as determined with MRI or with axiography. The kappa test indicates that there is no correlation between the two variables, and the null hypothesis of independence cannot be rejected

Table III

Relation between the visibility of the disc posterior landmark and the concordance of the diagnosis with MRI and axiography.

Disc posterior landmark visibility →

	0	1
0	29	28
1	8	14

↑ Diagnosis

	Value	d.f.	p
Kappa	0.113	∞	>0.20

Table IV

Morphology of the condyle.

Axiography →

	0	1
0	58	15
1	5	1

↑ MRI

	Value	d.f.	p
Kappa	-0.022	∞	>0.60
McNemar	5	1	<0.05

($p>0.60$). The McNemar test shows a significant asymmetry ($p<0.05$): fifteen condyles were considered "flattened" using the axiography, but "normal" with the MRI study.

2.3 Amplitude of the disc displacement.

The amplitude of disc displacement observed on the MRI is correlated with the amplitude of condylar movement before reduction as displayed on the axiographic tracings (table V). The variable characterizing the amplitude of disc displacement was graded "0" when there was no disc displacement, "1" for a partially displaced disc, "2" for a totally displaced meniscus. The variable describing the amount of condylar translation before reduction was graded "0" when the tracing was smooth and presented no evidence of a reduction-luxation pattern, "1" when the reduction occurred in the first third of the opening translation, "2" when the reduction occurred in the second third of the movement, "3" when the reduction occurred in the last third of the movement, and "4" when the axiographic tracings suggested a disc displacement without reduction.

The chi-square statistic (X^2) appraises the departure from independence, and is described as follows:

$$\frac{(O - E)^2}{E}$$ With : O = Observed count , E = Expected count.

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

The null hypothesis is true when there is no significant relationship between

Table V

MRI evaluation of disc displacement and length of the axiographic tracing before reduction.

Disc displacement.

MRI →	0	1	2
0	46	7	6
1	6	2	0
2	1	1	2
3	0	0	1
4	0	0	7

↑

Axiography

Condylar translation before reduction

$\chi 2$	d.f.	p
33.47	8	<0.001

the variables. Large values of chi-square in a table of given size throw doubt on independence. In this study, $\chi 2$ is high, and the hypothesis of independence can be rejected ($p<0.001$). Therefore, a significant relationship exists between the position of the meniscus as seen in the MRI, and the the amount of condylar translation before reduction observed in the axiographic study.

2.4 Amplitude of condylar movements.

The amplitude of condylar movement in opening, protrusion, and mediotrusion was recorded with the axiograph and correlated with the MRI diagnostic classification of internal derangement. The variable was rated 0 if there was no disc displacement; One (1) if there was a disc displacement with reduction; and 2 if there was a disc displacement without reduction (table VI). The Kruskal-Wallis test (Mosteller, 1983) was used to test for a significant difference in amplitude of condylar movement between the different categories of internal derangement. All the observations are ranked for the three samples (three classes of internal derangement).

ni = number of observations in sample i,

Ri = sum of ranks in sample i,

$N = \Sigma_{ni,}$ and,

$W = w^3-w$, where w is the number of tied observations at a given level.

H is a measure of departure from equality when there are no ties in rank. When there is some ties, i.e. the same amount of condylar displacement, H is corrected by the following divisor:

Table VI

length of the condylar path in opening
for the three classes of internal derangement (in mm).

	Mean	Stand. dev.	Variance
0	14.02	2.92	8.53
1	14.82	3.87	14.96
2	10.57	4.71	22.17

H	H'
7.206	7.287

d.f.	Ho	p
2	Can be rejected	<0.05

If classes "1" and "2" are combined into one class, H'=1.74 , p>0.1 with 1 d.f.

Length of the condylar path in protrusion
for the three classes of internal derangement (in mm).

	Mean	Stand. dev.	Variance
0	10.94	2.29	5.25
1	9.72	2.76	7.62
2	9.13	2.94	8.69

H	H'
10.35	10.48

d.f.	Ho	p
2	Can be rejected	<0.001

If class "1" and "2" inare combined into one class, H'=9.98, p<0.01 with 1d.f.

Length of the condylar path in mediotrusion
for the three classes of internal derangement (in mm).

	Mean	Stand. dev.	Variance
0	13.44	2.48	6.18
1	13.86	3.19	10.2
2	12.73	2.98	8.92

H	H'
2.14	2.16

d.f.	Ho	p
2	Cannot be rejected	>0.35

If classes "1" and "2" are combined into one class, H'=0.351 , p>0.5 with 1 d.f.

divisor for ties = $1 - \Sigma W/(N^3-N)$

$$H = \left[\frac{12}{N^*(N-1)} \cdot \Sigma_i \frac{Ri^2}{ni} \right] - 3(N-1)$$ With no ties.

$$H' = \frac{H}{\text{Divisor for ties}}$$ With ties.

When [ni] is sufficiently large, the distribution of H' is approximately chi-square with C-1 degrees of freedom, where C is the number of samples. In this study, the null hypothesis stating that there is no difference in amplitude of condylar movement between the three categories of internal derangement can be rejected for opening ($p<0.05$) and protrusive ($p<0.01$) condylar motion. However, it cannot be rejected for the mediotrusive motion ($p>0.35$). It is interesting to observe that if the two classes of internal derangement "1" and "2" are combined in in one single class, the null hypothesis can only be rejected for the study of the protrusive condylar motion ($p<0.01$). This indicates that length or amplitude of the protrusive path is the most significant measurment to differentiate between TMJ's with internal derangement and TMJ's without internal derangement.

3. Comparisons between MRI and clinical results.

3.1. Degenerative joint disease.

Table VII-I displays the correlation between crepitus, audible during the clinical examination , and the signs of degenerative joint disease (DJD) observed in the MRI study. The variable "crepitus" is rated "0" if there is no

Table VII-I

Crepitus noise and MRI symptoms of DJD.

Auscultation.

Crepitus →	0	1
0	63	2
1	13	1

↑ DJD MRI

	Value	d.f.	p
Kappa	0.059	∞	>0.20
McNemar	8.067	1	0.0045

Table VII-II

Crepitus noise and
axiographic classification of internal derangement.

Classification Internal derangement.

MRI →	0	1	2
0	53	11	13
1	0	0	3

↑ Auscultation: crepitus.

$\chi 2$	d.f.	p
10.06	2	<0.05

crepitus, and "1" if there is crepitus. The parameter "DJD" is rated "1" if at least one of the four signs of DJD are graded "1" , and "0" if there is no symptoms of DJD observed on the MRI. The kappa statistic is small and indicates a poor correlation between the two variables ($p>0.20$). The McNemar test shows that there is a significant asymmetry in the table VI ($p< 0.005$): thirteen "no crepitus" TMJ's had at least one sign of DJD seen with the MRI study.

The variable "Crepitus" was also observed in the different groups of TMJ internal derangement (table VII-II). The $\chi 2$ statistic shows that the hypothesis of independence can be rejected ($p<0.05$) because crepitus was always associated with non reducing joints.

3.2. Auscultation : Clicking.

Table VIII and IX correlate the occurrence of reciprocal clicking in opening and protrusion during the clinical exam with the MRI classification of internal derangement. The variable clicking was rated "1" if there was clicking, and "0" if no clicking was audible. The parameter "Internal derangement" has been previously defined (Study1.1). The $\chi 2$ statistic was used to test the distribution of the clicking in opening (table VIII) and protrusion (table IX) in the different subgroups of internal derangement. The null hypothesis can be rejected ($p<0.05$) in both cases. There is a significant correlation between the MRI classification of internal derangement and the occurrence of the clicking in opening and protrusion. However, in eleven cases, the TMJ was clicking in opening, and the MRI study revealed no disc

Table VIII

Clicking noise auscultation upon opening and MRI classification of internal derangement.

Clicking opening Auscultation. →

	0	1
0	42	11
1	4	7
2	12	3

↑ MRI Classification of internal derangement.

χ^2	d.f.	p
8.99	2	<0.05

Table IX

Clicking noise auscultation in protrusion and MRI classification of internal derangement.

Clicking protrusion Auscultation. →

	0	1
0	49	4
1	7	4
2	13	2

↑ MRI Classification of internal derangement.

χ^2	d.f.	p
6.85	2	<0.05

displacement , three clicking TMJ's did not show any reduction of the condylar head on the MRI, and four non clicking joints had an anterior disc displacement diagnosed with the MRI.

3.3. TMJ palpation.

Table X shows the correlation between the occurrence of pain during intrameatal palpation of the TMJ and the signs of internal derangement observed with MRI. The parameter "Intrameatal palpation" was rated "0" if there was no pain, and "1" if there was pain in the retrocondylar region when the patient was closing the mouth. The $\chi 2$ shows that there is a significant dependence between the two variables ($p<0.05$) and therefore pain to intrameatal palpation is an indicator of internal derangement of the joint.

3.4. History.

The correlation between the history of internal derangement and the MRI classification of internal derangement was analyzed (table XI). The parameter "History" was graded "1" when there was an history of internal derangement, and "0" when the patient had not reported any symptoms of internal derangement. The $\chi 2$ shows that there is a strong relationship between the two variables ($p<0.001$). The MRI observation and the history given by the patient are coincident in more than 75% of the cases.

3.5. Compressive pain.

Table X

Pain intrameatal palpation and
MRI classification of internal derangement.

Intrameatal pain Palpation →	0	1
0	42	11
1	7	4
2	7	8

↑ MRI Classification of internal derangement.

χ2	d.f.	p
6.33	2	<0.05

Table XI

History and MRI classification
of internal derangement.

History of internal derangement. Questionnaire →	0	1
0	42	11
1	4	7
2	2	13

↑ MRI Classification of internal derangement.

χ2	d.f.	p
24.49	2	<0.001

Pain due to joint compression was measured with the Krogh-Poulsen test of vertical loading. This test had a poor correlation with the presence of MRI symptoms of DJD. The parameter "DJD" was rated as in study 3.1 and the parameter "Compressive pain" was graded "1" when there was pain, and "0" when there was no pain. Table XII shows the result of the kappa test. The kappa value suggests a poor correlation between the two parameters. The variable "Compressive pain" is equally distributed in the group of joints with signs of DJD and in the group of TMJ with no signs of DJD ($p>0.1$).

3.6. Resiliency of the joints.

Table XIII shows the correlation between the MRI classification of internal derangement and TMJ resiliency. The discrete parameter "Resiliency" is graded "0" when there was no resiliency, "1" when the resiliency was 0.3mm, "2" when the resiliency was 0.6mm, and "3" when the resiliency was 0.9mm. The $\chi 2$ statistic shows that there is no significant relationship between the resiliency of the joints and the MRI classification of internal derangement ($p>0.5$).

4. Comparison between axiographic and clinical findings.

4.1.Range of motion.

The correlation between the amplitude of condylar motion measured on the axiographic tracings and the range of motion measured between the upper and lower incisors was studied. (Table XIV, Figure 30). The amplitude of the

Table XII

Compression test and MRI symptoms
of degenerative joint disease.

MRI
DJD

→	0	1
0	. 53	9
1	12	5

↑
Compressive pain.

	Value	d.f.	p
Kappa	0.159	∞	>0.10

Table XIII

TMJ resiliency for the three classes
of internal derangement.

	MEAN	SD	VAR
0	5.82	2.76	7.65
1	6.00	2.68	7.20
2	4.62	3.59	12.92

χ^2	d.f.	p
5.44	6	>0.50

TMJ resiliency

→	0	0.3	0.6	0.9
0	3	13	17	16
1	0	4	3	4
2	2	4	2	4

↑
MRI
Classification of internal derangement.

Table XIV

Correlation between the amplitude of condylar movement and the range of mandibular motion.

In opening.

b	1.3
a	30.73
r	0.55
r2	0.3

SE(b)	0.3
SE(a)	4.14
SE(r)	0.13
SExy	6.96

t(b)	4.34
t(a)	7.42
t(r)	4.34

N	45
d.f.	43
Ho	Can be rejected
p	< 0.01

In protrusion.

b	0.38
a	4.39
r	0.39
r2	0.15

SE(b)	0.14
SE(a)	1.44
SE(r)	0.14
SExy	2.1

t(b)	2.78
t(a)	3.05
t(r)	2.78

N	45
d.f.	43
Ho	Can be rejected
p	< 0.01

In right mediotrusion.

b	0.38
a	4.35
r	0.46
r2	0.21

SE(b)	0.11
SE(a)	1.49
SE(r)	0.14
SExy	1.95

t(b)	3.44
t(a)	2.92
t(r)	3.44

N	45
d.f.	43
Ho	Can be rejected
p	< 0.01

In left mediotrusion.

b	0.56
a	1.74
r	0.69
r2	0.47

SE(b)	0.09
SE(a)	1.24
SE(r)	0.11
SExy	1.61

t(b)	6.26
t(a)	1.4
t(r)	6.26

N	45
d.f.	43
Ho	Can be rejected
p	< 0.01

right and left condylar path was averaged in opening and protrusion. We used the linear regression analysis to analyze the relationship between the two variables. The slope of the regression line is described by :

$$b = \frac{\Sigma\,(x\text{-}xbar)*(y\text{-}ybar)}{(x\text{-}xbar)^{2}}$$

The intercept is : a = ybar-bxbar.

