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Sagittal changes in temporomandibular joint disc position over time in adolescents: A retrospective study

by

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ABSTRACT

Temporomandibular joint (TMJ) disc displacement is a mechanical condition in which the articular disc does not present a normal contact with the articular surfaces due to a change in its position. Magnetic resonance imaging (MRI) is a valid and reliable method to identify TMJ disc displacement. There are no longitudinal MRI studies evaluating if disc displacement progresses over time. The aim of this retrospective study was to provide such answer. TMJ MRIs from a sample of 94 adolescent patients were obtained at two different points in time. Articular disc position was measured at both times and statistically compared for sagital changes in position with respect to the condyle and articular eminence. This study found that sagittal disc position changed over time in approximately 10% to 14% of our total sample. TMJ pain, gender and history facial trauma did not present a clear association with the amount of disc displacement.

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I am happy to graduate in the University of Alberta 100th anniversary. The experiences I had, and all that I learned, during my time here will be engraved in me for at least another 100 years.

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95%CI = 95% confidence interval

CSF = cerebrospinal fluid

DJD = degenerative joint disease

FID = Free induction decay

HT= History of facial trauma

MRI = Magnetic resonance imaging

ms = milliseconds

P = p value

P-op= TMJ upon opening

P-pal= TMJ pain upon palpation

SD = standard deviation

SDP = Sagittal disc position

T-click= TMJ click

TE = Echo time

TR = Repetition time

TMD = Temporomandibular disorders

TMJ = Temporomandibular joint

V1 = first visit / Time 1

V2 = second visit / Time 2

chapter 1 : INTRODUCTION & LITERATURE REVIEW

chapter 1 : INTRODUCTION & LITERATURE REVIEW

1.1- INTRODUCTION

Temporomandibular disorders (TMD) is a broad diagnotic term including a variety of musculoskeletal conditions affecting the masticatory system. It involves mechanical and inflammatory conditions of the masticatory system, affecting the masticatory muscles and temporomandibular joint (TMJ). TMD are present in approximately 40 to 60% of the general population and include articular and/or muscular problems of the masticatory system. [1,2] TMJ disc displacement is a mechanical condition in which the articular disc does not present a normal contact with the articular surfaces due to a change in its position. When a disc is displaced from its natural position within the joint, its function during jaw movements may become affected, creating a wide spectrum of signs and symptoms such as clicking, difficulties with jaw function and pain. [3,4]

Magnetic resonance imaging (MRI) is a valid and reliable method to identify TMJ disc displacement.[5,6] Unlike other methods such as computerized tomography and traditional radiographs, MRI allows clear visualization of soft tissues within the TMJ and its relationship with the surrounding osseous and articular tissues. This technique is non invasive, pain-free, does not require exposure to ionizing radiation, and it can be applied to both control and treatment study groups.

Many causes have been proposed for TMJ disc displacement;[2] some are more consistently identifiable than others. Occlusion and orthodontic treatment have been proposed as a cause of disc displacement and TMJ dysfunction in general, but studies demonstrate very different results from each other, failing to show consistent evidence of such proposed causal relationships.[7-24] Furthermore, occlusal therapies, including orthodontic treatment, have been shown to be ineffective to solve disc displacements and other types of TMD.[25]

Other factors that may be related to TMD are age and gender. It is well known that TMD is more prevalent in females, especially between the 2nd and 5th decades of life.[17 18 26-30]

Orthodontic treatment has also been proposed as a factor related to TMJ disc displacement. Several studies in the literature failed to show a significant change in TMJ disc position after the use of certain types of orthodontic functional appliances.[31-39] No studies have reported the progression of TMJ disc position after full fixed orthodontic treatment in asymptomatic subjects. On the other hand, it is documented that a high percentage of adolescent patients present some degree of TMJ disc displacement prior to orthodontic treatment. A prevalence study using MRI in a pre-orthodontic sample by Nebbe et al [40] demonstrated normal disc position in approximately 50% of their male sample and 26% in females. Some of these subjects underwent orthodontic treatment. Follow up MRIs were obtained from 114 patients in the same sample, regardless of receiving orthodontic treatment, after an average of 4 years. Initial TMJ MRIs were obtained at a first visit (V1) from 1994 to 1996, and patients were re-called for a second visit (V2) to obtain updated images 2 to 5 years later.

The objective of the present study was to identify the presence or absence of a sagittal change in the articular disc position over time, and if present, to quantify it. This study is therefore expected to provide information regarding the expected probability of progression of TMJ disc displacement in a longitudinal sample of adolescent subjects with normal disc position and disc displacement.

1.2- PROBLEM STATEMENT

TMJ disc displacement and TMD in general affect a great number of people. It is reported that internal derangement occurs in approximately 30% of the population.[41] Although this condition is found in many asymptomatic individuals, it is well known that its progression to severe or disabling symptoms is not uncommon.[7] The societal costs of TMD are significant. It is estimated that approximately 17,800,000 workdays are lost each year for every 100,000,000 full-time working adults in the United States due to disabling TMD.[7]

The etiology of TMJ disc displacement is multifactorial; no single factor has been identified to be responsible. In fact, many factors such as demographic, environmental and genetic are thought to be somehow related to this condition.

In addition to these factors, there is no clear evidence in the literature to demonstrate that this condition progresses over time.

In many cases TMJ disc displacement is asymptomatic, with no complications and is considered non pathologic.[7] However, some patients with disc displacement experience pain, impaired jaw function and diminished range of opening, which deeply affect basic physiological activities such as mastication, talking and sleep.[3]

In clinical practice, patients often want to be informed if their condition will get worse over time, if it will lead to serious complications and what factors, if any, can influence such progression. It is not easy for the clinician to answer such questions as the literature does not provide definitive answers. To date, there is no available study that would specifically address these questions. Therefore, this investigation aimed to evaluate the possible association of time and other factors such as gender, TMJ pain and history of facial trauma to the progression of TMJ disc displacement.

1.3- RESEARCH QUESTIONS & STUDY OBJECTIVES

The following research questions and study objectives are based on Nebbe's pre-orthodontic adolescent sample: [40]

1- Are there sagittal changes in TMJ disc position over time?

If there is change:

2- How much sagittal change is observed over time?

3- Are factors such as gender, TMJ pain and history of facial trauma associated to an increased disc displacement over time?

Primary objective:

- To detect the presence of a sagittal change of TMJ disc position in the same orthodontic patient sample from V1 and V2
- To quantify the type of sagittal changes in TMJ disc position in the same orthodontic patient sample from V1 and V2

Secondary objective:

- To identify if gender, TMJ pain and history of facial trauma are associated with sagittal changes in TMJ disc position in the same patient sample from V1 and V2.

1.4- HYPOTHESES

Null hypothesis:

- There is no difference in TMJ sagittal disc position over time

Alternate hypothesis:

- There is a difference in TMJ sagittal disc position over time

1.5 – LITERATURE REVIEW

1.5.1 – THE TEMPOROMANDIBULAR JOINT

The temporomandibular joint (TMJ) is the area where the craniomandibular articulation takes place. It is the only mobile joint of the craniofacial complex and it is considered one of the most complex joints in the human body. Compound joints defined as in which three bones contribute to the articulation. The TMJ is classified as a compound joint because it is composed of two bones (the mandible and the temporal bone), plus an articular disc that acts as a third non-ossified bone to allow different movements of the joint (Figure 1.1).[3]

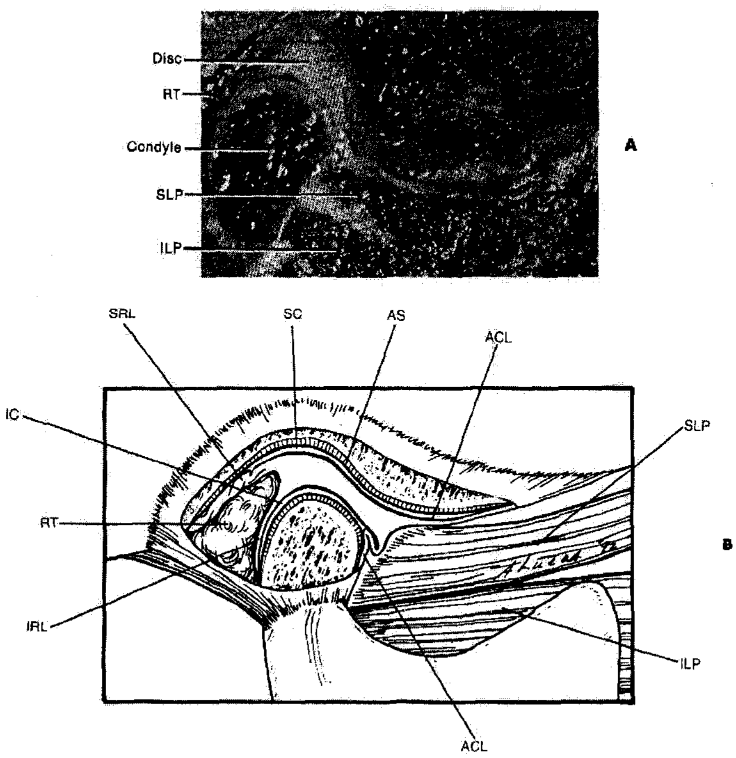


Figure 1.1:[3]: - Sagittal view of the TMJ: **A.** Lateral view of the TMJ. **B.** Diagram showing the anatomic components. ACL (anterior capsular ligament), AS (articular surfaces), IC (inferior joint cavity), ILP (inferior lateral pterygoid muscle), IRL (inferior retrodiscal lamina), RT (retrodiscal tissues), SC (superior joint cavity), SLP (superior lateral pterygoid muscle), SRL (superior retrodiscal lamina).

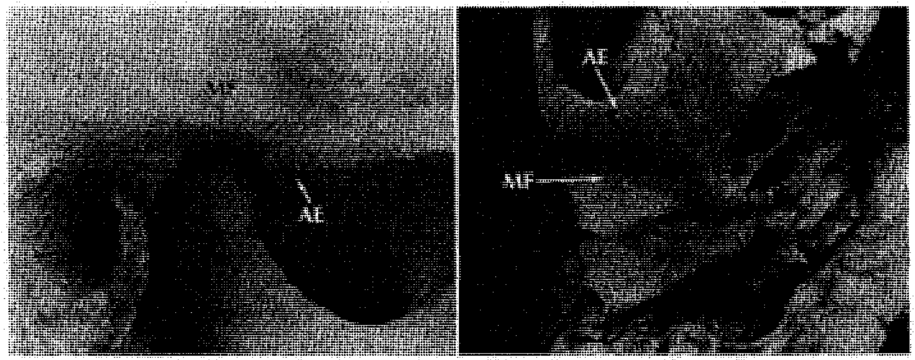
The superior part of the joint if formed by the squamous portion of the temporal bone, and, the posterior part by its tympanic portion. The anterior part of the joint consists of the articular eminence, which arises on the inferior border of the zygomatic process of the temporal bone. These three areas derived from the temporal bone form the glenoid fossa, in which the mandibular condyle articulates.[3]

The articular disc is interposed between the glenoid fossa and the mandibular condyle. The disc plays a protective role acting as a force buffer between the condyle and the glenoid fossa during movement and normal function.

The TMJ is considered a ginglymoarthroidal joint[3] because is capable of performing hinging and gliding movements. The hinging movements take place between the articular disc and the condyle, while the gliding movements occur between the disc and the glenoid fossa.

1.5.1.1 – OSSEOUS COMPONENTS OF THE TMJ

<u>The temporal bone</u>: The glenoid fossa of the TMJ is part of the temporal bone. The squamous portion of this bone forms the superior aspect of the fossa by the presence of a concave area where the head of the condyle articulates (figure 1.2). The posterior wall of the fossa is formed by the tympanic portion of the temporal bone. It is clearly divided from the squamous portion by the mediolaterally oriented squamous tympanic fissure. The mesial aspect of this fissure is divided into the petrosquamous fissure anteriorly and the petrotympanic fissure posteriorly (Figure 1.2). Anterior to the glenoid fossa, a convex bony surface, the articular eminence, arises from the inferior border of the zygomatic process of the bone (Figure 1.2). The degree of steepness of the eminence varies greatly among individuals. The main function of the articular eminence is to regulate the amount of anterior movement of the condyle when it moves forward during jaw opening. Unlike the posterior part of the fossa, which is very thin, the bone of the articular eminence is thick and is designed to sustain heavy forces.[3]



A B

Figure 1.2[3] – Osseous components of the TMJ: MF (mandibular fossa), AE (articular eminence). **A**. Lateral view. **B** Inferior view

<u>The mandibular condyle</u>: The ascending ramus of the mandible consists of a vertical bony plate that extends upwards and ends in two processes. The anterior one is the coronoid process which serves as the insertion area of the temporalis muscle. The posterior one is the condyle which articulates the mandible with the cranium in order to provide mandibular movement. From an anterior view the condyle has an elliptical shape with lateral projections also known as poles (Figure 1.3). The medial pole is usually more prominent. From above, the axis from the lateral to the medial pole is oriented medially and posteriorly towards the anterior border of the foramen magnum. The mediolateral length of the condyle ranges from 15 to 20mm and the anteroposterior width is 8 to 10mm. The superior part of its head is the articulating area of the condyle; this part of the head is quite convex anteroposteriorly and mildly convex mediolaterally.[3]

Figure 1.3 [3] **– Coronal view of the mandibular condyle:** Mandibular condyle showing the lateral pole (LP) and medial pole (MP)

<u>Histological structure of the articular surfaces</u>: The articular surfaces of the condyle and the glenoid fossa are covered by articular cartilage which consists of two main phases: a solid organic matrix of collagen fibrils and proteoglycan molecules, and a movable interstitial fluid phase which is predominantly water. [3]The articular cartilage is divided in four different layers, as illustrated in Figure 1.4:

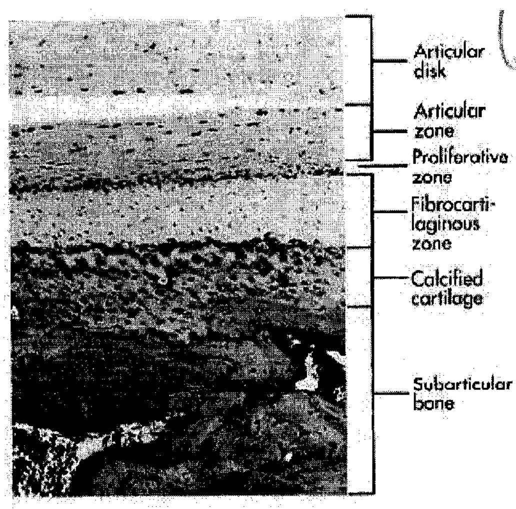


Figure 1.4 [3] **– Condylar histology:** Histological layers of the articular surface of the mandibular condyle.

1- The most superficial layer is the *articular zone*, which is in direct contact with the joint cavity and forms the most external functional surface. This layer is made of dense fibrous connective tissue and not hyaline cartilage like in other joints of the body. The collagen fibers are arranged in bundles parallel to the surface and are tightly packed to withstand forces of movement.[42 43] This dense fibrous tissue is less susceptible to break down over time and has a superior repairing ability. This layer is continuously maintained and repaired by replacement of cells and matrix secretion by chondrocytes in the cartilage layer within. [44]

2- The second zone is called the *proliferative zone* and is mainly cellular, containing mainly undifferentiated mesenchymal tissue. This zone is responsible to accommodate the proliferation of articular cartilage according to the functional demands placed on the articular surface during loading

3- The fibrous zone is the *fibrocartilaginous zone*, whose main function is to provide resistance against compressive and lateral forces. This layer is composed by collagen fibril bundles arranged in a crossing and radial orientation.

4- The *calcified zone* is the deepest zone and is composed of chondrocytes and chondroblasts distributed along the articular cartilage. In this zone the chondrocytes experience necrosis, and bone cells are formed from within the medullary cavity. The extracellular matrix provides an active site for remodeling activity and endosteal bone growth. [3]

In the adult the fibrocartilage is thicker (0.45mm) in the postero-inferior area of the slope of the articular eminence, compared to the roof of the fossa where it is thinner (0.07mm).[45] The articular cartilage of the TMJ has neither innervation nor blood vascular supply. Therefore, no pain can be perceived directly in this tissue. Its nourishment is provided by the synovial fluid within the joint cavity.[3]

1.5.1.2 – SOFT TISSUE COMPONENTS OF THE TMJ

The articular disc and its ligaments: This is a biconcave structure located between the head of the condyle and the glenoid and articular eminence. It is composed of dense fibrous connective tissue and for the most part lacks of innervation and blood vessels, except for its periphery. This portion is reported to be slightly innervated,[46 47] for reflex control of the mandibular musculature and joint function.[44] The dense fibrous tissue consists of Type I collagen with specific orientations depending on the area of the disc.

For descriptive and functional purposes the disc is divided in three regions in the sagittal plane according to thickness. These areas are the posterior band, the intermediate zone and the anterior band (Figure 1.1).[3] The intermediate or central zone is the thinnest portion(1.08mm). The disc becomes considerably thicker at the posterior and anterior margins to the intermediate zone. The posterior band is generally slightly thicker (average 2.90mm) than the anterior one (average 2.50mm).[45] In normal conditions, the posterior band is located between the most superior aspect of the head of the condyle and the anterior area of the glenoid fossa. The intermediate zone is the loading area and is located between the head of the condyle and the posterior surface of the articular eminence. Finally, the anterior band of the disc fills the anterior remaining space between the condyle and the posterior slope of the eminence.

The collagen fibers in the intermediate zone of the disc are sagittally oriented sagittal parallel to the osseous articular surfaces that are superior and inferior to this region of the disc. These fibers fan mediolaterally as they approach the anterior and posterior bands. The central and loading area of the disc possesses a higher concentration of sulphated glycosaminoglycans than the posterior and anterior non-loading areas. These consist mainly of chondroitin-6-sulphate, evenly distributed in a medio-lateral direction.[44 48] Dermatan sulphate and keratin sulphate are also distributed superficially in the surface area of the intermediate zone.[44 48]

From a three-dimensional perspective the disc appears to be ring-shaped with a thicker periphery and thinner central area. It is designed this way for load bearing purposes. The thicker periphery acts as a cushioning which makes it adaptive for force distribution.[49] A basic three-dimensional illustration of the disc is presented in figure 1.5. From a coronal view (Figure 1.6), the disc is usually thicker in the medial aspect than in the lateral aspect because there is a greater space to fill between the condyle and glenoid fossa medially. The precise shape of the disc in each individual will be determined by the morphology of the condyle and the glenoid fossa.[3] This morphology of the disc is usually maintained unless destructive or structural changes in the joint occur.

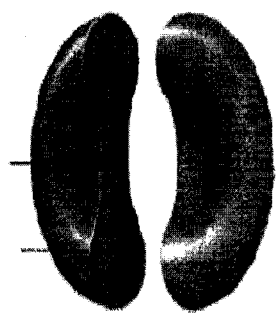


Figure 1.5: Shape of the articular disc: Basic three-dimensional representation of the articular disc without the ligaments

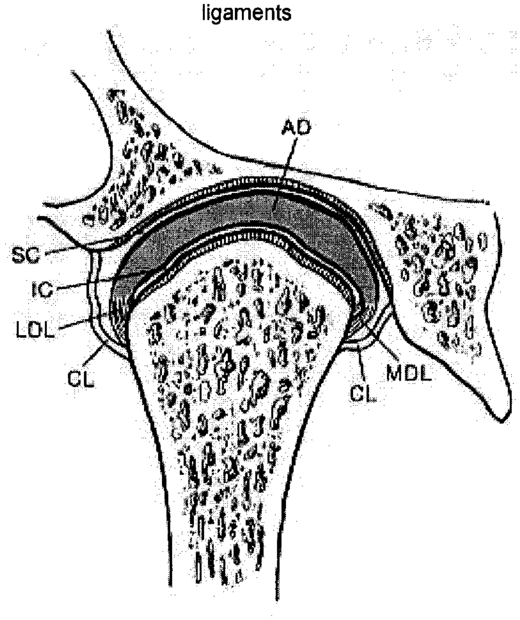


Figure 1.6[3]: Coronal view of the TMJ: AD (articular disc); CL (capsular ligament); IC (inferior joint cavity); LDL (lateral discal ligament), MDL (medial discal ligament); SC (superior joint cavity).

The disc is maintained in place by several different ligaments. In the medial and lateral aspects, the disc is attached to the head of the condyle by dense collagenous non-articular collateral ligaments. These ligaments are inserted in the lateral and medial poles of the condyle respectively and coordinate the range of anterior and posterior rotational movements of the disc and the condyle. [3 44] Lateral and medial movements of the disc are also restricted by such ligaments.[3]

The disc is attached posteriorly by superior and inferior ligaments called retrodiscal laminas. The superior retrodiscal lamina is composed of elastic fibers that originate from the superior border of the posterior band and attach to the squamous-tympanic fissure. One of its functions is to regulate the posterior movement of the disc on mouth opening by the elastic fibers balancing the anterior forces derived from the closing phase of mastication.[44] The inferior ligament originates from the inferior border of the posterior band and attaches to the posterior margin of the articular surface of the condyle. The function of this attachment is to coordinate posterior movement of the disc with the condyle when the condyle rotates posteriorly from mouth opening.[50 51]

Anteriorly, the disc also presents superior and inferior ligaments, attaching it to the anterior margin of the articular surface of the temporal bone and to the anterior margin of the articular surface of the condyle, respectively.[3] The superior head of the lateral pterygoid muscle inserts onto the condylar fovea in the antero-medial aspect of the neck of the condyle. Fibers from this muscle have been reported to be attached to the anterior band of the disc[52] but this is controversial as some studies have found opposite results.[53]

The retrodiscal tissues and the bilaminar zone: Located posterior to the articular disc and contained between the superior and inferior retrodiscal laminas, are the retrodiscal tissues (Figure 1.1).[54 55] The anatomical structure composed by the superior and inferior retrodiscal laminas with the retrodiscal tissues in between is defined as the bilaminar zone. The retrodiscal tissues are composed of loose connective tissue, fat, blood vessels and nerves. Therefore, this area of the joint is not designed for loading. The large venous complex within the retrodiscal tissues fills with blood the area when the condyle moves forward.[56 57] It is thought that this process is achieved by the elastic fibers of the superior retrodiscal lamina branching tree-dimensionally and penetrating into the thin wall of the veins. This stimulates the lumina of the anostomotic plexus of blood vessels to open when the mouth is open and the superior and inferior retrodiscal laminas are separated. This elastic tissue also acts as a pump to push the blood flow out the vessels during mouth closure.[54]

The capsule: The TMJ is wrapped by the capsular ligament or capsule (Figure 1.7). It is composed by thick bundles of collagen with a regular arrangement. It is located external to the attachments of the disc and to the osseous components.[3 44] The capsule is attached in the neck of the condyle; 7mm inferiorly from the most superior point of the condylar head in the anterior aspect of the neck and 9mm in the posterior aspect. The medial attachment is at or caudal to the medial pole and the lateral attachment is at the lateral pole.[44] Superiorly, the capsule is attached to the inferior border of the temporal bone all around the limits of the glenoid fossa anterior to the articular eminence and posterior to the tympanic fissure.