The formula of the sample correlation coefficient is given by:

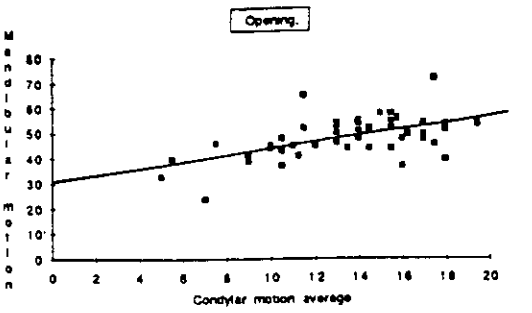
$$r = \frac{\Sigma\,(x\text{-}x)*(y\text{-}y)}{\sqrt{\Sigma\,(x\text{-}xbar)^{2} * \Sigma\,(y\text{-}ybar)^{2}}}$$

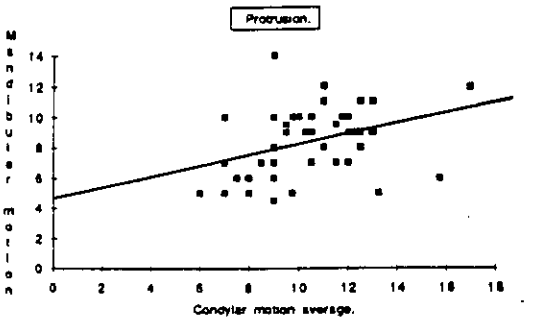
r varies between 1 and -1. Values of r close to 0 indicate that the variables bear no linear relationship to each other. The proportion of variability in the y values explained by the regression lineis obtained by squaring the r value. Values of r^2 may vary between 0 and 1. When r^2 is close to zero, the regression line is of no assistance in prediction of the y values. When r^2 is close to 1, the set of points is perfectly fitted by the regression line based on the x values. The null hypothesis (Ho) that r=0, is tested for all the pairs of variables with a Student t distribution and n-2 degrees of freedom.

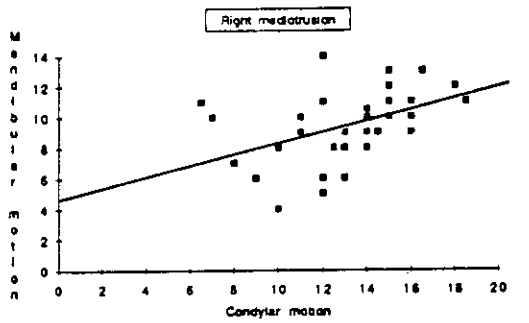
In the present study, the null hypothesis can be rejected for all the tests with the probability of a type I error less than one percent ($P<0.01$). There is a significant correlation between the condylar range of motion measured with the axiograph and the amplitude of the mandibular excursions measured between the lower incisors. However, the correlation

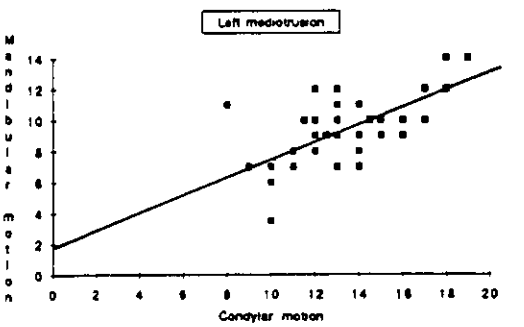
Figure 30.

Amplitude of the condylar head path correlated with the amplitude of the mandibular excursions measured between the incisors.


Opening.
Mandibular motion
Condylar motion average


Protrusion.
Mandibular motion
Condylar motion average.


Right mediotrusion
Mandibular motion
Condylar motion


Left mediotrusion
Mandibular motion
Condylar motion

coefficient is low for protrusion (r=0.39) and right mediotrusion (r=0.46). In addition, the proportion of variance explained by the regression line (r^2) is low for all comparisons.

4.2 Motion index.

This study examined the correlation between the motion index and the different classes of internal derangement determined by axiography (table XV). If O is the amplitude of the mandibular motion in opening, P in protrusion, RT and LT in right and left lateral excursion, the motion index (MI) is computed by the following formula :

$$MI = \frac{O}{(P+RT+LT)}$$

In this study, the variable "internal derangement" was rated "0" when there was no disc displacement in both TMJ's, "1" when there was a disc displacement with reduction in at least one of the TMJ, "2" when there was a disc displacement without reduction in at least one TMJ. The Kruskal-Wallis method was used to test for a significant difference between the three classes of internal derangement. In this study, the null hypothesis cannot be rejected (p=0.74). There is no significant difference in motion index among the different classes of TMJ internal derangement.

4.3. Neuromuscular dysfunction.

The muscular incoordination score, graded between zero and four by interpretating the axiographic tracing, was compared with the clinical

Table XV

Motion index for the three classes of internal derangement.

	MEAN	SD	VAR
0	1.82	0.27	0.07
1	1.86	0.61	0.37
2	2.20	0.95	0.90

H	H'
0.6614	0.6619

d.f.	Ho	p
2	Cannot be rejected	0.75

Table XVI

Muscle incoordination score (Axiography) and palpation score (Clinical exam).

	MEAN	SD	VAR
0	6.50	7.78	60.50
1	4.00	4.18	17.50
2	4.58	5.21	27.20

H	H'
2.54	2.76

d.f.	Ho	p
3	Cannot be rejected	0.46

palpation score. The clinical palpation score is the sum of the scores assigned to each muscle during the palpation. The Kruskal-Wallis method was used to test for a significant difference between the palpation score and the different groups of TMJ arranged according to muscular incoordination score (table XVI). In this study, the null hypothesis cannot be rejected ($p=0.46$) as there is no significant difference in muscle tenderness for the different TMJ groups when sorted by degrees of muscular incoordination. A linear regression analysis shows that the correlation between the two variables is weak ($r=0.11$), and there is no correlation between the muscle incoordiantion score obtained from the axiography and the clinical palpation evaluation of muscle tenderness.

4.4. Hyperactivity of the temporalis muscle.

The relationship between the axiographic evaluation of hyperactivity of the temporalis muscle and the clinical symptoms of temporalis muscle tenderness revealed by palpation was studied. The variable "Temporalis tenderness" was graded "0" when there was no tenderness for the three bellies of this muscle, and "1" when palpation revealed some pain in at least one area of the muscle. The results are shown on table XVII. The kappa statistic suggests a poor correlation between the axiographic and clinical diagnosis of temporalis hyperactivity ($p>0.1$)

4.5. Intrameatal pain.

The occurrence of pain during palpation of external auditory

Table XVII

Hyperactivity temporalis muscle.

Axiography →	0	1
0	64	19
1	7	0

↑

Palpation temporalis muscle.

	Value	d.f.	p
Kappa	-0.128	∞	>0.10

meatus was studied for each class of internal derangement (table XVIII). The variable "intrameatal pain" was graded "1" when there was some pain upon palpation, and "0" when no pain was elicited. The $\chi 2$ statistic shows that there was no significant relationship between intrameatal pain and axiographic classification of internal derangement ($p>0.2$).

4.6. Clicking.

The occurrence of audible TMJ clicking during the clinical examination was compared with the observation of disc-reduction detected on the axiographic tracings (table XIX). The variable "Clicking noise" was graded "1" when a clicking was audible, and "0" when there was no click. The value "1" was attributed to the parameter "Reduction" when there was an axiographic sign of reduction in opening. The kappa statistic shows a good correlation between the two variables ($k=0.67$). The hypothesis of independence can be rejected ($P<0.001$)as there is a good correlation found between clicking sound and the axiographic sign of reduction.

4.7. Palpation of the masticatory muscles.

The tenderness of the masticatory muscles to palpation was studied for the three classes of TMJ internal derangement (table XX). For this variable, the patient was considered to have significant muscular tenderness when the sum of the palpation scores was greater than three. The $\chi 2$ statistic shows that there was no significant relationship between tenderness of the masticatory muscles and the axiographic classification of internal

Table XVIII

Intrameatal pain upon palpation and
axiographic classification of internal derangement.

Intrameatal pain.

Palpation →	0	1
0	44	17
.1	9	4
2	4	4

↑ Axiography
Classification of internal derangement.

$\chi 2$	d.f.	p
1.63	2	>0.20

Table XIX

Clicking noise in opening and
symptom of reduction on the axiographic tracing.

Symptom of reduction

Axiography →	0	1
0	66	1
1	9	14

↑ Clicking in opening.

	Value	d.f.	p
Kappa	0.67	∞	<0.001

derangement ($p>0.2$).

4.8. Occlusal examination.

The relationship between occlusion and internal derangement was also studied for each class of internal derangement (table XXI). The variable "Dysfunctional occlusion" was considered positive if there was a premature contact in centric relation, or when there were interferences in laterotrusion and protrusion. The $\chi 2$ statistic demonstrates that no significant relationship exists between the axiographic classification of internal derangement and the occurrence of a premature contact in CR ($p>0.50$) or interferences in lateral excursions ($p>0.20$).

4.9. Deviation of the lower midline in function.

The direction of deviation of the lower midline in protrusion and opening during the clinical examination was compared to the amplitude of condylar movements determined from the axiographic tracings in opening and protrusion (table XXII). This study tests the assumption that a deviation of the lower midline is caused by an asymmetry between the movement of the right and left condylar head. The variable "Asymmetry condylar path" was graded "0" when the difference in amplitude between the right and left side was less than 2mm, "1" when the left path was longer than the right path, and "2" when the right path was longer than the left path. The variable " Deviation lower midline" was rated "0" when there was no deviation, "1" when there was a deviation to the right, and "2" when there was a deviation to

Table XX

Palpation score and
axiographic classification of internal derangement.

Tenderness Palpation →	0	1
0	47	14
1	10	3
2	4	4

↑ Axiography
Classification of internal derangement.

χ^2	d.f.	p
2.76	2	>0.20

Table XXI-II

Traumatic occlusion (premature contact in CR) and
axiographic classification of internal derangement.

Premature contact Occlusion →	0	1
0	4	23
1	2	8
2	1	3

↑ Axiography
Classification of internal derangement.

χ^2	d.f.	p
0.33	2	>0.5

Table XXI-II

Traumatic occlusion (interferences in laterotrusion)
and axiographic classification of internal derangement.

Occlusal Interference →	0	1
0	11	15
1	6	3
2	2	2

↑ Axiography
Classification of internal derangement.

χ^2	d.f.	p
1.59	2	>0.20

Table XXII-I

Midline deviation and asymetry
of the axiographic pathways in opening.

Midline deviation in opening. →

	0	1	2
0	28	3	5
1	0	2	0
2	2	2	0

↑ Axiography

	Value	d.f.	p
Kappa	0.225	∞	<0.05

Asymetry of the amplitude of the opening tracings.

Table XXII-II

Midline deviation and asymetry
of the axiographic pathways in protrusion.

Midline deviation in protrusion. →

	0	1	2
0	21	4	3
1	6	4	0
2	6	1	4

↑ Axiography

	Value	d.f.	p
Kappa	0.252	∞	<0.02

Asymetry of the amplitude of the protrusive tracings.

the left. The kappa statistic shows a weak, but significant correlation between the variables in opening ($p<0.02$) and protrusion ($p<0.05$). Observation of the tables suggests that the variables were not coincident in a large number of cases (28% in opening and 42% in protrusion).

4.10. Resiliency of the TMJ.

In each class of internal derangement, we observed the resiliency of the TMJ (Table XXIII). The "Resiliency" is a parametric variable that can take the value 0, 0.3, 0.6, or 0.9mm. The $\chi 2$ statistic demonstrates that there is a significant relationship between the axiographic classification of internal derangement and the TMJ resiliency ($p<0.05$).

4.11. Compressive pain.

The occurrence of pain upon loading of the condylar head in the fossa (Compression test) was studied for each class of TMJ internal derangement (table XXIV). The $\chi 2$ statistic demonstrates that there is a significant relationship between the axiographic classification of internal derangement and finding of compressive pain with loading of the condylar head in the fossa ($p<0.01$).

4.12. History.

The correlation between the history of internal derangement and the axiographic classification of internal derangement is shown in table XXV.

Table XXIII

TMJ resiliency for the three classes of internal derangement.

	MEAN	SD	VAR
0	6.05	2.61	6.78
1	5.40	3.10	9.60
2	2.63	2.97	8.84

χ^2	d.f.	p
14.18	6	<0.05

TMJ resiliency →	0	0.3	0.6	0.9
0	2	15	21	20
1	1	3	3	3
2	3	4	0	1

↑ Axiography

Classification of internal derangement.

Table XXIV

Compression pain and axiographic classification of internal derangement.

Compressive pain →	0	1
0	53	8
1	9	4
2	3	5

↑ Axiography

Classification of internal derangement.

χ^2	d.f.	p
11.44	2	<0.001

The parameter "History" is graded "1" if there was an history of internal derangement, and "0" if the patient did not report any symptoms of internal derangement. The $\chi 2$ statistic demonstrates that there is a significant relationship between the axiographic classification of internal derangement and the history of internal derangement ($p<0.01$).

5. Comparison between MRI variables.

5.1. Visibility of the disc posterior landmark.

Accurate identification of the junction between the posterior band of the meniscus and the retrodiscal ligament is important to assess the degree of relationship between the meniscus and the condylar head. The posterior landmark has been reported to be less visible when the meniscus is anteriorly displaced (Katzberg et al., 1985). Table XXVI shows a comparison of the operators ability to identify this landmark for each group of TMJ's with meniscal displacement. The variable describing the degree of disc displacement was graded "0" when there was no disc displacement, "1" for a partially displaced disc, and "2" for a totally displaced meniscus. The $\chi 2$ statistic reveals that the null hypothesis of independence between the two variables cannot be rejected ($p>0.20$). The occurrence of internal derangement was not significantly related to the visibility of the disc posterior landmark.

Table XXV

History and axiographic classification of internal derangement.

History of internal derangement →	0	1
0	49	12
1	1	12
2	1	7

↑ Axiography
Classification of internal derangement.

χ^2	d.f.	p
33.35	2	<0.001

Table XXVI

Visibility of the disc posterior landmark and MRI classification of internal derangement.

Visibility of the disc posterior landmark. →	0	1
0	26	27
1	3	8
2	8	7

↑ MRI
Classification of internal derangement.

χ^2	d.f.	p
2.05	2	>0.20

5.2. Morphology of the meniscus.

The chi-square method was also used to test if some morphologic characteristics of the meniscus appeared more frequently when there was an internal derangement with or without reduction. The morphology of the meniscus was observed in each class of TMJ internal derangement. Table XXVII shows the sample distribution for the disc morphology where "0" (Normal, biconcave shape), "4" (Hypertrophy of the posterior band), "5" (Hypertrophy of the anterior band), "6" (Flexture of the meniscus), and "7" (Even thickness). Other variations in disc morphology were not studied because of their small incidence. The normal biconcave shape of the meniscus was found in 81% of the normal joints, in 55% of the TMJ's with anteriorly displaced meniscus with reduction, and in 13% of the TMJ's with a non-reducing meniscus. The $\chi 2$ shows that the null hypothesis can be rejected ($p<0.001$). The distribution of the normal morphology of the meniscus does not follow a random distribution, but depends on the MRI classification of internal derangement. Hypertrophy of the posterior band of the meniscus was found in only 2% of the patients with normal disc position. In contrast, 9% of the TMJ's with a reducing disc, and 26% of the TMJ with a non reducing meniscus demonstrated thickening of the posterior band. The distribution of this characteristic depends on the MRI classification of internal derangement ($p<0.01$).

Table XXVII

Morphology of the meniscus and MRI classification of internal derangement.

➡ Morphology of the meniscus.

	0	1	2	3	4	5	6	7	8	9	10
0	43	1	0	2	1	6	0	7	0	0	0
1	6	0	0	0	1	2	0	3	0	1	0
2	2	0	0	0	4	3	8	7	1	1	1

⬇ MRI classification of internal derangement.

Tables of observed values

Obser.	non"0"	"0"	Total
0	10	43	53
1	5	6	11
2	13	2	15
Total	28	51	79

Obser.	non"4"	"4"	Total
0	52	1	53
1	10	1	11
2	11	4	15
Total	73	6	79

Observ.	Non5	"5"	Total
0	47	6	53
1	9	2	11
2	12	3	15
Total	68	11	79

Observ.	non"6"	"6"	Total
0	53	0	53
1	11	0	11
2	7	8	15
Total	71	8	79

Obser.	non"7"	"7"	Total
0	46	7	53
1	8	3	11
2	8	7	15
Total	62	17	79

Tables of frequencies.

%	"0"	non"0"
0	81.13	18.87
1	54.55	45.45
2	13.33	86.67

%	"4"	non"4"
0	1.887	98.11
1	9.091	90.91
2	26.67	73.33

%	"5"	non"5"
0	11.32	88.68
1	18.18	81.82
2	20	80

%	"6"	non"6"
0	0	100
1	0	100
2	53.33	46.67

%	"7"	non"7"
0	13.21	86.79
1	27.27	72.73
2	46.67	53.33

Chi-square tests.

X2	d.f.	p
24.05	2	<0.001

Ho can be rejected.

X2	d.f.	p
10.27	2	0.008

Ho can be rejected.

X2	d.f.	p
0.93	2	>0.5

Ho cannot be rejected.

X2	d.f.	p
37.98	2	<0.001

Ho can be rejected.

X2	d.f.	p
8	2	0.025

Ho can be rejected.

The symptom "hypertrophy of the anterior band of the meniscus" follows a random distribution ($p>0.5$). Fifty three percent of the joints with a non-reducing displaced meniscus were found to have a folded meniscus. Therefore, flexure of the meniscus is highly dependent on the classification of internal derangement ($p<0.001$). The meniscus was found to be of an even thickness in 13% of the normal joints, in 27% of the TMJ's with anterior displacement and reduction, and in 47% of the TMJ's with a non-reducing meniscus. The $\chi 2$ shows that the null hypothesis can be rejected ($p<0.05$). because the distribution of the finding "even thickness of the meniscus" does not follow a random distribution, as this variable correlates well with the MRI classification of internal derangement.

5.3. Degenerative joint disease.

Table XXVIII displays the correlation between the signs of degenerative joint disease (DJD) and the MRI classification of internal derangement. The parameter "DJD" was rated "1" if at least one of the four signs of DJD was present , and "0" if there was no symptoms of DJD observed on the MRI. The $\chi 2$ statistic demonstrates that there was a significant relationship between the axiographic classification of internal derangement and symptoms of DJD ($p<0.01$).

6. Comparison between the different axiographic parameters.

6.1. Amplitude of condylar movements.

The length of the axiographic tracings recorded during condylar

Table XXVIII

Symptoms of DJD and MRI classification of internal derangement

Symptoms of DJD →

MRI ↑	0	1
0	46	7
1	11	0
2	8	7

χ^2	d.f.	p
9.78	2	<0.01

Classification of internal derangement.

movement in opening, protrusion, and mediotrusion were compared to the axiographic diagnostic classification of internal derangement (table XXIX). The Kruskal-Wallis test is used to test for a significant difference between the amount of condylar movement and the different categories of internal derangement. The null hypothesis stating that there is no difference in amplitude of condylar movement between the three categories of internal derangement can be rejected for opening ($p<0.001$), protrusive ($p<0.01$), and mediotrusive ($p<0.01$) condylar motion. It is interesting to observe that if groups "0" and "1" are combined into one class, the null hypothesis can be rejected for the study of opening ($p<0.001$), protrusive ($p<0.01$), and mediotrusive condylar motion ($p<0.01$). If the two classes of internal derangement "1" and "2" are combined, the measurement of the protrusive and mediotrusive path can be used to differentiate joints with internal derangement from the joints without internal derangement (respectively, $p<0.01$ and $p<0.05$). The null hypothesis cannot be rejected in the study of the opening motion ($p>0.1$).

6.2. Correlation amplitude and looseness.

In this study, the amplitude of condylar movement was correlated with the looseness of the joint. TMJ looseness was observed on the axiographic tracings and graded between zero and four. Spearman's Rho method was used to test for a correlation between one discrete and one continuous variable. The two variables were sorted and ranked. The square of the difference between the ranks of the two variables was then computed for

Table XXIX

Amplitude of the condylar path in opening for the three classes of internal derangement.

	Mean	Stand. dev.	Variance
0	13.95	3.03	9.18
1	14.47	4.07	16.55
2	6.75	1.83	3.36

H	H'
19.57	19.76

d.f.	Ho	p
2	Can be rejected	<0.001

If classes "1" and "2" are combined in one class, H'=2.63 , p>0.1 with 1 d.f.
If classes "0" and "1" are combined in one class, H'=19.06 , p<0.001 with 1 d.f.

Amplitude of the condylar path in protrusion for the three classes of internal derangement.

	Mean	Stand. dev.	Variance
0	10.72	2.55	6.50
1	9.86	2.17	4.71
2	7.75	1.69	2.86

H	H'
10.74	10.88

d.f.	Ho	p
2	Can be rejected	<0.01

If classes "1" and "2" are combined in one class, H'=7.54, p<0.01 with 1d.f.
If classes "0" and "1" are combined in one class, H'=9.02, p<0.01 with 1d.f.

Amplitude of the condylar path in mediotrusion for the three classes of internal derangement.

	Mean	Stand. dev.	Variance
0	13.75	2.42	5.86
1	13.10	3.26	10.63
2	10.50	1.69	2.86

H	H'
11.1	11.24

d.f.	Ho	p
2	Can be rejected	<0.01

If classes "1" and "2" are combined in one class, H'=5.56 , p<0.05 with 1 d.f.
If classes "0" and "1" are combined in one class, H'=10.72 , p<0.01 with 1 d.f.

each TMJ. Let

$$C = \frac{n^3 - n}{6}$$

$Tx = \Sigma$ [(#of ties)^3-(#of ties)] /12 for the first variable.

$Ty = \Sigma$ [(#of ties)^3-(#of ties)] /12 for the second variable.

$D = \Sigma$ (Rank variable 1-Rank variable 2)^2

$$r = \frac{(C - Tx - Ty - D)}{2\sqrt{(\frac{C}{2} - Tx) * (\frac{C}{2} - Ty)}}$$ Correlation coefficient.

$$SE\ r = \frac{\sqrt{(1 - r^2)}}{\sqrt{(n - 2)}}$$

$$t = \frac{r}{SE\ r} \qquad d.f. = n-2$$

The null hypothesis (Ho) stating that r=0 was tested with a Student t distribution and n-2 degrees of freedom. In this study, Ho cannot be rejected (p= 0.0922). The correlation coefficient is small (r = 0.18) and the percentage of values of the first variable explained by the regression line is very small (r2 = 0.032). There is no significant correlation between looseness of the TMJ and amplitude of condylar movement in opening (p>0.05). However, the mean amplitude in opening increases slightly as the looseness of the TMJ increases (table XXX).

6.3. Correlation amplitude and subluxation.

The Kruskal-Wallis test was used to determine if there was a

Table XXX

Length condylar movement in opening and looseness.

➨ Amplitude in opening.

	Mean	SD	Var.
0	12.31	4.07	16.60
1	13.56	3.42	11.80
2	13.77	3.78	14.30
3	14.71	3.40	11.60
4	15.75	2.47	6.10

➨ Looseness of the TMJ

➨ Spearman test

n	90
C	121485
Tx	4996.5
Ty	578.5
D	95021
r	0.180
r-Sq	0.033
SEr	0.105
t	1.720
d.f.	88
p	0.092

significant difference in opening between the group of normal patients and the group of patients with subluxation (table XXXI). The null hypothesis, that there is no significant difference in amplitude can be rejected ($p<0.01$). therefore, subluxation of the condylar head occurs when the condylar head range of motion is significantly increased.

6.4. Correlation between looseness and internal derangement.

The axiographic observation of the TMJ looseness was graded from zero to four and correlated with the different classes of internal derangement. The Kruskal-Wallis test is used to test for a significant difference in looseness among the different groups (table XXXII). The null hypothesis stating that there is no significant difference in TMJ looseness among the three groups can be rejected ($p<0.05$). There is also a significant difference between normal and reducing TMJ's (Group 0 and 1), and non-reducing TMJ's (Group 2) ($p<0.05$). However, there is no significant difference in looseness between reducing and non reducing TMJ's internal derangements (Groups 1 and 2) and normal joints (Group 0)($p>0.5$).

7. Comparisons between different clinical variables.

7.1. Range of motion of the mandible and palpation score.

This study was used to test for a correlation between palpation score and motion of the mandible measured between the incisors. The palpation score is the sum of the grades characterizing the tenderness of the different muscles. A linear regression was used to compute correlation

Table XXXI

Correlation amplitude and subluxation.