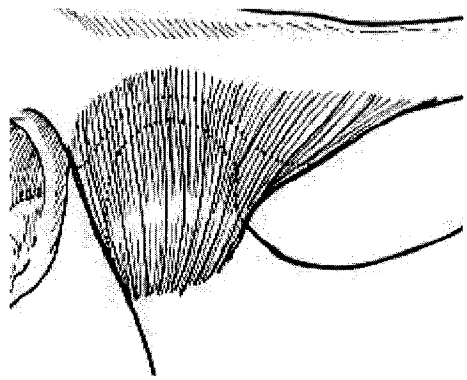


Figure 1.7[3]– TMJ capsule: Insertion and attachment of the TMJ capsular ligament

The articular disc is not only attached to the capsule anteriorly and posteriorly but also medially and laterally. This divides the TMJ into two different cavities with no direct communication between each other. The superior cavity is bordered by the articular fossa superiorly and the superior surface of the disc, inferiorly. The inferior cavity is contained between the inferior surface of the disc superiorly and the neck of the condyle, inferiorly.[3]

The entire capsule is surrounded by a rich vascular blood plexus that contributes to the blood supply to the TMJ. This capsular plexus originates from the maxillary superficial and middle meningeal arteries.[58] The lateral aspect of the capsule appears to be thicker than the medial and is less richly (or else not as "richly") supplied with blood vessels than other areas in the ligament. [44]

The capsule is innervated by branches of the trigeminal nerve. Many neural fibers are observed around the capsule anterior and posterior to the joint. These fibers travel to the anterior and posterior bands of the disc and form nerve endings at the discal attachments.[47] These structures are non-encapsulated pain-endings connected to lightly myelinated fibers and an array of encapsulated receptors connected to myelinated nerves that respond to mechanical stimuli.[47 59]

The synovial membrane: The non articular surfaces of the TMJ are lined by a synovial membrane which provides synovial fluid to the superior and inferior joint compartments. The articular disc is also covered by this membrane only at its periphery and attachments. For this reason the TMJ is considered a synovial joint.

The synovial membrane contains a variety of mesothelial cells disposed in two layers. The layer in direct contact with the interior of the joint cavity is called the *synovial intima*, which has a supportive or backing layer underneath called the subsynovial tissue or subintimal tissue. The subintimal tissue merges with the fibrous tissue of the joint capsule, which lays externally to it.[60] The synovial cells are normally shed from the intimal layer and are replaced by proliferation of cells in the subintimal tissue. The synovial intima has a depth of four to six layers of polygonal-shaped and spindle-shaped cells embedded in a matrix of collagen fibrils and amorphous material.[60] The subintimal tissue consists of collagen fibrils, interfibrillar matrix, fibroblasts, macrophages and mast cells.[44 60] Nerve fibers are not a feature of the synovial membrane; however, the only ones present are autonomic in nature for the adventitia of blood vessels.[60] The subintimal tissue is richly supplied with sinusoidal and fenestrated capillaries that play a role in water and solutes exchange.[60]

The function of the synovial membrane is to generate synovial fluid as well as removal of synovial fluid and debris from the joint space.[61] The synovial fluid is composed of transudate from the blood and hyaluronic acid and proteoglycans produced by synovial cells.[61] The synovial fluid serves two purposes. The first is nourishment and nutrition of the non-vascular articular surfaces. This is accomplished through free and rapid exchange between the vessels of the capsule, the synovial fluid and the articular tissues. The second purpose is lubrication of the bony articular surfaces and .the disc to eliminate friction between them during movement. [3]

Lubrication takes place through two different mechanisms. The first one is called *boundary lubrication* which prevents friction in the moving joint and is considered the primary mechanism of TMJ lubrication. Boundary lubrication occurs when there is movement of the joint and the fluid is forced from one area of the cavity to the other. The synovial fluid located in the border and recess areas is forced onto the articular surfaces to provide lubrication. The second mechanism is called *weeping lubrication*, which refers to the ability of the articular surfaces to absorb a small amount of synovial fluid. When forces are generated within the joint a small amount of synovial fluid is automatically driven in and out the articular surfaces. This facilitates metabolic exchange. Under compressive forces, such as clenching, a small of fluid is released to provide lubrication in the compressed but not moving joint. [3]

1.5.1.3 – NORMAL BIOMECHANICS OF THE TMJ

When the TMJ is at a resting position, the condyle approximates the posterior surface of the articular eminence with the intermediate zone of the disc interposed in between. As described above, the TMJ can be divided in two compartments for descriptive purposes (Figures 1.1 and 1.6). The inferior compartment is located between the condyle and the disc. The superior compartment is formed by the disc and the glenoid fossa.

As the depressor muscles of the jaw contract and open the mandible, rotation occurs in the inferior joint compartment between the condyle and the inferior surface of the articular disc. [3]The rotation is controlled by the coordinated antagonistic contraction of the elevator muscles and the ligaments, since they force the condyle to keep close approximation with the articular eminence[62] in this first phase of mouth opening. This antagonistic action of elevator muscles and ligaments is a mechanism to provide joint stability.

As mouth opening continues, more rotation occurs in this inferior joint compartment and translation begins to take place in the superior joint compartment, between the superior articular surface of the disc and the posterior surface of the articular eminence. [3]

The width of the articular disc space varies depending on the interarticular pressure, which is the pressure between the articular surfaces of the joint. The morphology of the disc allows continuous contact of the articular surfaces of the joint with the disc, which is necessary for joint stability. The articular disc space reduces with high interarticular pressure (i.e. teeth clenching) which drives the condyle to seat itself in the thin intermediate zone of the disc. When low interarticular pressure exists (i.e. resting position), the articular disc spaces widens, which causes either the posterior or anterior bands of the disc to move anteriorly or posteriorly to fill the space. [3]

When mouth opening takes place and the condyle is pulled forward down the articular eminence, the elastic superior retrodiscal lamina becomes stretched, creating increased forces to keep the disc retracted. This retraction force of the superior retrodiscal lamina holds the disc rotated as far posteriorly on the condyle as the width of the articular disc space permits. The interarticular pressure and disc morphology prevents the disc from being over-retracted posteriorly.[3] On the other hand, the other ligaments of the disc are not elastic and their main function is to passively restrict extreme border movements. The mechanism by which the disc is maintained with the condyle during translation is dependent on the relation between disc morphology and interarticular pressure. This is why disc morphology is a critical factor for healthy joint functioning.[3] During mouth closure the elevator muscles contract and the reverse movements take place in the superior and inferior joint compartments.[3 44] The opening and closing dynamics of the disc and articular surfaces are illustrated in Figure 1.8.

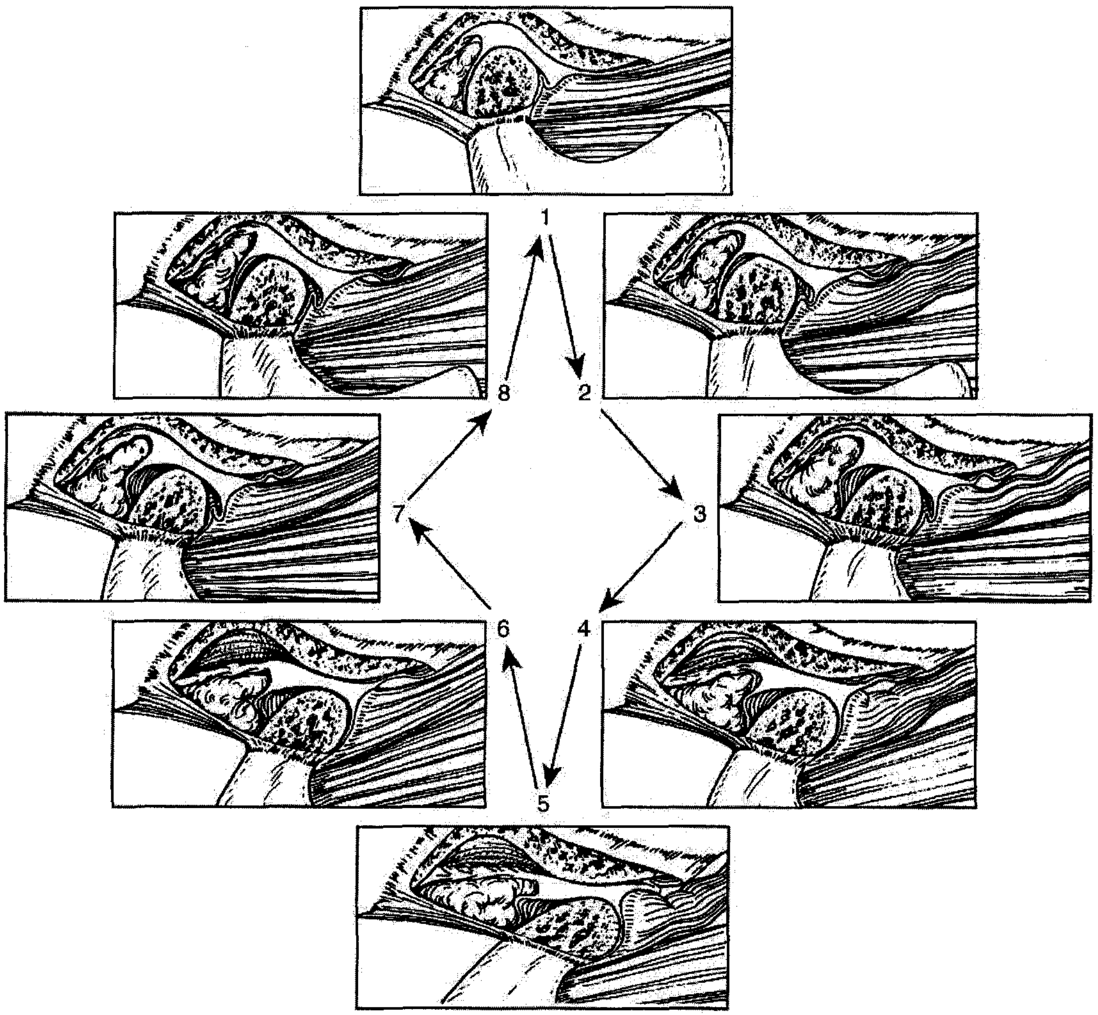


Figure 1.8[3]: Normal biomechanics of the TMJ : From 1 to 5: As the condyle moves forward for the opening movement, the disc is protracted but to a certain extent thanks to the action of the posterior ligaments. From 5-8: As the condyle moves back for the closing movement, the disc returns to its original position.

The superior lateral pterygoid muscle acts as a protractor of the disc because its active fibers pull the disc anteriorly and medially. Protraction of the disc does not occur during jaw opening. The inferior belly of the pterygoid muscle protracts the condyle forward during jaw opening, but the superior belly remains inactive; thus the disc is not brought forward with the condyle in opening movements. The superior belly of the lateral pterygoid is activated only during jaw closing movements. In the resting closed mouth position, the state of tonus of the superior lateral pterygoid exerts a very mild anterior and medial force to the disc. At this resting position, when the interarticular pressure is low and the disc space widened, the disc is in the most anterior position on the condyle allowed by the interarticular space. This is translated into the condyle being positioned in contact with the intermediate zone as well as the posterior area of the disc.[3]

During mastication, when food is crushed between the dentition, an increased force is received in the joint structures.[63 64] At this point, the articular disc acts as a shock absorber and load distributor, maintains joint stability, allows rotation movement within the joint and provides lubrication by spreading synovial fluid on the articular surfaces[60] by weeping lubrication. The disc is able to provide these mechanisms due to the presence of hydrophilic proteoglycans, hyaluronic acid, tissue fluids and collagen within the disc and the articular surfaces. The collagen matrix along with the high capacity of the disc and articular surfaces tissues to gain and loose water, allow the disc to have shock absorbing and tensile resistance properties.[44]

1.5.2 TMJ DISC DISPLACEMENT

TMJ disc displacement is a derangement of the condyle-disc complex in which the normal relationship between the condyle and the articular disc changes. This condition is also known as *internal derangement*. It is important to remember that the amount of movement of the disc is limited by the anterior, posterior and collateral discal ligaments. The amount of rotation of the disc on the condyle is also determined by the disc morphology, the degree of interarticular pressure, the superior lateral pterygoid muscle and the superior retrodiscal lamina.

If for any reason, the morphology of the disc is altered and its ligaments elongated, the disc will be able to slide across the articular surface of the condyle. This situation does not occur in a normal joint. The degree of such movement will depend on the amount of disc morphology alteration, and the amount of elongation of the discal ligaments. [3]

Ligaments are elastic to a certain extent, meaning that if they become significantly elongated beyond their elastic capacity; they cannot recover their original length. If discal ligaments become elongated and the morphology of the disc is altered, the relationship of the condyle with the disc, to provide joint stability when the interarticular pressure changes, becomes compromised. In the resting closed mouth position, when the interarticular pressure is very low, the tonicity of the lateral pterygoid muscle would easily drag the disc anterior to the condyle if the discal ligaments are elongated. The anterior displacement of the disc will be limited by the length of the discal ligaments and by the thickness of its posterior band. The anterior pulling generated by the lateral pterygoid tonicity will cause thinning of the posterior band of the disc over time, which would contribute to an increase of anterior disc displacement.[3] This simple or functional disc displacement usually does not cause pain.