	MEAN	SD	Var.
0	13.11	3.65	13.32
1	18.20	1.64	2.69

H	H'
10.39	10.5

d.f.	Ho	p
1	Can be rejected	<0.01

Table XXXII

TMJ Looseness for the three classes of internal derangement.

	Mean	SD	Var.
0	1.21	1.08	1.17
1	1.76	0.83	0.69
2	0.50	0.75	0.57

H	H'
7.74	8.41

d.f.	Ho	p
2	Can be rejected	<0.05

If Classes "1" and "2" are combined in one single class, H'=0.196 , p>0.5 with 1 d.f.
If Classes "0" and "1" are combimned in one single class, H'=4.52 , p<0.05 with 1 d.f.

coefficients (table XXXIII) and there was no significant correlation between the palpation score and mandibular range of motion in opening or protrusion ($p>0.20$). However, there was a weak correlation between palpation score and mandibular range of motion in left ($p<0.01$) and right ($p<0.05$) laterotrusion. The correlation coefficients were small, and the percentage of variance in the range of motion predicted by the palpation score was small. There was also a significant correlation between the motion index and the palpation score ($p<0.05$).

7.2. Relation between occlusal interferences and history.

Table XXXIV shows the relationship between the history of internal derangement and myofacial pain dysfunction and the presence of a traumatic occlusion. The occlusion was considered traumatic and graded "1" when there was a premature contact in centric relation or an interference in laterotrusion. When there were no occlusal symptoms the variable was graded "0". The parameter "History of internal derangement" was graded "1" when there was an history of internal derangement and "0" when no symptoms were reported. The parameter "History of myofacial pain dysfunction" was graded "1" when there was an history of muscle pain and "0" when no symptoms were reported. The kappa statistic shows no correlation between the occurrence of interferences in lateral excursions or premature contact in centric relation and the history of internal derangement ($p>0.80$) or myofacial pain dysfunction ($p>0.20$).

Table XXXIII

Correlation between the amplitude of mandibular movement and the palpation score.

In opening.

b	-0.289	SE(b)	0.25	t(b)	-1.15	N	45
a	49.47	SE(a)	1.67	t(a)	29.67	d.f.	43
r	-0.173	SE(r)	0.15	t(r)	-1.15	Ho	Cannot be rejected
r2	0.03	SExy	8.23			p	>0.20

In protrusion.

b	-0.62	SE(b)	0.07	t(b)	-0.9	N	45
a	8.57	SE(a)	0.46	t(a)	18.69	d.f.	43
r	-0.13	SE(r)	0.15	t(r)	-0.9	Ho	Cannot be rejected
r2	0.017	SExy	2.26			p	>0.20

In right laterality.

b	-0.15	SE(b)	0.06	t(b)	-2.43	N	45
a	10.04	SE(a)	0.42	t(a)	23.69	d.f.	43
r	-0.34	SE(r)	0.14	t(r)	-2.43	Ho	Can be rejected
r2	0.116	SExy	2.09			p	<0.05

In left laterality.

b	-0.18	SE(b)	0.06	t(b)	-2.96	N	45
a	10.18	SE(a)	0.41	t(a)	24.99	d.f.	43
r	-0.41	SE(r)	0.14	t(r)	-2.96	Ho	Can be rejected
r2	0.168	SExy	2.01			p	< 0.01

Correlation between the motion index and the palpation score.

b	0.026	SE(b)	0.01	t(b)	2.03	N	45
a	1.72	SE(a)	0.09	t(a)	19.8	d.f.	43
r	0.296	SE(r)	0.15	t(r)	2.03	Ho	Can be rejected
r2	0.088	SExy	0.43			p	< 0.05

Table XXXIV-I

Traumatic occlusion and history of internal derangement.

Interference
Premature contact
Occlusion →

	0	1
0	5	27
1	3	10

↑ History of internal derangement.

	Value	d.f.	p
Kappa	-0.048	∞	>0.80

Table XXXIV-II

Traumatic occlusion and MPD history.

Interference
Premature contact
Occlusion →

	0	1
0	2	18
1	6	19

↑ History of myofacial pain dysfunction.

	Value	d.f.	p
Kappa	-0.149	∞	>0.20

7.3. Compressive and intrameatal pain.

The occurrence of pain triggered by the compression test and pain elicited by palpation within the external auditory meatus were compared (table XXXV). Grade "1" was assigned to the painful TMJ and grade "0" to the non-painful joints. The $\chi 2$ statistic indicates that the null hypothesis of independence between the two variables cannot be rejected ($p>0.20$). No significant correlation was found between the pain caused by intrameatal palpation and the pain provoked by vertical loading of the condyle.

7.4. Compressive pain and resiliency.

TMJ resiliency was studied in the groups of TMJ's with and without compressive pain (table XXXVI). Grade "1" was assigned to painful TMJ's and grade "0" to non-painful joints. The Kruskal Wallis test method was used to determine if there was a significant difference in resiliency between the two groups. The null hypothesis stating that there was no significant difference between the two groups cannot be rejected ($p>0.20$).

7.5. Resiliency and age of the patient.

Table XXXVII shows that there is no relationship between the average resiliency of the right and left temporomandibular joints and the age of the patient.

Table XXXV

Pain compression test and pain intrameatal palpation.

Intrameatal pain
Palpation →

	0	1
0	49	19
1	13	9

↑
Compressive test.

χ^2	d.f.	p
1.30	1	>0.20

Table XXXVI

TMJ compressive pain and resiliency.

	Mean	St. dev.	Variance
0	5.74	2.76	7.61
1	4.40	2.97	8.83

H	H'
2.486	2.73

d.f.	Ho	p
1	Cannot be rejected	>0.20

Table XXXVII

TMJ resiliency and age in days.

➨ Average resiliency of the right and left TMJ.

Resiliency:	Mean:	Stdev :	Var :
0.0	8096	5659	32,024,005
1.5	10015	6611	43,701,901
3.0	7821	3962	15,697,187
4.5	6435	2884	8,318,692
6.0	5638	1925	3,707,368
6.0	5638	1925	37,073,668
7.5	7666	6019	36,225,930
9.0	7607	4334	18,785,205

➥ Age in days.

8. Correlation between examiners.

8.1. Classification of internal derangement.

8.1.1. Interrater reliability for the same type of examination.

The axiographic and MRI findings were compared between the expert and two different examiners (table XXXVIII). The values of kappa illustrate a "fair to good" concordance between the ratings. The null hypothesis stating that there is no agreement between the expert and the other examiners can be rejected ($P<0.001$). It is interesting to note that there was generally more concordance between the expert and the two other raters in the axiographic study than in the MRI study. The evaluation of the examiner number 2 was also closer to the expert's findings than the conclusions of the examiner number 1 for both MRI and axiographic studies. Rater number 1 had a large number of false positive axiographic and MRI findings for the category "Displacement with reduction", and some false negative axiographic readings in the category "displacement without reduction". Rater number 2 had a large number of false positive MRI findings for the category "Displacement with reduction".

8.1.2. Comparison of axiographic and MRI findings with expert and non-expert raters.

The values of the kappa statistic (table XXXIX) show that there is a significant correlation between the expert evaluation and the other raters conclusions for all the tests ($p<0.001$) except when the axiographic findings

Table XXXVIII

Classification of internal derangement.
Interrater reliability for the same type of examination.

					test	k	p
Axiography	Expert	vs	Axiography	Rater 1	kappa	0.50	<0.001
Axiography	Expert	vs	Axiography	Rater 2	kappa	0.89	<0.001
MRI	Expert	vs	MRI	Rater 1	kappa	0.43	<0.001
MRI	Expert	vs	MRI	Rater 2	kappa	0.71	<0.001

Axiography

Rater 1 →	0	1	2
0	56	9	2
1	2	13	0
2	6	0	2

↑ Expert

Axiography

Rater 2 →	0	1	2
0	66	1	0
1	1	14	0
2	2	0	6

↑ Expert

MRI

Rater 1 →	0	1	2
0	31	20	1
1	2	9	0
2	0	4	10

↑ Expert

MRI

Rater 2 →	0	1	2
0	23	14	2
1	2	9	0
2	1	0	14

↑ Expert

Table XXXIX

Classification of internal derangement.
Comparison of the axiographic and MRI findings with expert and non-expert raters.

					test	k	p
MRI	Expert	vs	Axiography	Expert	kappa	0.39	<0.001
MRI	Expert	vs	Axiography	Rater 1	kappa	0.01	>0.20
MRI	Expert	vs	Axiography	Rater 2	kappa	0.32	<0.001
MRI	Rater 1	vs	Axiography	Expert	kappa	0.20	<0.001
MRI	Rater 2	vs	Axiography	Expert	kappa	0.37	<0.001
MRI	Rater 1	vs	Axiography	Rater 1	kappa	0.11	>0.10
MRI	Rater 2	vs	Axiography	Rater 2	kappa	0.41	<0.001

MRI Expert / Axiography Expert

	0	1	2
0	46	7	0
1	7	4	0
2	6	2	7

MRI Expert / Axiography Rater 1

	0	1	2
0	37	13	2
1	7	4	0
2	12	1	2

MRI Expert / Axiography Rater 2

	0	1	2
0	45	7	0
1	7	4	0
2	8	2	5

Axiography Expert / MRI Rater 1

	0	1	2
0	31	24	5
1	4	7	2
2	0	2	4

Axiography Expert / MRI Rater 2

	0	1	2
0	38	15	7
1	0	10	2
2	0	0	7

Axiography Rater 1 / MRI Rater 1

	0	1	2
0	25	21	9
1	6	11	1
2	2	1	1

Axiography Rater 2 / MRI Rater 2

	0	1	2
0	38	15	9
1	0	10	2
2	0	0	5

of rater number 1 were compared with both the expert's MRI results ($p>0.20$) and rater number 1's MRI results ($p>0.10$). However, these correlations were poor and the correlation between the MRI and axiographic findings of the experts (study 1.1) was much higher.

8.2. Chronological consistency.

The axiographic findings were evaluated by the same investigator at two different times (table XXXX). All the tests demonstrated a significant consistency over time ($p<0.001$). The chronological reliability of the classification of internal derangement was very good (kappa = 0.89). There was also significant agreement between the occurrences of the symptom "Flat condylar head" (kappa = 0.71). However, the value of kappa suggests a fair reliability in the detection of the temporalis hyperactivity. The Spearman test was used to measure the consistency of the rating of TMJ looseness and muscular incoordination. There was a significant chronological reliability for both estimations ($p<0.001$) with a very good consistency.

9. Summary of the most significant results.

9.1. Displacement of the meniscus.

Table XXXXI summarizes the correlation between the axiographic and the MRI diagnosis of internal derangement. There was a significant correlation between the two methods of diagnosis. However, the strength of the correlation was generally fair. The study of the interrater consistency shows that the quality of the correlations are dependent on the proficiency of

Table XXXX

Interrater consistency.
Expert evaluation of the axiographic findings at two different times (T1 and T2).

				test	k	p
Classification internal derangement	T1	vs	T2	kappa	0.89	<0.001
Flat condylar head.	T1	vs	T2	kappa	0.71	<0.001
Hyperactivity of the temporalis.	T1	vs	T2	kappa	0.59	<0.001
Evaluation of the TMJ looseness.	T1	vs	T2	Spearman	0.77	<0.001
Muscular incoordination score.	T1	vs	T2	Spearman	0.81	<0.001

Classification internal derangement

1\2	0	1	2
0	66	1	0
1	0	14	1
2	2	0	6

Flat condylar head.

1\2	0	1
0	72	0
1	7	11

Hyperactivity of the temporalis.

1\2	0	1
0	68	3
1	8	11

Evaluation of the TMJ looseness.

1\2	0	1	2	3	4
0	24	3	0	0	0
1	3	18	3	1	0
2	2	8	17	2	0
3	0	0	2	5	0
4	0	0	0	0	2

Muscular incoordination score.

1\2	0	1	2	3
0	2	0	0	0
1	0	10	2	0
2	0	2	17	4
3	0	0	3	5

Table XXXXI

Classification of internal derangement.
Comparison of the axiographic and MRI findings with expert and non-expert raters.

Study :						test	k	p
2.1	MRI	Expert	vs	Axiography	Expert	kappa	0.39	<0.001
8.1	MRI	Expert	vs	Axiography	Rater 1	kappa	0.01	>0.20
8.1	MRI	Expert	vs	Axiography	Rater 2	kappa	0.32	<0.001
8.1	MRI	Rater 1	vs	Axiography	Expert	kappa	0.20	<0.001
8.1	MRI	Rater 2	vs	Axiography	Expert	kappa	0.37	<0.001
8.1	MRI	Rater1	vs	Axiography	Rater 1	kappa	0.11	>0.10
8.1	MRI	Rater 2	vs	Axiography	Rater 2	kappa	0.41	<0.001

Classification of internal derangement.
Interrater reliability for the same type of examination.

Study :						test	k	p
8.1	Axiography	Expert	vs	Axiography	Rater 1	kappa	0.50	<0.001
8.1	Axiography	Expert	vs	Axiography	Rater 2	kappa	0.89	<0.001
8.1	MRI	Expert	vs	MRI	Rater 1	kappa	0.43	<0.001
8.1	MRI	Expert	vs	MRI	Rater 2	kappa	0.71	<0.001

Interrater consistency.
Expert evaluation of the axiographic findings at two different times.

Study :		test	k	p
8.2	Classification internal derangement.	kappa	0.89	<0.001
8.2	Flat condylar head.	kappa	0.71	<0.001
8.2	Hyperactivity of the temporalis.	kappa	0.59	<0.001
8.2	Evaluation of the TMJ looseness.	Spearman	0.77	<0.001
8.2	Muscular incoordination score.	Spearman	0.81	<0.001

Correlation of the internal derangement classification with the history.

Study :		$\chi 2$	d.f.	p value
3.4	MRI CID* and History.	24.49	2	<0.001
4.12	Axiographic CID* and History.	33.35	2	<0.001

*CID = Classification of internal derangement.

the examiners (table XXXXI).

9.2. Chronological consistency.

The axiographic findings were evaluated by the same person at two different times. All the tests demonstrate a significant consistency over time ($p<0.001$). The chronological reliability of the classification of internal derangement with axiography is very good (kappa = 0.89) (table XXXXI).

9.3. History.

There is a significant correlation between the history and the MRI and axiographic diagnosis of internal derangement ($p<0.001$). However, the history was best correlated with the axiography (table XXXXI).

9.4. Articular noises.

The MRI classification of internal derangement was significantly correlated with the occurence of a clicking noise in opening and protrusion ($p<0.05$), and was also significantly correlated with the presence of a crepitus with opening ($p<0.05$). There was a good correlation between the symptom of reduction, detected on the axiographic tracing, and the TMJ clicking sound ($p<0.001$)(table XXXXII).

9.5. Range of motion.

The motion amplitude of the condylar head was observed with the axiograph in opening, protrusion, and mediotrusion for the three categories

Table XXXXII

Articular noises.

Study	Variables :	test	value	d.f.	p value
3.1	MRI CID* and crepitus.	$\chi 2$	10.06	2	<0.05
3.2	MRI CID* and clicking in opening.	$\chi 2$	8.99	2	<0.05
3.2	MRI CID* and clicking in protrusion.	$\chi 2$	6.85	2	<0.05
4.6	Axiographic symptom of reduction and clicking.	kappa	0.67	∞	<0.001

*CID = Classification of internal derangement.

Range of motion.

Study	Variables :	test	value	d.f.	p value
6.1	Axiographic CID* and condylar path opening.	K.W.	19.76	43	<0.001
6.1	Axiographic CID* and condylar path protrusion.	K.W.	10.88	43	<0.01
6.1	Axiographic CID* and condylar path mediotrusion.	K.W.	11.24	43	<0.01
2.3	MRI disc position and condyle trans before reduction	$\chi 2$	33.47	8	<0.001
4.1	Range of motion mandible and condyle in opening.	t	4.34	43	<0.01
4.1	Range of motion mandible and condyle in protrusion.	t	2.78	43	<0.01
4.1	Range of motion mandible and condyle in right mediot.	t	3.44	43	<0.01
4.1	Range of motion mandible and condyle in left mediot.	t	6.26	43	<0.01
7.1	Range of motion right laterality and palaption score.	t	-2.43	43	<0.05
7.1	Range of motion left laterality and palaption score.	t	-2.96	43	<0.01
4.9	Direction dentale in protrusion and asym. amplitude.	kappa	0.225	∞	<0.05
4.9	Direction dentale in opening and asym. amplitude path.	kappa	0.252	∞	<0.02

*CID = Classification of internal derangement.

of internal derangement. The range of motion of the condyles was significantly different for all the movements ($p<0.01$). There was a significant relation between the sagittal position of the meniscus seen in the MRI, and the amplitude of condylar head translation before reduction observed in the axiographic study ($p<0.001$). There was a significant correlation between the condylar range of motion measured with the axiograph, and the amplitude of the mandibular excursions measured between the incisors ($p<0.01$). The tenderness of the masticatory muscles was correlated with the amplitude of the lateral mandibular excursions ($p<0.05$). There was a correlation between a right and left asymetric condylar range of motion and the deviation of the lower midline in opening and protrusion ($p<0.05$).

9.6. Morphology of the meniscus.

The morphology of the meniscus was observed in the different classes of TMJ internal derangement (table XXXXIII). Some morphologic characteristics of the TMJ disc appeared more frequently when there was an internal derangement with or without reduction. The incidences of the "hypertrophy of the posterior band, flexture of the meniscus, and even thickness of the meniscus" were found to be significantly more frequent in various cases of internal derangement.

9.7. Validity of some clinical tests.

There was a significant difference in the amount of TMJ resiliency between the three axiographic classes of internal derangement ($p<0.05$).

Table XXXXIII

Morphology of the meniscus.

Study :	Variables :	χ^2	d.f.	p value
5.2	MRI CID* and "normal biconcave" morphology distribution.	24.05	2	<0.001
5.2	MRI CID* and "hypertrophy posterior band" distribution.	10.27	2	<0.01
5.2	MRI CID* and "flexture of the disc" morphology distribution.	37.98	2	<0.001
5.2	MRI CID* and "even thickness" morphology distribution.	8	2	<0.025

*CID = Classification of internal derangement.

Validity of some clinical tests.

Study :	Variables :	χ^2	d.f.	p value
4.10	TMJ resiliency and axiographic CID*.	14.18	6	<0.05
4.11	Pain triggered by compression test and axiographic CID*.	11.44	2	<0.001

*CID = Classification of internal derangement.

Degenerative joint disease.

Study :	Variables :	χ^2	d.f.	p value
5.3	DJD and MRI classification of internal derangement.	9.78	2	<0.01

There was also an important relation between the axiographic classification of internal derangement and the occurence of a compressive pain upon loading of the condylar head in the fossa (Compression test of Krogh-Poulsen)($p<0.01$).

9.8. Degenerative joint disease.

The MRI signs of DJD were significantly more frequent in the cases with internal derangement ($p<0.01$)(table XXXXIII).

DISCUSSION

1. Diagnosis of internal derangement.

There was a significant agreement between the MRI and axiographic methods when diagnosing internal derangement. However, the correlation between the two techniques was only fair. Retrospective study of the cases where MRI and axiography produced a conflicting diagnosis provides useful information for improving our interpretation of both MRI and axiographic studies.

Seven joints diagnosed as normal with the MRI were diagnosed as anterior displacement with reduction by axiography. Two factors could be responsible for this discrepancy.

- A careful reexamination of the axiographic findings of these seven joints reveals that the reduction of the condylar head onto the meniscus was detected at an early stage in the translation of the condylar head. This early reduction is often considered the earliest stage of the dysfunction. At this stage, the internal derangement is often chronic (Farrar, 1978). Indeed, four of these joints had an history of intermittent clicking noise in opening. For practical reasons, the axiographic and the MRI examination were not conducted at the same time and inconsistency of the click could therefore explain the discrepancy between the MRI and the axiographic diagnosis.

- The magnetic resonance images of these seven TMJ's were also reevaluated. Four MRI studies had poor resolution, and the junction between

the posterior band of the meniscus and the bilaminar zone (disc posterior landmark) was difficult to locate. In three cases, the disc posterior landmark was positioned within a normal range, but located at 11 in the clock reference system, (figure 22), at the borderline with the " partial anterior disc displacement" category . In these last three cases, the interpretation of MRIs was not able to detect very early disc derangements.

Seven joints were diagnosed as deranged joints with a reducing displaced disc with the MRI study and as normal TMJ's with the axiographic findings. In this group, four TMJ had no history of internal derangement and no subjective symptoms. Three joints had an history of intermittent clicking noise, but were not clicking at the time of the axiography. It was observed in several instances that the patient was clicking during the TMJ auscultation and was not clicking during the axiographic recording. An individual tray (clutch) was used to anchor the mandibular bow of the axiograph to the lower teeth. The clutch was positioned to minimize jaw opening. However, because the tray covers the occlusal surface of all the lower teeth, the amount of vertical change was dependent upon the amount of incisor overjet and overbite. This increase in vertical dimension might have prevented the condyle from luxating off the meniscus, especially in the case of a very early click. Indeed, two of these patients had an overbite deeper than four millimeters. Slavicek, (1988) suggests using a cast functional clutch that does not interfere with the occlusion for more precise axiographic analysis. Among the four patients with no history of internal derangement, two had an MRI in closed position with poor soft tissue resolution. Reevaluation of the

MRI showed that two TMJ had a meniscus posterior landmark positioned at 10 in the clock reference system. This subnormal position reflects a mild disc displacement that may not cause any dysfunction.

Six TMJ had a locked joint diagnosed with the MRI study, and a normal TMJ diagnosed with the axiographic examination. Reexamination of the axiographic and clinical findings shows that none of the TMJ's had a limited range of motion of the condyles. Because the axiograph is a dynamic test of TMJ function, these joints were classified as normal. However, four TMJ had an history of locking, and one patient reported a sensation of tightness upon opening. Only one TMJ had no history of pain or locking. Internal derangement of the meniscus without reduction is commonly thought to follow an episode of disc displacement with reduction (Farrar, 1978; Ogus and Toller, 1986). In our study, three of the six joints had no history of clicking. This finding indicates that a characteristic pattern of progression of internal derangement from clicking to locking may not exist. However, patient history depends on the ability of the patient to recall past events and is a subjective variable. This finding does indicate that a longitudinal prospective studyis needed to determine the natural history of internal derangement. Anterior displacement of the meniscus without reduction is generally thought to be characterized by limited range of motion. However, our results confirm that normal condylar movement is often seen in patients with anteriorly displaced menisci without reduction. This suggests that limitation of the range of condylar motion may disappear and soft tissues may adapt to the new physiology of the joint. The range of condylar head movement

gradually increases and stretches the tissues of the bilaminar zone (Farrar, 1978). Reevaluation of the MRI examinations shows 3 of the 6 joints had an unquestionable disc displacement without reduction. Two of the remaining joints had an anteriorly displaced disc in mouth closed position. The MRI study in mouth open position of these two joints demonstrates a condylar head positioned under the posterior band of the meniscus for one TMJ and under the anterior band for the other one. The radiologist defined the term "reduction" as an ideal position of the condylar head onto the thinnest portion of the disc when the mouth is opened. Observation of the axiographic findings for these two joints shows smooth tracings, with no evidence of deviation in the condylar path. The discrepancy between the axiographic and the MRI findings in these particular cases can only reflect a variation in the TMJ condition between the two studies. The remaining film had a poor resolution. This retrospective study provides evidence that axiographic tracings alone cannot detect the difference between an anatomically abnormal joint that functions normally and an anatomically and functionnally normal joint. By definition, axiography is a functional test and a "normal joint" is one which functions or moves normally. A joint adapted to an irreducible disc displacement that functions normally will have an axiographic diagnosis of normal. In addition, even objective symptoms such as clicking can vary with time and may lead to different axiographic and MRI test results. Therefore, a clinical examination should be done at the time of the MRI or axiographic tests to eliminate this variasbility and provide a more accurate diagnosis of internal derangement.

Two patients presented with one TMJ diagnosed as a non reducing condylar head with the MRI and as a reducing condylar head with the axiographic findings. Both joints had objective axiographic symptoms of internal derangement with reduction of the condylar head onto the meniscus in opening. One patient had a late reduction in the opening cycle. A late reduction, or late click in opening often leads to a complete dislocation of the disc throughout the functional range of condylar movement (Farrar, 1978). This patient may have had a reducing joint the day of the axiographic study and a locked joint when the MRI was performed. As the margin between these two clinical findings can be very slim, a late reducing joint that may occasionally lock is suggestive of continued chronic degeneration of the joint. Reevaluation of the MRI of this patient showed a partial reduction of the condylar head in the mouth open position. Again, the radiologist applied the strict definition of a non-reducing joint, and did not consider this joint reduced because the condylar head was not in the thinnest portion of the meniscus.