When the disc is displaced anteriorly from the condyle, the function of the joint can be compromised. In this situation, when the condyle moves forward to accomplish mouth opening, a short translatory movement occurs between the disc and the condyle, which does not occur in a normal joint. In the first stage of the opening movement, there is a translation of the condyle on the posterior surface of the disc into the intermediate zone. Once the normal condylar-disc articulation is recovered (with the condyle seated in the thin intermediate discal zone), the condyle continues to translate forward for the rest of the opening movement to occur normally. After the closing movement, the muscle tonus of the lateral pterygoid, the status of the elongated ligaments and the interarticular pressure demands will drive the disc back to an anterior position.[3]

When analyzing the TMJ through sagittal slices in a MRI, a disc displacement can be identified by describing its relation to the condyle. Drace and Enzmann have developed a method to describe the condyle and disc relationship.[65] In this method, the normal disc position has been described as the posterior band of the articular disc being within +/- 10 degrees of the 12 o'clock position of the condyle. This would automatically imply that the intermediate zone of the disc is being interposed between the condyle and the posterior surface of the articular eminence. [65 66] This is considered a reference point of normal disc position, from which the severity of the disc displacement can be analyzed.[44] When a disc is displaced anteriorly, its posterior band is no longer within 10 degrees of the 12 o'clock position, thus, such angle is increased anteriorly.

1.5.2.1 PREVALENCE OF TMJ DISC DISPLACEMENT

The reported prevalence of TMJ disc displacement varies widely among different studies. One of the reasons of such variations arises from differences in descriptive terminology, data collection methods, analytical approaches and individual differences of research subjects.[27 67-69]

Cross-sectional epidemiologic studies of selected non-patient adult populations show a prevalence ranging from 40% to 75% in those populations presenting with at least one symptom of joint dysfunction (i.e. movement abnormalities, joint noise, pain, etc).[3 44]

It has been reported that approximately 50% of healthy persons present with joint sounds or deviation of mouth opening.[50] MRI studies have demonstrated a disc displacement in 30% of asymptomatic individuals.[70-72] On the other hand, it has been reported that approximately 86% of individuals with TMJ symptoms present a disc displacement.[71] These figures do not indicate the type nor amount of disc displacement.[44] Mouth opening limitation can also be related to disc displacement; this is reported less commonly in only approximately 5% of the population. [29 73]

It is reported that 26% to 31% of patients seeking treatment for TMD present a TMJ internal derangement and 30% to 35% present a muscle disorder.[41] Another diagnostic study found similar numbers, reporting that in a TMD population, the disorder was articular in nature in 33% of patients, and muscular in 41%. However, only in 7% was the disorder severe enough to result in symptoms and become part of the clinical population,[51] meaning that many patients have a TMD without any symptoms. Similarly, 9% to 13% of asymptomatic joints were detected to have a disc displacement in MRI studies.[70 74 75]

1.5.2.2 ETIOLOGICAL FACTORS ASSOCIATED WITH TMJ DISC DISPLACEMENT

TMJ disc displacement is considered to be a problem that has a multifactorial etiology. No single factor can always be considered completely responsible for the occurrence of this condition. The etiology of TMJ disc displacement remains a controversial topic despite many factors that have been suggested to predispose, initiate and maintain this condition over time.[7] The following have been identified as factors potentially associated with the onset of this condition:

1- Macrotrauma: Macrotrauma involves any sudden, excessive force to the joint that can result in structural alterations.[3] Tissue damage in the TMJ along with elongation or perforation of discal ligaments can occur when direct trauma exerts excessive forces to the mandible in a resting position.[3, 76, 77] This can lead to fibrillation of the disc as well as inflammation and fibrosis of the retrodiscal tissues. When the integrity of these tissues becomes compromised following trauma, the result is abnormal function of the joint. As a consequence, abnormal function of a joint with roughened articular surfaces may perpetuate and increase tissue damage, resulting in elongation of discal ligaments and secondary disc displacement.[3, 44] Examples of macrotrauma include a blow to the chin, whiplash during a motor-vehicle accident, and iatrogenic over-extension of the mandible such as in during intubation for general anesthetic[78, 79] and third molar extraction procedures that could cause overextension and elongation of the discal ligaments.[76]

2 – Microtrauma: Microtrauma refers to small forces that are repeatedly applied to the TMJ over long periods of time.[3] Parafunctional oral habits, orthopedic instability, bruxism or clenching and excessive gum chewing are microtrauma factors. The loads are usually applied when the mandible is in an abnormal, non-functional position.[44] When the articular tissues are loaded excessively for long

periods of time, the capacity of the tissue to maintain their integrity and to regenerate becomes compromised. Without regeneration capacity, tissue breakdown will occur due to fibrillation, loss of proteoglycans, loss of tissue compressiveness and formation of micro-adhesions.[80] [81] Decreased compressibility and loss of normal disc anatomy, along with alterations in discal mobility may lead to elongation of the discal ligaments and finally to disc displacement. [3]

3 – Orthopedic instability and malocclusion: Orthopedic instability occurs when the intercuspal position of the teeth is not in harmony with the musculoskeletally stable position of the condyles.[3] This has been proposed a possible risk factor for disc displacement. When the masticatory forces are applied on a masticatory system with orthopedic instability, the joints shift from their physiological position to an unstable position in order to allow the teeth to come together. This results in a translatory shift between the condyle and the disc, which can lead to elongation of the discal ligaments and thinning of the disc. The non-physiological position of the condyle within the glenoid fossa leads to abnormal loading. This would cause microtrauma to the disc, especially when the joint loading is excessive or for extensive periods of time.

As for malocclusion, there is no clear evidence in the literature demonstrating that this is a risk factor for disc displacement or any type of TMD in general. Published research findings are contradictory with some studies reporting occlusal factors as a potential risk for disc displacement,[10-13 15 18 19 21 23 82] whereas others have failed to identify a significant correlation.[8 9 14 16 17 22 24 83-86] If only the studies that found a positive association between TMD and occlusal factors are examined, there are many occlusal factors listed such as posterior occlusal crossbites,[15 19] occlusal interferences,[85] increased incisal overjet and overbite[8 15 20 84] poor overbite[15 19] and lost of posterior molar support. Such studies however fail to show consistency of the same occlusal factors when repeated over time. It is important to keep in mind that certain occlusal characteristics can be consequence, rather then a cause of TMD.[7]

4- Orthodontic treatment: Although proposed in the past as a risk factor for TMJ disc displacement,[87-90] long-term studies and more recent orthodontic publications do not consider orthodontic treatment to be associated with this condition.[7 91-99] In reality, the incidence of TMD symptoms in patients receiving orthodontic treatment is not greater than in the untreated general population. Furthermore, no specific type of orthodontic technique has been related to internal derangements. [95 100-102] In addition neither extraction nor non-extraction treatment was associated with this condition.[98 103-106]

5- Age, race and gender: A general age pattern has been consistently reported for the presentation of signs and symptoms of TMD. Many studies report that signs and symptoms of TMD are not common among children, but are more common in adulthood. In the same way, patients older than 60 years of age rarely present TMD symptoms. It appears that the development of TMD symptoms is more common between puberty and adolescence until approximately age 60.[27 107-110] Epidemiologic studies reveal that TMD symptoms occur mainly between 20 and 40 years of age.[27 29] The incidence of joint sounds in individuals within this age range appears to be as high as 17.5% over a two years period [21] and clicking may come and go spontaneously over a 5-year period.[111] Unlike age, race does not seem to present a specific preference for the prevalence of disc displacement.

Regarding gender, it is well known that females have a higher prevalence for TMD in general than men. When looking specifically at joint symptoms women present more TMJ clicking and TMJ pain than men.[26 28-30 41 69 112-114] This difference between females and males is reported in ratios ranging from 3:1 to 9:1 in patients seeking treatment for TMD.[7 115 116] It is important to keep in mind that the fact that women appear to seek TMD treatment more than men may be related to their increased health awareness.[117] The age and gender distribution of TMD is illustrated in Figure 1.9.

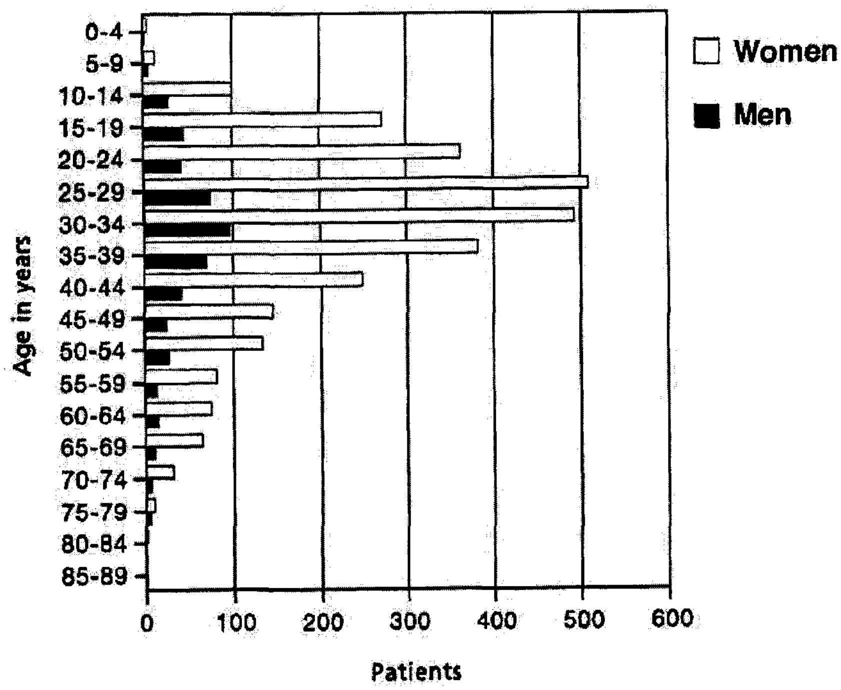


Figure 1.9 [7] **- Demographics of TMD:** Age and sex distribution of TMD patients

6 – Degenerative Joint Disease (osteoarthritis) of the TMJ: It is also suggested in the literature[118] that disc displacement progression may be associated with degenerative joint disease (DJD) of the TMJ, in other words to TMJ osteoarthritis. However, the direction of such relationship is not known. It is not clear if the displacement of the TMJ disc would lead to DJD or vice versa. Thus, DJD cannot be considered a complication of TMJ disc displacement progression. When DJD is present it tends to occur mainly in females between puberty and menopause.

7 – Hormonal factors: It has been observed that hormonal factors are associated to the fluctuation of TMD symptoms.[119] TMJ laxity also appears to be related to hormonal factors in women,[119-122] providing that, generally, women tend to have

greater laxity in their joints than males.[123] Since the majority of patients reporting TMD are women, it is proposed that female hormonal fluctuations can predispose to the manifestation of TMD symptoms.[119] [124] Hormonal fluctuations during menstruation and pregnancy have been associated with changes in the presentation of pain in general and TMD symptoms.[3] [119]

Recent studies identified higher serum levels of sexual hormones, such as estradiol and estrogen, in patients with TMD than in asymptomatic individuals of both genders.[125] [126] The authors suggest that some articular tissues such as cartilage, bone collagen, as well as certain proteins may be a target for such hormones.[121] [122]

8- Anatomical factors: The degree of steepness of the articular eminence varies from individual to individual. As the level of steepness increases, a greater rotational movement between the disc and the condyle is required. This excessive movement between the condyle and the disc can lead to elongation of the discal ligaments. The association between steepness of the articular eminence and disc displacement remains controversial and it can only be considered as a predisposing factor that becomes significant only when combined with other factors that influence this condition. [3]The morphology of the condyle and the fossa can also play a role in the development of disc displacement. Flat condyles articulating with a deep glenoid fossa tend to present a greater rate of disc displacements.[127]

The amount of TMJ laxity may also be a predisposing factor for disc displacement. Some studies demonstrate that women with general joint laxity have a higher incidence of TMJ disc displacement than women without this feature.[128-131] However, the consideration of this trait as a predisposing factor for disc displacement is still controversial, as other studies have demonstrated no relationship.[59 132]

9– Joint hypermobility: TMJ hypermobility has been related to disc displacement. Overextension of the mandible causes elongation of the main TMJ ligaments and the smaller discal ligaments. This can occur in traumatic episodes such as third molar extractions, whiplash during motor-vehicle accidents, oral intubation for general anesthesia, prolonged dental appointments and even uncontrolled yawning. [3]Patients are at risk for this to occur whenever they are sedated and the normal joint stabilization by the muscles is diminished.[3] Some associations between increased condylar translation and joint sounds have been shown in an adolescent sample but the significance of joint hypermobility still requires investigation.[86] TMJ hypermobility is dependent on certain anatomical factors of the condyle and glenoid fossa, including steepness of the articular eminence and laxity of the TMJ ligaments. [3]

10 – Genetic predisposition: Little is yet known regarding the possibility of genetics as a predisposing factor for the development of TMD. It is proposed in

the literature that genetic factors can influence the onset of TMD and pain perception in the population. Furthermore, certain genetic molecules have been associated with this condition.[133-135] However, this topic remains controversial as other studies have demonstrated no association whatsoever between TMD and genetics,[136] suggesting that environmental factors play the major role in the multifactorial etiology of TMD.