In conclusion, the intermittence of objective symptoms of internal derangement may explain the discrepancies between the two methods in the diagnosis of internal derangement. The objective signs of temporomandibular dysfunction of several patients varied between the time of the axiographic and the MRI examination. This suggests that further investigation is needed to correlate the axiographic and MRI studies simultaneously with objective clinical symptoms. The MRI studies showed a lack of sensitivity and

specificity in the diagnosis of a dysfunctional meniscus, especially when the disc posterior landmark is located between 10 and 11 in the clock reference system. Axiography is a dynamic test that cannot effectively discriminate between an anatomic and functionally normal joint and an anatomically abnormal joint that functions normally. Because of its dynamic nature, axiography failed to detect internal derangement in joints with long standing disc displacement without reduction because condylar range of motion was normal. The axiographic diagnosis of TMJ function is more important for the clinician than the diagnosis of normal TMJ anatomy. However, the MRI evaluation of condylar anatomy might be helpful to diagnose early subclinical changes that might lead to internal derangement. Further investigation is needed to determine the incidence of these morphologic changes, and their position in the causal change of events leading to internal derangement and degenerative joint disease.

For the purpose of this study the MRI and axiographic tests were interpretated with the experimentor blinded to the results of any other examination. In a clinical situation, axiographic and MRI findings should be interpretated along with the clinical examination findings. Several patients were clicking during the clinical examination and not during the axiography. The individual tray used to anchor the mandibular bow of the axiograph to the teeth produced an increase in vertical dimension. This vertical discrepancy may prevent the condyle from luxating in closed position. Slavicek, (1988) advocates the use of a functional clutch with no occlusal interference for

these patients. However, the used of a cast functional clutch is a time consuming and expensive operation. The axiodapt (Great lakes orthodontics, Ltd) should be used for further axiographic investigations on patients with an early click. This adjustable paraocclusal fork is prepared on the lower model with acrylic bridging the gap between the buccal surface of the teeth and the inner surface of the clutch. The acrylic interfering with the occlusion is trimmed away and the axiodapt is cemented.

2. Interrater consistency.

The observation of the tables of consistency between the different examiners (tables XXXVIII- XXXIX) reveals that there was a tendency for rater#1 to diagnose an internal derangement with reduction when the "Expert rater" was diagnosing a normal TMJ (20 cases for the MRI evaluation, 9 cases for the axiographic evaluation). While interpreting the axiography, rater#1 failed to diagnose six cases of disc displacement without reduction. There was an excellent correlation between the " expert rater" and rater#2 for the axiographic diagnosis of internal derangement. Rater#2 had a tendency to diagnose a disc displacement without reduction from the MRI findings when the "expert rater" was diagnosing a normal joint (14 cases).

In conclusion, the quality of the interrater findings correlations depend largely on the proficiency of the examiners. A large number of differences between the expert and the non-expert examiners reflected:

- the difficulty in differentiating between the TMJ with a non-reducing

disc and an anatomically normal TMJ with the axiograph,

- the lack of diagnostic sensitivity of the MRI when the disc was only slightly anteriorly displaced.

- Some discrepancies between examiners about the interpretation of the definition of a reducing joint in mouth opened position.

3. Chronologic consistency (Intrarater consistency).

Good chronologic consistency of interpretation of the axiographic findings was observed. Out of the ninety TMJ tracings reevaluated, only four had a discrepancy in the diagnosis of internal derangement between the first and the second reading. Half of the conflicting results consisted of a diagnosis of non-reducing TMJ considered normal at the second reading. This confirms our earlier finding that axiography cannot reliably differentiate between a normal joint and a joint with a displaced meniscus without reduction that has normal condylar movements. This suggests that the axiographic studies demonstrating smooth tracings of a normal amplitude should indicate a diagnosis of "normal condylar function" and not simply "normal joint". The consistency in interpretation of subjective symptoms such as "hyperactivity of the temporalis" or "flat condylar head" was more variable than for objective symptoms.

4. History.

The statistics reveal a strong correlation between the patients' history and both the MRI and axiographic diagnosis of internal derangement.

However, the history was best correlated with the axiography. Only twelve percent of the joints had a history of internal derangement that was not confirmed by MRI or axiography. The ability of the axiographic and MRI methods to identify joints with internal derangement when the joints had a history of internal derangement (sensitivity of the tests) was high and equivalent for both tests. The specificity of the MRI and axiographic tests is their ability to detect normal patients among patients with no relevant history. In our study, the specificity of axiography (96%) was higher than the specificity of MRI (86%). The proportion of patients correctly identified as having internal derangement was higher with axiography than MRI. Therefore, a false positive diagnosis is less likely to occur using axiography than MRI. The proportion of patients correctly identified as being normal was equivalent with axiographic and MRI studies.

Greene and Laskin (1988), showed that most of the TM joints with internal derangement can accommodate to an abnormal position of the disc. The retrodiscal tissue has an excellent adaptative capacity when subjected to repeated functional loading. The anterior part of the posterior attachment becomes fibrotic and the external shape, as well as the internal architecture of the meniscus changes in characteristic ways (Scapino,1983). When the TMJ is adapted to the abnormal position of the disc, the patient may report a history of temporomandibular dysfunction but no current symptoms of TMJ internal derangement. One possibility that has not been considered heretofore is that meniscus displacement may be a transient phenomenon. This may be

another possible explanation for the variability between the patient's history of TMJ internal derangement and the MRI and axiographic findings.

5. Articular noises.

Sounds from the TMJ can be divided into two separate groups:

1. Crepitations (multiple grinding, scraping sounds).
2. Clicking (a distinct snap, crack, or popping sound).

Crepitations usually occur unilaterally and indicate the presence of osteoarthritis in the joint (Isberg-Holm and Ivarson, 1980). According to Slavicek(1989), a lack of synovial fluid can induce a crepitus sound. The crepitus noise was observed in the different groups of TMJ internal derangement defined with the MRI study. Crepitus was audible in only three cases, all of which were diagnosed as non-reducing temporomandibular joints. This finding supports the concept that a relationship exists between crepitus and anterior displacement without reduction (Solberg,1985). No statistical correlation was found between the occurrence of the crepitation and the MRI signs of degenerative joint disease (DJD). This finding disagrees with the generally accepted theory that crepitus is indicative of a degenerative change (Ogus and Toller,1986). Although signs of DJD have been described on MRI films in different studies, (Katzberg et al., 1985,1986; Kirk, 1989), magnetic resonance imaging is not considered by radiologists as a good method to detect osseous changes, as the visualization of the bony structures is indirect. The cortical bone surrounding the condylar head and the temporal eminentia emits a low signal intensity and is delineated

because of its contrast with the bordering soft tissues. When these tissues emit a low signal intensity, the image of the cortical bone is no longer well delimited. In the present study, the absence of crepitus in the joints with MRI symptoms of degenerative joint disease may simply reflect a deficiency inherent in magnetic resonance imaging, rather than a lack of correlation between crepitus and degenerative joint disease. Further studies with laminographic or computed tomographic methods are needed to evaluate osseous morphology on patients with crepitus.

A significant correlation was found between the MRI classification of internal derangement and the occurrence of the clicking noise in opening and protrusive movements. This correlation was more significant in opening than in protrusion. The vast majority of the normal TMJs and joints with a non-reducing displaced disc were not clicking. However, some joints diagnosed as normal or locked joints with the MRI study presented with clicking at the clinical examination. The current literature supports the theory that joints sounds are not always the result of a reduction or luxation of the condylar head. Clicking may also be caused by irregularities in the articular surface of the temporal eminentia. The TMJ produces a click when the condylar head and the meniscus slip over an obstacle on the temporal articulating surface (Isberg 1989). Therefore, the clicking sound and the bulge in the tracing of the condylar path occurs at the same place in the excursive and incursive movements. TMJ sounds can also be produced by ligamentous morphologic abnormalities and scarifications of the capsule (Slavicek 1989). Some

patients having a distinct opening and closing click were shown arthrographically to have normal meniscus-condyle function (Oster et al., 1984). Observations with fluoroscopy during arthrography demonstrated the occurrence of the opening and closing clicks as the condylar head passes beneath the apex of the articular eminence. In our study, two patients were identified as producing an eminence click. One had a normal condyle-disc relationship, and the other had a reciprocal click in addition to the eminence click. In both cases, the eminence click was unique and was produced at the very end of the excursive movements. Osborn (1985) describes the TMJ meniscus as a structure with viscoelastic mechanical properties. During opening and closing movements, the disc is not only compressed between the joint surfaces, but also forced up and down the articular eminence. These forces can compress and distort the disc along the eminence and when the stored potential energy is suddenly released, an audible click is produced. Unsworth et al. (1971) demonstrated than when the articular surfaces of the finger joints are pulled apart, vapor filled cavities arise due to the creation of a vacuum. The subsequent collapse of these cavities results in cracking. Yavelow and Arnold (1971) suggested that the synovial fluid of the joints must move constantly to equalize the pressures and therefore accommodate the changes in joint volume. An obstruction of the synovial flow may give rise to the clicking noise. Because of the good conduction of the TMJ noises through the mandible between the right and the left side, the auscultation with a stethoscope is often misleading. An echo of the clicking noise is audible around the contralateral joint. A trained operator can differentiate the sounds using a

stereostethoscope. However, the antetragal palpation of the TMJ appeared to be more reliable than the auscultation. Abnormal relationships between the condylar head and the meniscus produce a characteristic vibration of the mandible that can be felt by palpation. Additional information can be obtained clinically by testing if the TMJ clicking is affected by an increase in vertical dimension or by mandibular protrusion. Abolition of the clicking noise with this test usually indicates a disc displacement with reduction.

In the present study, sixty four percent of the joints diagnosed with MRI as having a displaced meniscus with a reduction had a reciprocal click audible during the clinical examination. The variability of the occurrence of the clicking can be attributed not only to the inconsistency of the symptoms of disc displacement, but also to the other factors responsible for the production of clicking noises. A more accurate evaluation of clicking noises should involve a detailed study of joint noise production over several visits which was beyond the scope or intent of this study. Further investigation in this area should be encouraged.

There was also a very significant correlation between the symptoms of reduction and luxation identified on the axiographic tracings and the occurrence of a reciprocal clicking recorded during the clinical examination. The auscultation showed a high sensitivity (93%) and specificity (88%) in detecting joints with axiographic symptoms of reduction. In a reducing joint, the clicking noise has been shown to occur when the distance between the condylar head and the temporal articular surface is minimal. The clicking is

usually produced at the moment when the condylar head is slipping beneath the posterior ridge of the disc and when the condylar head reduces into the thinnest portion of the meniscus (Isberg-Holm and Westesson, 1981). It is therefore not surprising to see the clicking sound associated with a bulge in the axiographic tracings. In addition, because the clinical auscultation and the axiography were conducted during the same session, the intermittency of the internal derangement symptoms was not a source of variation. Reciprocal clicking was the most frequent joint sound (68%) in patients with internal derangement. Subluxation of the condylar head should also be considered as a major cause of clicking (22%).

6. Movements of the condyles and the mandible.

The average length of the condylar head path in opening, protrusion and mediotrusion is significantly different in the various groups of TMJ internal derangement. For a normal joint, the average length was 13.95 mm in opening, 10.72 mm in protrusion, 13.75 mm in mediotrusion. These results are close to the reported findings of Slavicek (1988), who found an average of 14 mm in opening, 8 to 10 mm in protrusion, and 12 mm in mediotrusion.

Internal derangement does not restrict the range of movement of the condylar head in opening when there is a disc displacement with reduction. However, the condylar path was found to be slightly restrained in protrusion and mediotrusion (less than 1mm). Therefore, limitated opening of the

mandible is not the most reliable indicator of disc displacement with reduction. All condylar excursive movements were significantly restricted in cases of disc displacement without reduction. The decrease in amplitude is a reliable symptom of a locked TMJ, but the mandible has to be guided during the axiographic procedure and the movement must be repeated several times to differentiate the diagnosis of a muscle splinting reflex from that of a true disc displacement without reduction. Muscle pain results in protective splinting and restricts the amplitude of condylar movement. Repetition of the mandibular excursions usually increases the amount of condylar movement. If the limitation is due to an abnormal condylar head - disc relationship or mechanical obstruction, the limitation cannot be improved by manipulation (Slavicek, 1988). Splint therapy can also reduce muscle tenderness and assist in determining the relative contribution of muscle splinting and disc disc displacement in limiting mandibular range of motion (Mongini and Capurso, 1982).

The degree of disc displacement observed on the MRI is highly correlated with the length of condylar head movement on the axiographic tracing before reduction occurs ($p<0.001$). A good correlation exists between MRI and axiographic interpretation of the extent of disc displacement. Therefore, the extent of disc displacement observed on the MRI is a good predictor of the dysfunction. This finding supports the pantographic classification of internal derangement into early, intermediate, and late reductions depending on the degree of displacement of the meniscus.