1.5.2.3 TYPES OF DISC DISPLACEMENT: PATHOPHYSIOLOGY AND CLINICAL EVALUATION

As the disc is chronically positioned forward by the anterior pull action of the lateral pterygoid, the ligaments become more elongated and the posterior band thinner.[137] The combination of these factors will drive the disc even more anteriorly to the point of the condyle being positioned more posteriorly on the posterior band.[72] The increasing anterior positioning of the disc will then cause further elongation of the superior retrodiscal lamina. [3]

When the disc is anteriorly displaced, loading occurs in the posterior band rather than in the intermediate zone. The way the collagen fibrils are arranged and the concentration of proteoglycans in this area of the disc are different than in the intermediate zone;[48 54 55] therefore, the posterior band is much less capable of supporting loading. Over time, the collagen structure in the posterior band becomes compressed, losing its ability to hold proteoglycans and joint fluid. This leads to thinning of the posterior band, which will contribute to further joint instability and disc displacement.[81]

In addition to the posterior band thinning, loss of discal fluid and the resulting poor lubrication increases tissue damage when loading occurs with poor lubrication. This, along with increased frictional drag from collagen surface fibrillation, disturbs the normal movement of the disc relative to the condyle. Increased rotational movement between the condyle and the disc will contribute even more to the elongation of the attachments and further increase in disc displacement.[44]

When the disc is displaced anteriorly, the retrodiscal tissues are also dragged forward between the condyle and the glenoid fossa. In acute situations, this could cause inflammation of the retrodiscal tissues and severe pain, a condition known as *retrodiscitis*.[3 138] Continued functional loading on the retrodiscal tissues in the presence of acute inflammation, and reduced tissue repair and regeneration, may lead to perforation of the posterior attachment; this will further interfere with condylar mobility and more disc displacement.[44] In situations where functional loading does not exceed the physiologic limit of the tissue, the retrodiscal tissues undergo an adaptive process of scarring. The increased amount of fibrous tissues allows the retrodiscal tissue to function as a "pseudo disc".[139 140]

During inflammation and tissue damage within the joint, the synovial membrane also becomes affected. Abnormal loading of the synovial tissues causes an inflammatory reaction though the vascular supply to the membrane. Inflammatory exudates is produced that causes compression of tissues, exceeding their adaptive capacity and reducing the surface area covered by synovial membrane. This affects the quantity and quality of the synovial fluid production.[44]

In the presence of severe disc displacement, the surfaces of the condyle that are no longer in contact with the articular disc will be in contact with other osseous surfaces such as the articular eminence and the glenoid fossa. These structures are not compatible from a morphological point of view, which changes the dynamics of loading and force distribution. During loading or mastication, the force per unit area in the fibrocartilage is increased, leading to tissue fatigue, loss of tissue fluid and reduced compressibility. This will create breakdown of the collagen and proteoglycans of the articular cartilage. As loading continues, the breakdown proceeds deeper into the different layers of the articular cartilage, affecting the chondrocytes and the ability of the tissue to repair.[44] The osseous tissues can also be affected at the level of the trabeculae, which can become fractured. This stimulates an inflammatory response, activating osteoclasts and osteoblasts, which can result in further resorption of the trabeculae or the formation of a reparative callus.[44]

There are two types of disc displacement, depending on the amount of anterior dislocation of the disc from the articular surfaces of the TMJ.

The first one is defined as ***disc displacement with reduction***, which refers to the ability of the disc to return to its normal articulation with the condyle during opening movement. In this case, as the condyle moves forward during the opening movement, it translates from the posterior band of the disc into the thinner intermediate zone to recover normal articulation. At this point, a joint sound defined as a "click" can be perceived. This is a short lasting sound that is created when the condyle fits back into the intermediate zone of the disc. In some cases, a second click can be detected during closing movement as the disc translates back from the intermediate zone below the posterior band of the disc. This situation is known as *reciprocal click.* The biomechanics of a disc displacement with reduction is illustrated in Figure 1.10.

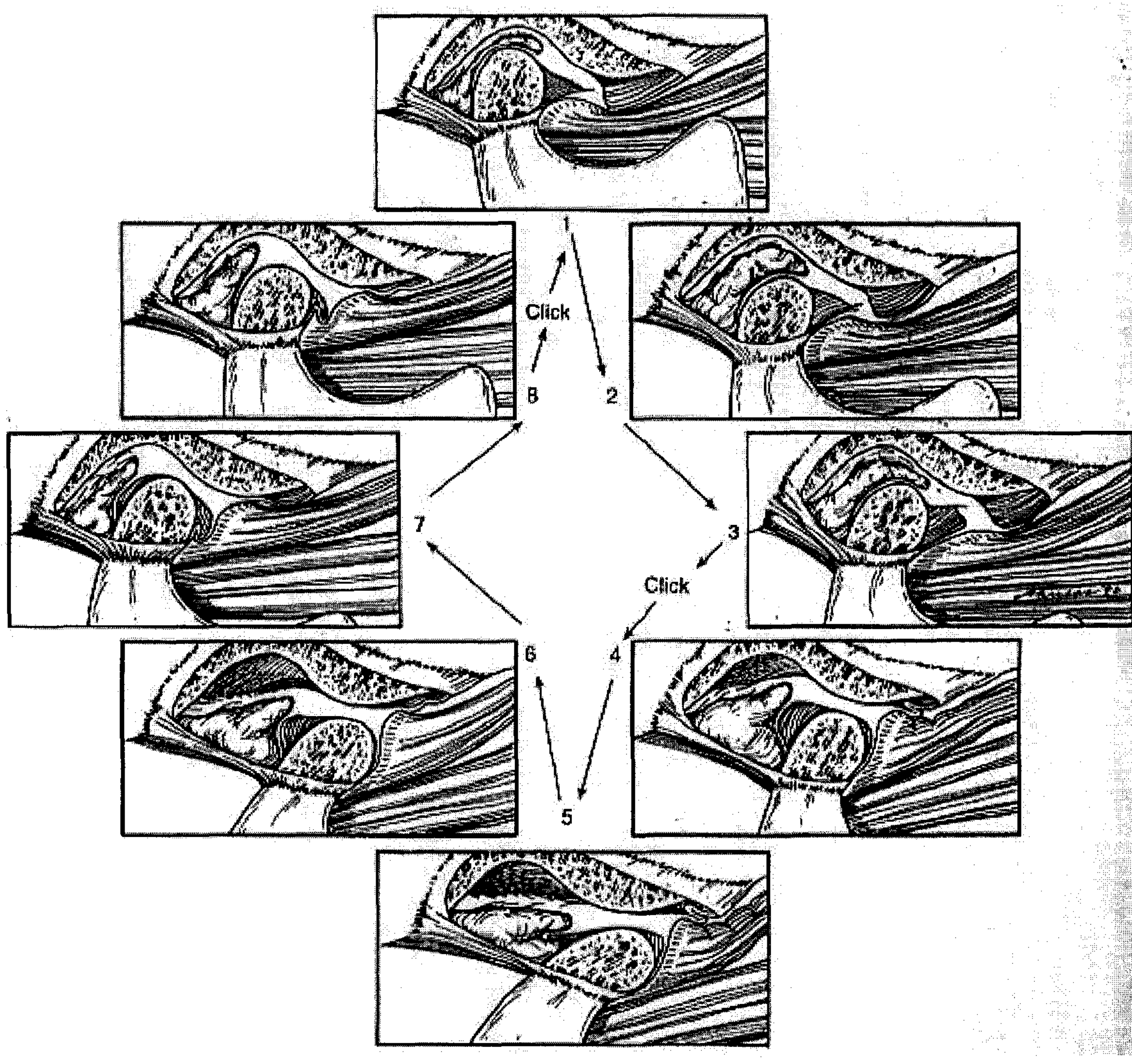


Figure 1.10 [3] **- Biomechanics of disc displacement with reduction:** From 1 to 3: In this case the disc initial position is dislocated from the condyle. Therefore, as the condyle moves forward for the opening movement, the disc acts as a mechanical interference. However, the ligaments are still capable of retracting the disc enough to recover its normal position (4) during the opening movement. From 5 to 8: As the condyle moves back for the closing movement, the disc returns to its original position anterior to the condyle

This situation can present with or without pain depending on the integrity of the articular structures, such as the retrodiscal tissues. Clinically, at the initial stage of opening, it can be observed that the midline deviates to the affected side with limited range of opening, but, once the disc is reduced and the click sound occurs, the opening path of the jaw recovers the midline. After this point, the opening movement continues normally with a normal range of motion (>40mm interincisally).

The second type of internal derangement is called ***disc displacement without reduction***. This condition is also commonly known as *closed lock.*[141] In this case the disc is completely dislocated from the condyle acting as a full mechanical interference to the opening movement when the condyle comes forward. It is thought that part of the reason why the disc is unable to recover a normal articulation over the condyle is because the elasticity of the superior retrodiscal lamina has been completely lost, [3] thus the disc cannot be dragged backwards. In this condition, the condyle never recovers a normal relationship with the disc, but instead, pushes the disc forward during jaw opening. This mechanical interference to the opening path may limit the amount of forward translation of the condyle, which results in a limited range of motion. In some cases only condylar rotation is achieved, not allowing a complete translation of the condyle. The biomechanics of a disc displacement without reduction is illustrated in Figure 1.11.