The present study demonstrates a significant correlation between the amplitude of condylar motion measured on the axiographic tracings and the range of motion measured between the upper and lower incisors. However, this correlation was weaker for protrusion than for opening movements. Therefore, the measurement of interincisal opening has greater prediction value for translation of the condyle than the clinical measurement of protrusion. Lavigne (1971) reported that a true rotational movement of the mandible occurs during the first stage of the opening motion. This rotation varies individually between 6 and 25 mm of vertical opening. This finding leads to the assumption that the amplitude of mandibular movement in protrusion is a better predictor of condylar translation than mandibular opening. Our results do not support this finding. Measurement of the lateral movements of the mandible were compared with the length of the condylar motion in mediotrusion. As expected, a significant correlation was found on both sides. However, the measurements were best correlated in the left joint. No valuable explanation or comparable investigations were found to support this last finding. To summarize, the measurements of the mandibular range of motion are significantly correlated with the length of the condylar path. The opening and lateral excursions are best correlated with the condylar head motion. The measurements of the condylar pathways in opening and protrusion are of a better diagnostic value than the amplitude of mandibular movements because mandibular motion reflects only an average between the mobility of the left and right TM joints.

The palpation score was used as an index to measure the amount of tenderness of the masticatory muscles. No significant correlation between the palpation score and the mandibular range of motion was found in opening or protrusion. However, there was a correlation with lateral excursions. This suggests that lateral mandibular excursions are better indicators of muscular dysfunction. This finding is supported by the results of a study comparing the mandibular excursions of 78 MPD patients with a control group of 3697 healthy patients (Cornu and Dechoux,1982; Rozencweig,1982). These investigators found that horizontal mandibular movements, (protrusion and lateral excursions), are more affected by temporomandibular dysfunction than opening movements. The opening excursion shows a 10% limitation in comparison to healthy patients and the average limitation of horizontal movement was 24%. Rozencweig (1982) concluded that protrusion and mediotrusion are the best indicators of muscle dysfunction. The mandibular range of motion has been shown to be correlated with statural measurement (weight, height) and facial measurement (facial index, face width, nasion-gnathion, subnasale-gnathion)(Cornu and Dechoux, 1982). These individual factors increase the spread of the measurements (variance) of the mandibular motion. The only way to eliminate these anatomical factors is to establish a ratio between the different measurements of mandibular motion (Rozencweig, 1982). The Motion Index divides the opening amplitude by the sum of the range of motion in protrusion and left and right lateral excursions. A significant correlation was found in the present study between the Motion Index and the Palpation score. This is

probably related to the fact that the amplitude of the right and left lateral excursions are significantly correlated to the palpation score. However, no significant correlation could be found between the motion index and the axiographic classification of internal derangement. This suggests that the Motion index is a better diagnostic tool to comprehend the level of dysfunction caused by muscle tenderness than by internal derangement.

Midline deviation during protrusion or opening is thought to be a sign of internal derangement. The midline has been reported to deviate to the side of the derangement. In this study, a poor correlation was found between the direction of the lower midline deviation in opening and protrusion, and the asymmetry of amplitude of the right and left axiographic tracings. This discrepancy between the axiographic and clinical results may be generated by the neuromuscular environment. Muscular dysfunction and incoordination influence the symmetry of the movements (Slavicek,1988). As mentioned earlier in the present study, the length of the condylar path in opening was not limited in cases with a reducing displaced meniscus. In this study, midline deviation was not a very reliable predictor of internal derangement. However, the path of the lower midline may be deviated during the opening or the protrusion, and be normal at the end of the excursive movement. Further investigation should be conducted to correlate a dynamic classification of the midline deviation with the axiographic classification of internal derangement.

7. Morphology of the meniscus.

Some morphologic characteristics of the meniscus appeared more frequently when there was an internal derangement with or without reduction. Disc abnormalities, like "hypertrophy of the posterior band" or "flexure of the meniscus", were most frequent in case of disc displacement without reduction.

Eight TM joints were reported to have an upward flexure of the meniscus. All of these TMJ were found to have an anteriorly displaced disc without reduction. As the TMJ disc changes its function, it apparently changes in anatomic shape. This finding is supports the theory of Osborn (1985). He proposes that the TMJ meniscus is a viscoelastic structure that adapts in response to the compression forces to which it is subjected. The shape of the disc is continuously changing throughout function and the adaptability of the meniscus in function explains the morphologic changes found in cases of internal derangement. Scapino (1983) demonstrated that the upward flexure of the meniscus is not a transient, reversible deformation. This fibrous pattern of the meniscus reflects an adaptation to a permanent dislocation.

Kirk (1989) and Katzberg et al. (1985)(1986) concluded that the chronically displaced portion of the disc can show remarkable thinning. They report that the posterior band of the disc undergoes fibrosis and it becomes progressively more difficult to discern the posterior band of the disc from

the posterior attachment tissues because of an increase in MRI signal intensity. In this study, no correlation was found between internal derangement and atrophy of the posterior band of the meniscus. A correlation was found with hypertrophy of the posterior band of the meniscus. Our findings are supported by the histologic studies of Scapino (1983) on autopsy and surgical specimens with internal derangement. Scapino did not find a thinning of the posterior band of the meniscus, but a thickening of the posterior band of the meniscus. Adaptative changes of the disc may be the result of trauma which induces a redistribution of the fibrous pattern.

The study of the visibility of the posterior landmark did not show any correlation with internal derangement. Only the overall quality of the MRI influenced the visibility of the posterior landmark of the disc. This contradicts the reports of Katzberg et al. (1985) and Westesson et al. (1987) who suggested that the visibility of the disc posterior landmark was altered in cases of disc displacement.

8. Degenerative joint disease.

There was a significant correlation between the symptoms of DJD and the classification of internal derangement. The observation of the frequencies shows that the symptoms of DJD are more frequent when there is a disc displacement without reduction. The correlation between disc displacement and DJD has often been mentioned in the literature (Farrar,1978 and Solberg, 1985). Solberg et al. (1985) and Scapino (1983) reported that an

osseous and cartilaginous adaptation of the articular surfaces usually respond to the altered function. Osteophytes of the anterior margin of the articular surface are detected in some cases of disc displacement. The origin of osteophytes has been attributed to an excessive contractile force of the lateral pterygoid muscle required to overcome the obstruction to forward motion of the condyle caused by the displaced disc (Scapino, 1983). In our study the three osteophytes were diagnosed in cases with a non-reducing displaced meniscus.

Internal derangement is often encountered at an early stage in the disease process, before any signs of degenerative joint disease are detected. Bone abnormalities of the TMJ are not specific to internal derangement. A patient can develop a systemic inflammatory arthritis with no meniscus abnormality. Other patients with internal derangement will never report any symptoms related to DJD (Greene and Laskin, 1988). Therefore DJD is not always the natural consequence of an internal derangement. We mentioned in this chapter that disc displacement without reduction does not always follow an episode of disc displacement with reduction. Therefore, the concept of a breakdown of the TMJ caused by internal derangement must be seriously questioned.

9. Looseness of the joint.

TMJ looseness was evaluated as the maximum vertical discrepancy between the excursive and incursive movements of the condylar head. TMJ

looseness shows the distraction of the articular surfaces. Our results demonstrated that there was a significant difference in TMJ looseness between the different groups of patients. The TMJ looseness of the joints with a non reducing meniscus was smaller than the looseness of the normal TMJs. However, the looseness of the deranged joints with reduction was larger then the one of the normal joints. A joint with "looseness" may be more susceptible to internal derangement. If the articular surfaces are not constantly coapted, the meniscus may be more easily displaced. Further studies should be encouraged to determine if TMJ "looseness" detected with the axiograph is the cause or the consequence of disc displacement. A longitudinal study could be designed to follow up patients with increased looseness and no symptoms of internal derangement to see the long-term probability of developping a disc displacement. In this study, no significant correlation was found between the looseness of the joints and the amplitude of condylar head movements. The length of the condylar path was not solely determined by the capsule and ligaments. Other factors such as osseous morphology and muscle function appear to affect condylar range of motion. This may also explain why some joints have increased laxity in the antero-posterior, and not in a vertical direction.

10. Validity of some clinical tests.

10.1. Resiliency.

Slavicek (1988) has reported that TMJ resiliency varies with the age of the patient and the integrity of the TMJ soft tissue components. He reports

that the resiliency of a healthy TMJ should be 0.6 mm for an adult patient, and 0.9 mm for a child. A lack of resiliency reflects a decreased histologic quality of the TMJ's soft tissue components (Slavicek,1988). In my study, the age distribution in the symptomatic and asymptomatic groups was not homogenous. The symptomatic patients were globally older than the asymptomatic patients and we expected to have a significant difference in resiliency between the groups. However, no correlation was found between age and average resiliency of the left and right joints. Resiliency was also compared among the different groups of internal derangements. There was a significant relation between TMJ resiliency and the axiographic classification of internal derangement, but not with the MRI classification of internal derangement. The level of significance was too low to consider the resiliency test as a reliable diagnostic test for internal derangement. However, the distribution of the resiliency of the non-reducing joints was significantly different from the normal joints. Therefore, the resiliency test could be used to detect non-reducing joints. In many patients with internal derangement, the resiliency test was painful because it caused loading of the TMJ. This test might not measure the resiliency of the joints, but the ability of a patient to bite heavily on a metal strip.

10.2 Provocation of TMJ pain (Compressive test of Krogh Poulsen)

The occurrence of compressive pain, provoked by a vertical loading of the condylar head into the fossa, was significantly correlated with the

axiographic classification of internal derangement. When the TMJ disc was anteriorly displaced, the condylar head was usually posteriorly displaced. The cranial loading of the condylar head might produce pressure on the bilaminar zone and cause pain. Compressive pain occurred more frequently in TMJs with disc displacement without reduction than in joints with disc displacement with reduction. A thick wooden stick may increase the vertical dimension enough to cause reduction of the condylar head onto the meniscus. Therefore, the further use of this test with a thinner bite block is suggested. The occurrence of pain upon intrameatal palpation of the TMJ also correlated well with the axiographic classification of internal derangement. In summary, the compressive pain test of Krogh-Poulsen appeared to be a more reliable test to identify internal derangement than intrameatal palpation.

SUMMARY AND CONCLUSIONS

Because of the high incidence of TMJ internal derangement in the general population (Solberg et al., 1979) and among teenagers (Nilner,1985), the orthodontist is necessarily involved with patients who will have symptoms of TMJ dysfunction before, during, or after the orthodontic treatment. Despite the increasing amount of research devoted to the temporomandibular joint, many of the diagnostic and most of the therapeutic issues remain controversial. The diagnosis of internal derangement has recently been enhanced by the utilization of two techniques:

1. MRI studies provide information concerning deep soft tissue structures without being invasive, or subjecting the patient to any form of ionizing radiation. Because of its good soft tissue resolution, MRI is now considered by practitioners to be superior to any other non invasive technique to diagnose TMJ internal derangement.

2. Movements of the condylar heads within the glenoid fossa can be measured with an axiograph. The axiograph is a pantograph which simultaneously tracks and records the path of the hinge axis of the condylar heads in the horizontal, vertical, and transverse dimensions. When the meniscus is displaced, the path of the condylar head is deviated. This deviation is recorded with the axiograph on a graph paper.

The purpose of this investigation was to compare the diagnosis information obtained from interpretation of an MRI with the interpretation of

axiographic tracings of the temporomandibular joint and the clinical information in human subjects with or without temporomandibular joint dysfunction.

Twenty seven subjects presenting symptoms of internal derangement and eighteen asymptomatic patients were studied. Every subject of both groups underwent a TMJ evaluation consisting of an axiography and a clinical examination. Four patients were financially unable to have their MRI done. The same operator did all the clinical examinations, before recording the axiographic tracings. Interpretation of the axiographies was done by two orthodontists and one oral and maxillofacial surgeon. The MRI studies were examined by three different practitioners including one radiologist, one orthodontist, and one oral and maxillofacial surgeon. The record of all the patients were randomized before interpretation.

Results of this present study may be summarized as follows:

Diagnosis of TMJ internal derangement.

1. A significant agreement was found between the axiographic and MRI diagnosis of internal derangement. However, the correlation between the two techniques was fair. Retrospective study of the MRI and axiographic data led to some assumptions about the causes of the conflicting diagnosis:
   - Symptoms of internal derangement might have been intermittent, in cases of a very early reduction,
   - The individual tray used to anchor the mandibular bow of the axiograph to the lower teeth produced an increase in vertical dimension and might prevent the condyle from luxating off the meniscus.
   - When the posterior band of the meniscus is in a "border line" position, the sensitivity of the MRI is too low to reliably detect the condition.
   - The quality of the MRI affects the accuracy of the diagnosis.

Because axiography is a dynamic test of TMJ function, some joints with a long standing disc displacement without reduction and a normal range of motion were classified as normal. This study provides evidence that axiography alone cannot accurately discriminate between a joint with a non reducing meniscus and a normal joint.