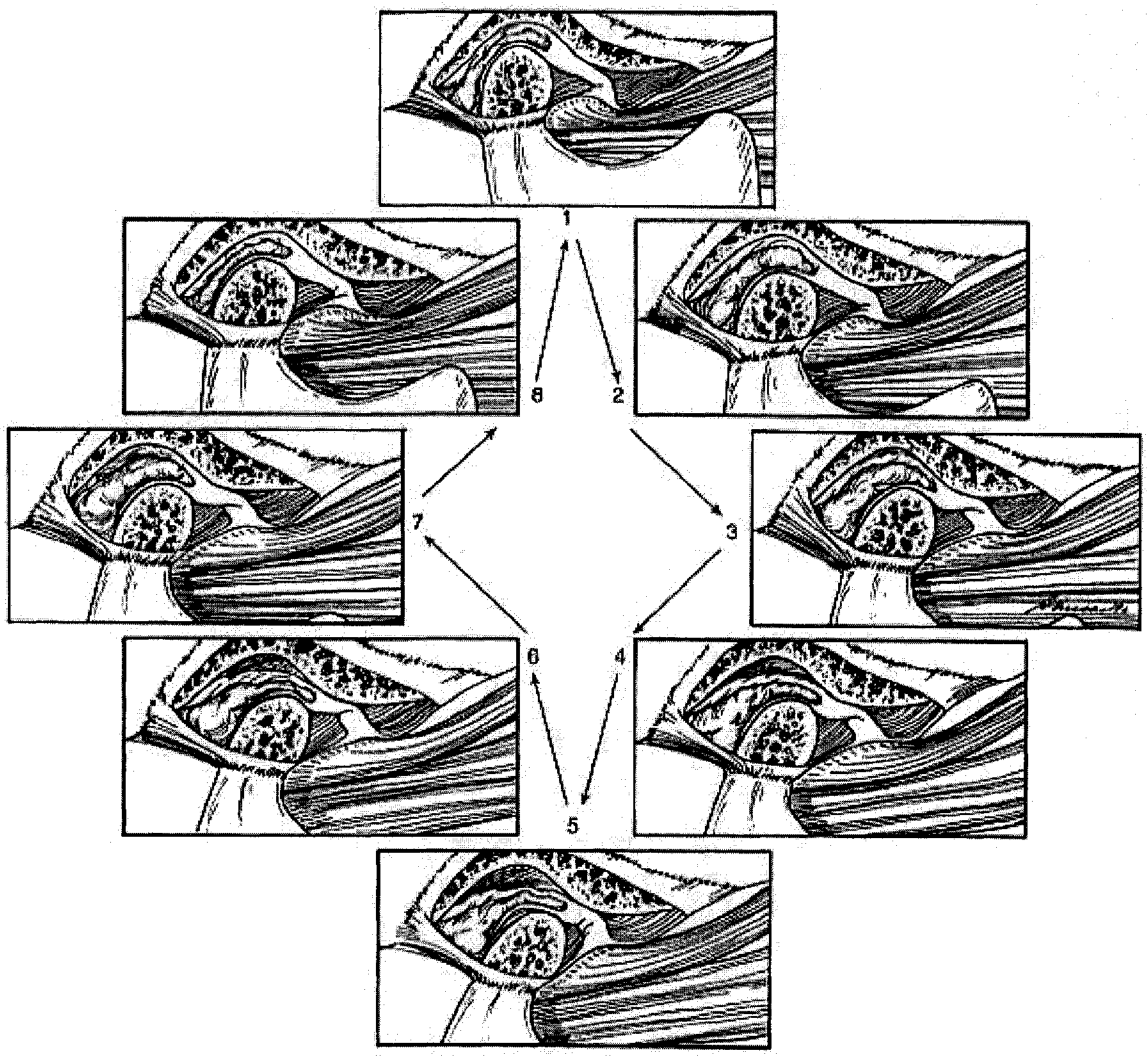


Figure 1.11 [3]: Biomechanics of disc displacement without reduction: From 1 to 8: In this case the disc initial position is dislocated from the condyle. Therefore, as the condyle moves forward for the opening movement, the disc acts as a mechanical interference. However, the ligaments are not capable of retracting the disc to recover its normal position during the opening movement. Therefore the amount of protraction of the condyle becomes limited. From 5 to 8: The condyle moves back for the closing movement, and the disc remains in its original position anterior to the condyle

From a clinical perspective, acute disc displacement without reduction can be diagnosed by the limited range of opening (25 to 30mm interincisally), which represents the maximum rotation of the joint. Although this is usually one of the classical diagnostic features, it is important to keep in mind that in some cases, as the disc is further displaced forward and no longer acts as a mechanical interference to the condyle, many patients will have full range of motion and may even be hypermobile. A characteristic pattern of mandibular movement is observed involving a deflection of the mandible to the affected side, without recovering the midline. Pain can be present with such condition, but does not happen in all cases.[72 142-144]

In this type of disc displacement, the disc is no longer with the condyle, which is in close contact with the glenoid fossa and articular eminence with elongated posterior attachments of the disc interposed. At this point, the articular disc is located anterior to the condyle in the joint recess at the height of the articular eminence. This space is extremely limited for the disc and during mouth opening the condyle pushes the disc forward without reduction. As a consequence of the limited space available in this area for the disc in its fully extended form, the disc bends in the region of the intermediate zone. The direction of the bend can be superiorly or inferiorly depending on the amount of space available.[44] This is one of the main changes in disc morphology observed in advanced cases of disc displacement.

TMJ disc displacement can also be classified according to the type of disc dislocation in the sagittal and coronal planes. This classification was created from multi-planar MRI methods of the TMJ.[145] Three types of disc displacement have been described in this regard (Figure 1.12):

1- Straight disc displacement: In the closed mouth position the posterior band of the disc is positioned anteriorly to the superior aspect of the mandibular condyle. Posterior disc displacement has been reported but is extremely rare in the population.[145 146]

2- Sideways disc displacement: In this case there is no anterior component of displacement at all. The disc is strictly displaced either laterally or medially. This condition is only identifiable in MRI coronal slices of the TMJ.[145]

3- Rotational disc displacement: This type of displacement has a combination two components, one in the sagittal plane and the other in the coronal plane. There is not only an anterior displacement but also the disc is rotated medially or laterally. Therefore, a rotational disc displacement can be described as either antero-laterally or antero-medially

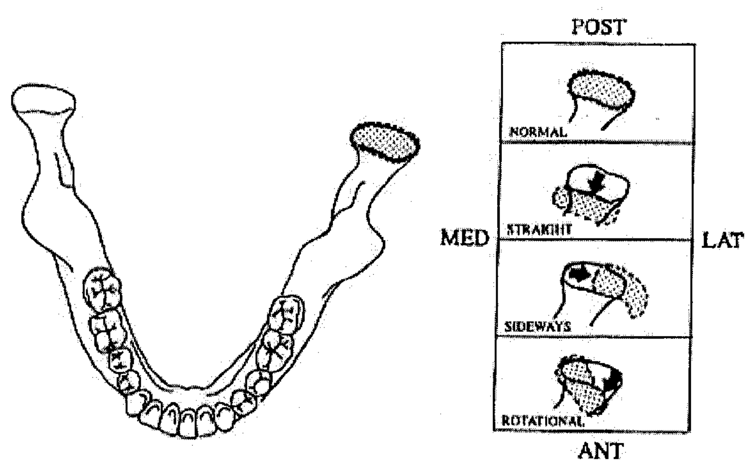


Figure 1.12 [44] **- Types of rotational disc displacement:** POST: posterior; MED: medial: LAT: lateral: ANT: anterior

1.5.3 MAGNETIC RESONANCE IMAGING OF THE TMJ

MRI offers direct visualization of the soft and hard tissues components of the TMJ. The images can be performed in any plane making it easier to identify the location of each structure and the detection and orientation of a disc displacement. MRI also offers the advantages of being non-invasive, pain free and it is free of exposure of ionizing radiation.[147] When compared to other imaging methods such as arthrography, MRI produces neither pain nor soft tissue distortion due to the injected contrast medium into the joint cavity.[5]

Two types of images are obtained with MRI depending on the contrast and spatial resolution. Each type of image offers advantages for visualization or specific characteristics and conditions of the TMJ tissues:[44 148]

<u>T1 weighted images</u>: These images are indicated to identify general disc morphology and its position within the joint. It can also detect changes within the disc that may be suggestive of proteoglycans concentration. T1 weighted images also aid in detection of disc mobility issues, interpreted as disc adhesions and pannus formation in chronic inflammatory joint disease [44].

<u>T2 weighted images</u>: These are mainly used to detect joint effusion and inflammation. They are also helpful in visualizing condylar bone marrow changes associated with inflammation and sclerosis.

MRI is reported to be 90% accurate in detecting disc position, cortical erosions, osteophytes and flattening of the mandibular condyle.[149] In addition, acceptable interobserver agreement in the identification of disc position through MRI interpretation has been reported.[149 150]

MRI of the TMJ also has some disadvantages such as the inability to detect perforations of the disc or of its posterior attachments. Other disadvantages include:[44]

- Motion artifacts can significantly reduce the quality of the images.
- Since the TMJ contains tissues that generate signals of significant different intensities, the images are subject to truncation (an artifact that may occur when the interface between high and low signal intensities is encountered in one imaging plane) and greater susceptibility to other types of artifacts in general[151]
- Fluid flow and chemical shift can become complications at high field strengths
- Claustrophobia is observed in some patients when they are inside the magnetic chamber
- MRI is contraindicated in patients with metallic prostheses. .

The current standard for interpretation of TMJ images depends on the subjective evaluation of the examiner reading the MRI. Therefore, accuracy of interpretation depends on the background and familiarity with such images and with the TMJ anatomy and function. MRI is considered the "gold standard" to evaluate the soft tissues within the TMJ in both closed and open mouth position [44]

Magnetic resonance images are obtained by placing nuclear magnetic fields (living tissues) into another larger externally applied magnetic field (MRI equipment). In other words, images of living tissue are produced when the nuclear magnetic properties of the hydrogen nuclei in the atoms are excited to emit a signal. In this way, images of hard tissue, soft tissue and tissue fluid can be obtained through slice information of anatomical structures. Slice selection and formatting of MRI is termed spatial encoding.[44]

1.5.3.1 SPATIAL ENCODING

Of all atoms in the living tissue, hydrogen possesses the most magnetic nucleus. The nucleus of hydrogen is simply a proton. There are two hydrogen atoms in each water molecule, and at the same time, water accounts for 80% of the living tissue. Since each of these hydrogen nuclei acts as a "small magnet", it is mostly the hydrogen in the water and fat of the living tissue that is imaged by MRI methods.[152]

Each hydrogen nucleus (proton) has a positive electric charge located at a small distance from the nuclear center. In other words, it is an ideal atom for MRI because its nucleus has a single proton and a large magnetic moment. The large magnetic moment means that, when placed in a magnetic field, the hydrogen atom has a strong tendency to line up with the direction of the external magnetic field. The positive charge spins around the nuclear axis (Figure 1.13), creating a magnetic field. In this way, the individual magnetic field created at the level of each hydrogen atom interacts with an externally applied magnetic field originating from the MRI equipment.[152]

The most important component in an MRI system is the magnet. The magnet in an MRI system is rated using a unit of measure known as a *tesla*. Magnetic fields greater than 2 tesla have not been approved for use in medical imaging [152] though much more powerful magnets (up to 60 tesla) are used in research. When hydrogen nuclei are exposed to an external greater magnetic field, they align parallel to this field. At this point, the hydrogen nuclei spin, or precess, at the resonant frequency, which is proportional to the strength of the externally applied magnetic field.[152] The term "resonance frequency" refers to the frequency at which a resonance phenomenon occurs. An atom will only absorb external energy if that energy is delivered at precisely its resonant frequency.

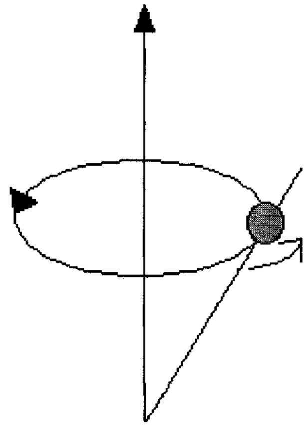


Figure 1.13 – Representation of magnetic field: A hydrogen atom spins about a magnetic field

The MRI machine applies radio waves or a radiofrequency pulse that is specific only to hydrogen. The system directs the pulse toward the area of the body we want to examine. The pulse causes the protons in that area to absorb the energy required, making them spin in a different direction. This is the "resonance" part of MRI. The radio frequency pulse forces them to spin at a particular frequency, in a particular direction. The specific frequency of resonance is called the *Larmour* frequency and is calculated based on the particular tissue being imaged and the strength of the main magnetic field.[152]

The hydrogen nuclei placed inside the core magnet are stimulated by the radiofrequency pulse to allow their localization. These nuclei absorb the frequency and change their energy state. After this stimulation by radio frequency, the hydrogen nuclei re-emit the absorbed energy in the form of radio waves. This energy re-emitted from the tissue lasts only for a short period of time, and is detected by a short-wave radio antenna.[44 152]

As discussed above, the resonant frequency of hydrogen nuclei stimulation depends on the magnetic field strength. A magnetic field with a graded strength will induce hydrogen nuclei to resonate at different frequencies according to the graded magnetic field strength. In this way, the gradient magnetic fields allow localization of the hydrogen nuclei. If gradients were not used, the entire anatomical region being imaged would respond as one whole single entity and no localization or differentiation of tissues would be possible.[44 152]

To obtain a single slice of tissue a gradient is established along the longitudinal axis (Z-axis) of the magnetic field from the foot-end to the head-end of the magnet. The specific radio wave frequency is then applied, which is absorbed by the tissue located in the specific magnetic field. The absorbed energy causes the hydrogen nuclei to move from the Z-axis in to the transverse (X-Y) axis. The degree of change (deflection) depends of the amplitude of the radio frequency that was applied. The larger the radio frequency is, the greater the amount of deflection. Deflections up to 90 to 180 degrees can be created. The remaining tissue on either side of the slice will remain stimulated and retain its longitudinal magnetization.[44] (Figure 1.14)

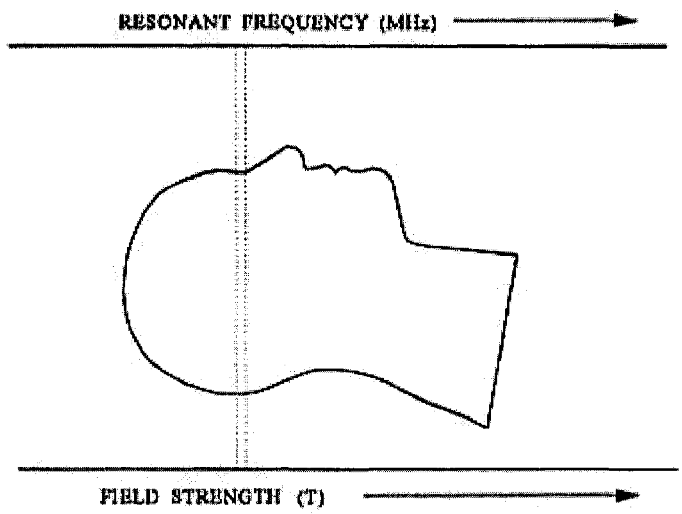


Figure 1.14 [44] – **Production of image slices**: Field strength and resonant frequency orientation to obtain imaging slices

At this point only a single slice of tissue is localized, but with no information on the different structures present in such slice because the whole tissue unit resonates at the same frequency. To differentiate and visualize each one of these structures, a second step of encoding is required. This second step is achieved by applying another magnetic gradient at the right angles to the previously applied gradient. The nuclei in the slice that originally resonated at the same frequency are now exposed to new magnetic fields with different strengths (a new graded field).[44 152] The interactions of the nuclei with the new intensities of the local magnetic fields will cause them to resonate at new frequencies in each slide, depending on their position in the transverse gradient. In this way, the resonance frequencies of the nuclei are spatially encoded so that nuclei in the weaker end of the gradients field resonate at lower frequencies than those in the stronger field.[44 152]

The plane of tissue of interest is then divided into parallel lines that radiate a specific frequency and intensity of radio wave. The strength of the radio signal gives information on the amount of hydrogen present. The frequency provides the location of the line in the transverse slice of the tissue.

Once the data are collected the process is repeated, starting again from the restoration of a new Z-axis. The same transverse slice of tissue is located and excited by radio frequency. Once again, the Z-axis gradient is turned off, and the transverse gradients is activated across the isolated slice of tissue; this time, in a slightly different direction. That is why the hydrogen concentration along a new set of parallel strips is in a slight different orientation to the first set. This process is then repeated many times, slightly changing the orientation of each gradient applied, until the original slice of interest has a number of parallel lines that will cross the plane of the slice at a different angle.[44 152]

1.5.3.2 TISSUE CHARACTERIZATION: T1 AND T2 WEIGHTED IMAGES

The specific radio frequency for a tissue exposed to a particular magnetic field can be used to obtain different types of tissue contrast. This is achieved by using the gradient magnetic field to locate proton density along with longitudinal and transverse relaxation.

Immediately after the stimulation of protons by radio frequency, the tissue under examination begins to re-emit the absorbed energy. At this point, the hydrogen nuclei are moving from the transverse plane of stimulation back to the longitudinal plane. This return of magnetization to the longitudinal plane is called T1 relaxation. T1 relaxation refers to the time that is required for approximately 63% of the remaining relaxation to reappear in the longitudinal plane.[44 152] T1 is also known as longitudinal relaxation.

The re-growth of magnetization in the longitudinal plane of the magnet is not the same in all tissues. Some tissues have a more rapid re-establishment of magnetization in the longitudinal magnet plane than others. Pure liquids, such as water have relatively long T1 relaxation times, while other more solid ones have a short relaxation time as their molecules are less mobile.[44 152]

When the signal is emitted after excitation, the reduction in the signal occurs long before the magnetization in the longitudinal plane has been fully re-established. The reduction in signal is called T2 relaxation. This reduction in signal arises due to the random local variations in magnetic field strength as a result of thermal motion of particles, causing nuclei to diphase. The interactions of the many emitted radio waves cancel each other and produce the dephasing. T2 is defined as the time required for the transverse magnetization vector to drop to 37% of its original magnitude after its initial excitation. T2 is also known as transverse relaxation. After excitation, the re-emitted signal decays exponentially and is known as the free induction decay (FID). Different regions of the slice have different rates of decay of the signal with T2 relaxation being shorter for solids than liquids.[44 152]

The variation of T1 and T2 relaxation times in healthy and diseased tissues provides an excellent source of contrast. The differences in relaxation times in different tissues are presented in Table 1.1. Various sequences and timing of radio wave stimulation are applied to take advantage of the differences between tissue imaging. These are called pulse sequences, which are used to accentuate either T1 or T2 differences between the tissues of interest.[44]

Tissue	T1 relaxation time	T2 relaxation time
Fat	180ms	40ms
Muscle	600ms	90ms
Blood	800ms	180ms
CSF	2000ms	300ms
Water	2500ms	2500ms

Table 1.1 - Relaxation times: (courtesy of Dr. Sharon Brooks, University of Michigan): Different T1 and T2 relaxation times in milliseconds (ms) for different tissues such as fat, muscle, blood, cerebrospinal fluid (CSF) and water.

After excitation the spins will tend to return to their equilibrium distribution in which there is no transverse magnetization and the longitudinal magnetization is at its maximum value and oriented in the direction of the static magnetic field. After excitation the transverse magnetization decays toward zero with a characteristic time constant T2, and the longitudinal magnetization returns toward equilibrium with a characteristic time constant T1.

The time between successive pulse sequences applied to the same slice is called repetition time (TR). TR takes place between the first radio frequency pulse of the sequence and repeating the same radio frequency pulse. Variations in TR have an important effect on the regulation of image contrast. Short values of TR (< 1000 ms) are common in images exhibiting T1 contrast, and long values of TR (> 1500 ms) are common in images exhibiting T2 contrast. TR is also a major factor in total scan time. The time between the 90 degree pulse and the maximum in the echo in a spin-echo sequence is called Echo time (TE). TE tends to be longer for T2 images (100-125ms) and much shorter in T1 weighted images (10 – 25ms).

1.5.3.3 PULSE SEQUENCES

There is a strong relationship between frequency of spinning and applied magnetic field strength. The transmitter pulse will determine the angle through which the magnetization precesses during the pulse. For example, a pulse that tips the magnetization into the transverse plane (X-Y axis) is called a 90° pulse, and, a pulse of double duration will place the magnetization along the longitudinal plane (Z-axis) and is defined as a 180° pulse.[152] There are three main types of pulse sequences: Inversion-recovery pulse sequence, saturation recovery pulse sequence and echo pulse sequence. The first two are used to generate T1 weighted images, and the last one T2 weighted images.

A 90° pulse drives the magnetization into the transverse plane out of the longitudinal plane of the magnet. Once the tissue relaxes back into the longitudinal plane and re-emits a signal called the free induction decay (FID). If a second 90° pulse is applied when only a portion of the tissue has realigned with the longitudinal field there will be fewer hydrogen nuclei arranged parallel to the longitudinal axis ready to be returned to the transverse plane. If the tissue is now re-excited and allowed to relax back, the re-emitted FID signal will be weaker. This play between tissue relaxation and pulse sequencing is used to accentuate differences between tissues.[44]

1.5.3.4 MRI INTERPRETATION OF THE TEMPOROMANDIBULAR JOINT

The principles of magnetization discussed above are applied in the same way to the selected slice for TMJ imaging. Generally, images that are generated with a short TE and short TR will be T1 weighted and those produced with long TR and TE will become T2 weighted. T1 and T2 images will differently accentuate the contrast of the TMJ tissues. In other words, the same tissue in the same slice will have a different contrast on a T1 weighted image than on a T2 weighted image.[66]
153 154

When reading T1 images it can be noted that the cortex of the condyle, posterior surface of the articular eminence and the glenoid fossa appear black. This is because the protons contained in the cortical bone are not capable of producing a signal since they are not mobile within the osseous structure. On the other hand, the trabecular bone area is able to produce a signal due to the amount of fat, lymphatic tissue, blood, blood vessels, and water located in between the trabeculae. The protons in these tissues are mobile and therefore have a short T1 value. Therefore, this tissue produces a relatively bright signal.[147 155]

Muscles such as lateral pterygoid and temporalis can be observed in TMJ MRIs. The protons in the muscle are less mobile than in fluids or fat, but more mobile than in bone. The organization of muscles is more complex due to the great amount of proteins and macromolecules present. Therefore, muscle tissue appears as an intermediate gray signal divided by darker bands of fascia.[155] The lateral pterygoid can be observed in sagittal images fanning out anteriorly from the neck of the condyle. The masseter and medial pterygoid muscles can be identified in coronal images lateral and medial to the ramus, respectively.

The morphology of the articular disc can be also identified from a sagittal perspective with the thicker, anterior and posterior, bands and the thinner intermediate zone in between, resembling the appearance of a bow tie. The disc contains a high concentration of fibrous tissue and some proteoglycans that attract water and synovial fluid. The protons of the fibrous tissue are less mobile, whereas those contained in the synovial fluid within the disc are more mobile and capable of producing a signal. Therefore, the articular disc has a longer T1 than muscle and appears proportionally darker, but slightly brighter than cortical bone. The retrodiscal tissues usually appear as a bright signal due to the high presence of soft tissues, such as blood and fat that they contain. In many cases the superior and posterior retrodiscal laminae can be clearly identified as dark bands contrasting the bright signal from the retrodiscal tissues superiorly and inferiorly. These bands usually present the same darkness or signal than the articular disc.

In cases where the disc is displaced with morphological alterations, the signal emanating from it may be different. Due to the loss of proteoglycans and fluid, the disc and its posterior attachments may appear darker than in the image of a healthy joint.[147] In some cases the retrodiscal tissues have suffered scarring and fibrosis, emanating a dark rather than the bright appearance that they show in a normal situation. This fibrosis of the retrodiscal tissues usually generates a signal very similar to the disc, which can lead to a false-negative identification of a disc displacement. Therefore, it is always important to examine the anterior joint compartment for the presence of discal structures that may be distorted in shape.

The synovial fluid is also identifiable, especially in those areas of the joint cavity where it easily accumulates. The synovial fluid surrounds and lubricates all the articular surfaces within the TMJ capsule. It has a high plasma composition and it penetrates the disc and the articular cartilage present in the osseous articular surfaces. On T1 weighted images the synovial fluid can be clearly identified as a bright signal in the anterior or posterior joint cavity recesses. In addition it also helps to identify the articular disc as it clearly separates it with its bright signal from the superior and inferior bony articular surfaces.[147 155]

1.5.3.5 COMPARING MRI TO OTHER TMJ IMAGING METHODS

MRI is considered the gold standard to visualize a combination of hard and soft tissues of the TMJ. Other methods are also used for TMJ visualization but they have some limitations when compared to MRI.

Plain film radiography (transcranial, transpharyngeal, transmaxillary, transorbital and submental-vertex views) have been used to evaluate the TMJ. They are difficult to interpret due to great amount of superimpositions of other osseous structures. [3]Panoramic films are also used, as they can aid in detecting gross abnormalities of the osseous surfaces of the joint such as fractures or advanced DJD. These imaging techniques can be used as initial screening tools.[150] Although plain film radiographs can allow detecting some level of osseous articular detail, they do not provide direct imaging of the articular disc. Methods trying to predict the disc position through these images have not been proved to be reliable or accurate. These images are therefore of limited application to diagnose disc displacements.

Tomography is another imaging technique used to evaluate the TMJ. Individualized tomography corrects for vertical and horizontal condylar angulations, providing images of improved clarity and free of distortion. Tomographic slices of the joint can be generated in any of its regions. It provides an excellent source to study in detail the osseous architecture of the TMJ structures and the spatial relationship between them. The condyle may appear in different positions in the glenoid fossa, which are not indicative of the position of the disc.[156-159] This is a great source to evaluate the osseous components of the joint and diagnose fractures or DJD, however, information regarding the disc or sift tissues is not possible through this method.