2. The quality of the interrater findings correlations depend largely on the proficiency of the examiners. A large number of differences between the expert and the non-expert examiners reflected:
- the difficulty to differentiate between the TMJ with non reducing disc displacement, and the normal TMJ with the axiograph,
- the lack of diagnosis sensitivity for the MRI study when the disc was slightly anteriorly displaced.

3. There was a very good chronologic intrarater consistency of interpretation of the axiographic findings. Half of the conflicting results consisted of diagnosis of non reducing TMJ, considered normal at the second reading. This confirms our earlier finding that axiography cannot reliably differentiate between a normal joint and a joint with a displaced meniscus without reduction that has normal condylar movement.

Axiographic and MRI findings were also compared with history and clinical findings.

1. Statistics show a strong correlation between the patient's history and both-MRI and axiographic diagnosis of internal derangement.

2. Crepitus, audible during the TMJ auscultation was always associated with an MRI diagnosis of meniscus displacement without reduction.

3. There was a good correlation between the symptom of reduction detected during the axiographic tracing and the TMJ clicking sound.

4. The range of motion of the condylar heads, observed in opening, protrusion, and mediotrusion was significantly different for the various categories of internal derangement (normal, disc displacement with reduction, disc displacement without reduction).

5. There was a significant correlation between the sagittal position of the meniscus seen in the MRI, and the amplitude of condylar head translation before reduction observed in the axiographic study.

6. There was a significant correlation between the condylar range of

motion measured with the axiograph, and the amplitude of the mandibular excursions, measured between the incisors.

7. Tenderness of the masticatory muscles was only correlated with the amplitude of the lateral excursions.

8. The deviation of the lower midline in opening and protrusion was correlated with an asymmetry between the left and right range of motion.

9. Some morphologic characteristics of the meniscus appeared more frequently when there was an internal derangement with or without reduction. Disc abnormalities, like "hypertrophy of the anterior band" or "flexure of the meniscus", were most frequent in case of disc displacement without reduction.

10. The TMJ internal derangement had no bearing on the visibility of the disc posterior landmark.

11. The TMJ resiliency was not found to be a reliable diagnostic test for internal derangement.

12. The occurrence of a compressive pain provoked by vertical loading of the condylar head into the fossa was significantly more frequent in cases with internal derangement.

The results of this study indicate that axiography can be a valuable test to aid in the diagnosis of patient's presenting with symptoms of TMJ disorders. Axiography was well correlated with both clinical and MRI examination. One important difference between MRI and axiography is that axiography is a dynamic test of condylar motion and not a static examination of joint anatomy. Therefore, a normal axiographic tracing indicates normal function and not necessarily normal anatomy. However, a slight disc displacement may result in a change in condylar function. This change is recorded by the axiograph but can not be demonstrated with MRI.

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Appendices

Appendix A

Axiographic findings summary chart.

Investigator : Patient Nb :

Right TMJ :

R1	Anter. disc displacement :		Yes =1 No =0
R2	Medial disc displacement :		Yes =1 No =0

R3	Reduction opening :		**Excursive motion :**
R4	Luxation closing :		First third of the movement : 1
R5	Reduction protrusion :		Second third of the movement : 2
R6	Luxation retrusion :		Third third of the movement : 3
R7	Reduction mediotrusion :		**Incursive motion :**
R8	Luxation medioretrusion :		First third of the movement : 3
			Second third of the movement : 2
			Third third of the movement : 1
			No = 0

R9	Subluxation condyle in opening :		Yes =1 No =0
R10	Irregular surface eminentia :		Yes =1 No =0
R11	Flat condylar head :		Yes =1 No =0
R12	Openers muscular hyperactivity :		Yes =1 No =0
R13	Temporalis muscular hyperactivity :		Yes =1 No =0

R14	No 0	Slight 1	Moderate 2	Severe 3	Critical 4
Signs of looseness :					

Left TMJ :

L1	Anter. disc displacement :		Yes =1 No =0
L2	Medial disc displacement :		Yes =1 No =0

L3	Reduction opening :		**Excursive motion :**
L4	Luxation closing :		First third of the movement : 1
L5	Reduction protrusion :		Second third of the movement : 2
L6	Luxation retrusion :		Third third of the movement : 3
L7	Reduction mediotrusion :		**Incursive motion :**
L8	Luxation medioretrusion :		First third of the movement : 3
			Second third of the movement : 2
			Third third of the movement : 1
			No = 0

L9	Subluxation condyle in opening :		Yes =1 No =0
L10	Irregular surface eminentia :		Yes =1 No =0
L11	Flat condylar head :		Yes =1 No =0
L12	Openers muscular hyperactivity :		Yes =1 No =0
L13	Temporalis muscular hyperactivity :		Yes =1 No =0

L14	No 0	Slight 1	Moderate 2	Severe 3	Critical 4
Signs of looseness :					

Muscles : SMI	No 0	Slight 1	Moderate 2	Severe 3	Critical 4
Signs of muscular incoordination :					

Appendix B

Clinical findings summary chart.

Name:
Date:
Dental History :

- Do you have any problem when you chew ?
- Do you have any sensitive teeth ?
- Do you ever have pain when you open your mouth very wide, or on a big bite, or yawn ?
- Do any teeth bother you when you close, chew , or swallow ?
- Do your joints make noises ? If so on which side ?
- Do you have any pain in front, or behind, or in your ears ?
- Do you suffer from headaches ? Morning, noon, evenings ?
- Do you ever have cramps or spasms,in head, neck or throat ?
- Do you ever have a feeling your mouth is dry, hot, or burning ?
- Do you ever have to look for space or place to close ?

• Dysfunction index :

If DI < 5 , Minimal problem.
If DI > 10, More questions:

- Do you take drugs for the conditions described ? What drugs ?

- Have you had problems in the head and neck area after an accident ?

- Did you have orthodontic treatment or equilibration in the past ? How many years ago ? How many equilibration sessions ? Have you had periodontal problems ?

- Do the problems you describe influence your general well being ?
- When was the last time you had dental treatment? What was done ?
- What is your main concern?
- Do you think there is a serious desorder or illness ?
- Do you think treatment is necessary ?
- Do you think we should discuss any related history ?
- Have you ever had a tendency to brux your teeth ?

- Comments :

Name :

Date: **Age :**

Muscle palpation : Scale 1-2-3

	Right side	Left side
Temporalis A.	---------0----------0----------	
Temporalis M.	---------0----------0----------	
Temporalis P.	---------0----------0----------	
Masseter	---------0----------0----------	
Lat. Pteryg.	---------0----------0----------	
Med. pteryg.	---------0----------0----------	
Digastric	---------0----------0----------	
Neck	---------0----------0----------	

TMJ palpation : Scale 1-2-3

	Right side	Left side
Intrameatal	---------0----------0----------	
Skin ant. tragus	-----0----------0----------	

TMJ Sounds :

Right	Clicking opening	(**None, Early, Intermediate, Late**)
	Clicking closing	(**None, Early, Intermediate, Late**)
	Crepitus	(**Yes, No**)
Left	Clicking opening	(**None, Early, Intermediate, Late**)
	Clicking closing	(**None, Early, Intermediate, Late**)
	Crepitus	(**Yes, No**)

Range of motion :

Non guided

Opening :
Propulsion :
Lat. right :
Lat. left :

OJ = OB =
Motion index =

Occlusion :

CR/CO shift : FWD LFT RT NO

First contact in CR : Between :

Interferences : W NW None

Provocation test of Krogh-Poulsen :

Test on side : RIGHT On the same side : Relief Pain N
On the opposite side : Relief Pain N

Test on side : LEFT On the same side : Relief Pain N
On the opposite side : Relief Pain N

Protrusion/Opening test :

End to end : RT LFT : mm
Hyperpropulsion : RT LFT : mm
Opening :

Resistance tests (Frumker and Solberg). Scale 1-2-3

MOVEMENT	MUSCLES TRIGGERED	RESULT
1 Opening1	Digastric Genio-hyoid Mylo-hyoid	:0
2 Opening2	Pteryg. lat. inf belly Openers	:0
3 Closing1	Superficial masseter Temporalis	:0
4 Closing2	Deep masseter Elevators	:0
5 Laterotru. L.	Right lat.pteryg. Inf Belly Right med. pteryg. Left Temporalis M and P fibers.	:0
6 Laterotru. R.	Left lat. pteryg. Inf Belly Left med. pteryg. Right Temporalis M and P fibers.	:0
7 Propulsion	Lat. pteryg. inf. belly	:0
8 Retropulsion	Lat. pteryg. Sup. belly Deep Masseter Temporalis M and P fibers.	:0

Resiliency test :

Right side holds : 0.0 0.3 0.6 0.9 mm Tin foil.
Left side holds : 0.0 0.3 0.6 0.9 mm Tin foil

Appendix C

MRI findings summary chart.

MRI DIAGNOSIS SUMMARY Patient nb : Side : Right

Investigator: Side : Left

1. Resolution :

R1
Image quality resolution : 0 : Non readable
1 : Inferior quality. Lack of resolution.
2 : Good resolution

L1
Image quality resolution : 0 . Non readable
.1 : Inferior quality. Lack of resolution.
2 : Good resolution

2. Disc displacement :

R2.1
Disc posterior landmark : 1 : Distinct delineation between the posterior band and the bilaminar zone.
0 : Meniscus posterior landmark non visible.

R2.2
Sagittal disc position : Closed position.
0 : Meniscus normally positionned (11 to 1).
1 : Meniscus partially displaced anteriorly (9 to 11).
2 : Meniscus completely anteriorly displaced (7 to 9).
3 : Meniscus posteriorly displaced (1 and later).

R2.3
Sagittal disc position : Mouth full open .
0 : Condylar head reduced in the meniscus. 3 : Image non available.
1 : Meniscus anteriorly displaced.
2 : Meniscus posteriorly displaced.

R2.4
Medio/later. disc position 0 : Normal 3 : Not possible to appreciate.
1 : Medial disc displacement.
2 : Lateral displacement.

L2.1
Disc posterior landmark : 1 : Distinct delineation between the posterior band and the bilaminar zone.
0 : Meniscus posterior landmark non visible.

L2.2
Sagittal disc position : Closed position.
0 : Meniscus normally positionned (11 to 1).
1 : Meniscus partially displaced anteriorly (9 to 11).
2 : Meniscus completely anteriorly displaced (7 to 9).
3 : Meniscus posteriorly displaced (1 and later).

L2.3
Sagittal disc position : Mouth full open .
0 : Condylar head reduced in the meniscus. 3 : Image non available
1 : Meniscus anteriorly displaced.
2 : Meniscus posteriorly displaced.

L2.4
Medio/later. disc position 0 : Normal. 3 : Not possible to appreciate
1 : Medial disc displacement.
2 : Lateral displacement.

3. Morphology :

R3.1
Morphology of the condyle 0 : Normal, rounded.
1 : Flattened .

R3.2
Morphology of the disc** 0 : Normal, biconcave. 4 : Hypertrophy posterior band. 8 : Low resolution
1 : Biconvexity. 5 : Hypertrophy anterior band. 9 : Myxoid degeneration
2: Atrophy anterior band. 6 : Flexture ofthe disc. 10: Perforation.
3 : Atrophy posterior band. 7 : Even thickness.

L3.1
Morphology of the condyle 0 : Normal, rounded.
1 : Flattened .

L3.2
Morphology of the disc** 0 : Normal, biconcave. 4 : Hypertrophy posterior band. 8 : Low resolution.
1 : Biconvexity. 5 : Hypertrophy anterior band. 9 : Myxoid degeneration.
2: Atrophy anterior band. 6 : Flexture ofthe disc. 10: Perforation
3 : Atrophy posterior band. 7 : Even thickness.

4. Degenerative joint disease (DJD).

R4.1
Delineation of the articular cortical bone : 0 : Good definition.
1 : No continuity.
R4.2
Erosion condyle or Fossa : 0 : No.
1 : Yes.
R4.3
Concavity or subchondral lacuni : 0 : No. 1 : Yes.
R4.4
Osteophyte: 0 : No. 1 : Yes.

L4.1
Delineation of the articular cortical bone : 0 : Good definition.
1 : No continuity.
L4.2
Erosion condyle or Fossa : 0 : No.
1 : Yes.
L4.3
Concavity or subchondral lacuni : 0 : No. 1 : Yes.
L4.4
Osteophyte: 0 : No. 1 : Yes.

5. Adhesions :

R5
Adherence condyle/fossa : 0 : No. 1 : Yes.

L5
Adherence condyle/fossa : 0 : No. 1 : Yes.

** More than one digit can be put in this box.

** More than one digit can be put in this box.