Computed tomography (CT) is capable of revealing great detail of the status of the bony structures such as erosions, or small sequestra within the condylar head. [44] Three-dimensional reconstruction of CT data can be used to determine the boundaries of ankylosed areas, and to localize tumours.[160] The determination of disc position has been reported with CT,[161-163] but with very poor reliability.[149] [153] CT provides slightly better bony detail than regular axial corrected tomography, however, its cost is significantly higher and it delivers higher doses of radiation.

Arthroscopy consists of injecting a radiopaque contrast fluid into the superior and inferior compartments of the joint cavity to provide an indirect image of the articular disc.[160] This method is highly sensitive in diagnosing the position of the disc with an accuracy that is reported to range between 84% and 93%.[164] The morphology of the disc is also clearly demarcated. The flow of the radiopaque fluid within the joint cavity can also reveal the presence of disc perforations and adhesions with an accuracy of 97%.[164 165] Although it is a good technique to visualize the TMJ disc position, arthrography is invasive, painful and possess risks such as allergic reactions, infection and facial nerve palsy. In addition, the introduction of fluid in the joint distends the soft tissue structures creating distortion of their real positions.[164]

Arthroscopic surgery is also used as a diagnostic method in TMJ evaluation. It allows visualizing the superior joint space. Adhesions of the disc to the glenoid fossa can be diagnosed with this method.[44] Evidence of synovitis such as edema, hyperemia, and hemorrhage in subsynovial tissues can be observed. The amount of condylar surface covered by the articular disc can be quantified as a possible indicator of disc displacement.[166] This technique is costly and invasive, so its use as a diagnostic tool for disc displacement is limited to a select population.

1.5.4 – SUMMARY

The TMJ is formed by osseous and soft tissue components. The mandibular condyle articulates with the glenoid fossa of the temporal bone. In between these two structures the articular disc serves as a shock absorber and plays an important role in the motion of the joint for opening and closing movements. This disc is maintained in its physiologic position by its ligaments branching anteriorly, posteriorly and laterally. If these ligaments become elongated or distorted, the position of the disc with respect to the condyle and glenoid fossa becomes altered, leading to a disc displacement.

TMJ disc displacement is one of many conditions included in the TMD family. It is clinically represented by joint sounds and sometimes pain. Its etiology is multifactorial and not completely understood. Trauma, genetic predisposition, gender, orthopedic instability, hormonal factors, among others, have been proposed as potential factors related to the onset of this condition. The progression of disc displacement over time is unknown.

Many imaging techniques have been used to visualize the TMJ. Computer tomography and axially corrected tomograms are used to visualize cortical lining of the bony components of the joint. They are usually good tools to diagnose breakdown of the bone like it occurs in degenerative joint disease. MRI, arthroscopy and arthrography can be used to visualize hard and soft tissue components of the joint. However, the last two are quite invasive and MRI appears as the preferred option to look at the relationship of the articular disc and other soft tissue components with the osseous surfaces of the TMJ.

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chapter 2: RESEARCH PROJECT

Sagittal changes in temporomandibular joint disc position over time in adolescents: A retrospective study

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2.1 INTRODUCTION

Temporomandibular disorders (TMD) is considered a wide number of conditions affecting the masticatory system. Such problems can be articular, muscular in nature or a combination of both. TMD are present in approximately 40 to 60% of the general population.[1 2] As part of the articular problems present in the temporomandibular joint (TMJ), disc displacement is a mechanical condition in which the articular disc does not present a normal contact with the articular surfaces due to a change in its position. This condition is also known as internal derangement. When a disc is displaced from its natural position, the TMJ function during jaw movements becomes affected, potentially creating a wide spectrum of signs and symptoms such as clicking, difficulties with jaw function and pain.[3]

The intra-articular stability of the disc is provided by the discal ligaments, the tonicity of the lateral pterygoid muscle and the morphology of the disc.[4] The ligaments of the articular disc not only hold the disc in its normal position but also regulate its amount of movement during jaw function. When the discal normal morphology becomes altered or the ligaments that hold the disc in place become elongated, the disc is displaced from its normal position on the condyle. Most commonly the disc becomes displaced anteriorly rather than posteriorly and such displacement can also present a medial or lateral orientation. When the disc becomes completely dislocated anteriorly, it acts as a complete mechanical interference to the condyle, thereby limiting its opening movement, creating a diminished range of motion. This condition is known as disc displacement without reduction or closed lock.

An anterior TMJ disc displacement is thought to have a multifactorial etiology. Etiological factors such macrotrauma, microtrauma, age, gender, hormones, history of orthodontic treatment, among others, have been proposed.[4] Clinical characteristics of TMJ internal derangement include clicking sounds on opening and/or closing, pain in the TMJ area, limited range of opening, and deviation or deflection of the mandible during mouth opening. Patients often report difficulties with mastication and other jaw movements.

MRI studies have demonstrated a prevalence of approximately 30% of disc displacement in asymptomatic individuals.[5-7] On the other hand, it has been reported that approximately 86% of individuals with TMJ symptoms present a disc displacement.[6] Therefore, it is not an uncommon clinical situation to find in an orthodontic practice.[8]

Magnetic resonance imaging is considered a reliable and valid imaging method to visualize the position of the articular disc in respect with the osseous components.[9] [10] In comparison to other imaging methods such as axially corrected tomography and computed tomography, MRI provides information not only of the osseous structures but also the soft tissue within the TMJ. Unlike arthrography and arthroscopy, MRI is non-invasive and pain free.

Although it is commonly assumed that TMJ disc displacement progresses with time, there are no MRI longitudinal adolescent studies evaluating this situation. Sagittal changes of the disc from a normal to a non-physiological position or the progression of a disc displacement over time have not been evaluated with MRI in a longitudinal manner. The clinician often faces questions from patients who ask if the disc displacement will get more severe over time.

The objective of this study was to evaluate changes in disc position over time in an adolescent sample.

2.2 METHODS AND MATERIALS

2.2.1. SAMPLE

The protocol of this study was approved by the University of Alberta Human Ethics Research Board (Appendix 1).The sample of records for this study was obtained from a longitudinal study performed by Brian Nebbe et al in 1998.[8 11] A total of 194 pre-orthodontic adolescent subjects from the city of Edmonton and surrounding areas were recruited for Nebbe's study from 1995 to 1997. These subjects were recruited from private practices and the University of Alberta Orthodontic Graduate Clinic. At that time (V1), a set of clinical records was obtained from these subjects, including MRI and axially corrected tomography of the TMJ, a lateral cephalogram, a panoramic radiograph, a posterior-anterior cephalogram and a hand wrist film. Clinical signs and symptoms of TMD were also recorded. The same sample of subjects was re-called in 1999 and 2000 to obtain a second set of records. Out of the original 194 subjects, 114 returned for the new set of records.

The sample for the present study consisted of the 114 subjects who returned for a second visit (V2). Subjects who received orthognathic surgery during the time between V1 and V2 were not included in the study. Subjects with missing images or inadequate image quality were also excluded. The final sample consisted of Clinical records of 94 adolescent subjects with age ranging from 7 to 22 years.

Table 2.1 illustrates the sample size included and excluded for this study.

Initial Sample Size	114
Poor quality images	3
Surgical cases	5
Missing Image	12
Total	94

Table 2.1 – Sample size: Number of included and excluded records for MRI tracing in this study.

2.2.2 MRI ANALYSIS

The magnetic resonance imaging equipment utilized at V1 was a Shimadzu 1.0 Tesla magnet with a 3-inch receiver coil. All images were T1 weighted pulse sequences of 500TR ms/ 20 TE ms.[12-14] The slice thickness of these images was set at 3mm without intermediate gap. This MRI equipment was replaced in 2000 and a small part of the follow-up images were taken with a Siemens Magnetom-Symphony Maestro Class (serial #14330, year 1999).

An initial axial scout image was produced to identify the long axis of the condylar head (medio-lateral). Coronal images were obtained parallel to the long axis of the head of the condyle. Parasagittal images were produced perpendicular to the long axis of the condyle and obtained for each patient in open mouth position and maximal intercuspation. Open mouth position was held constant for the duration of the imaging procedure with the use of an adjustable Burnett caliper set at 10mm below the maximal voluntary interincisal opening. Intercuspation was registered with a polyvinylsiloxane bite registration.[15]

The main investigator (PK) was trained and calibrated against experts in the field (i.e. maxillofacial radiologist) for tracing the MRIs. The disc and articular structures of the TMJ were outlined in the tracing of the images. The most representative sagittal image within the middle third of the TMJ was traced in order to obtain the most defined outline of the anatomical structures, and also to avoid errors in terms of anatomy interpretation.

Tracing on the MRI was performed based on the method described and validated by Nebbe et al.[11 15] A digital caliper measuring in thousands of millimeters was used for measuring the distance between landmarks. For this study, only the last 2 significant digits were considered clinically relevant and recorded.

The following reference landmarks are considered in this method:

Reference plane for the articular eminence: For parasagittal images of the TMJ the reference plane was identified as "the longest posterior slope of the articular eminence". This was defined by two circles with the closest fit to the anterior fossa and articular eminence, respectively. The reflection of the posterior slope of the eminence from the two circumferences provided two points to form a single tangent to the two circles, which was also parallel to the articular eminence. The midpoint of the posterior slope of the eminence reference plane was defined as the "eminence point" (Figure 2.1).

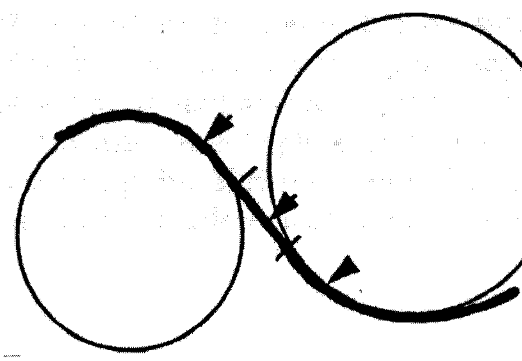

Figure 2.1 [11] **– Eminence point:** Eminence point is represented as the midpoint of the posterior slope of the eminence plane. The arrow in the middle represents the eminence point. The other two arrows represent the points of greater curvature of the eminence slope identified with 2 circles

Disc position in relation to the articular eminence: The midpoints of the anterior and posterior bands of the articular disc of each parasagittal image, as well as the midpoint of the disc were identified. A perpendicular line projected from each of these points to the eminence reference plane gave the relative position of the disc to this plane. This indicated the position of the disc in relation to the articular eminence.

Condyle position in relation to the articular eminence: The closest joint space position between the head of the condyle and the posterior slope of the articular eminence was sought and marked on the outline of the condylar head. This point served as the "condylar load of reference point". A perpendicular line from this point to the eminence reference plane served as the position of the condylar reference point relative to the articular eminence as well as to the disc (Figure 2.2).

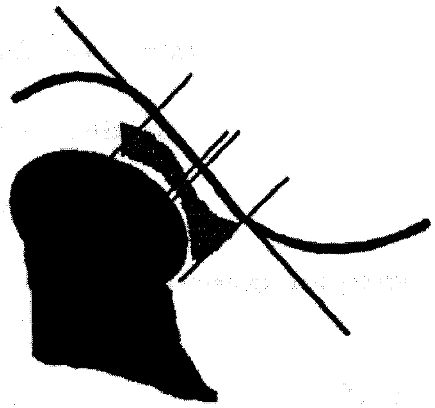

Figure 2.2 [11] **- Condylar reference point and anterior and posterior limits of the disc:** Condylar reference point is at the shortest distance from the eminence and is determined by a perpendicular line from the condyle to the eminence reference plane. The perpendicular lines to the eminence reference plane indicate the anterior and posterior borders of the disc as well as the disc mid point. Next the line from the disc mid point another line indicates the condylar load of reference point.

All parasagittal images containing some component of the posterior slope of the articular eminence were used for analysis. Each of the traced points on the articular eminence reference plane for each MRI parasagittal slice was used to reconstruct a "frontal image of the disc and condyle load point" relative to the articular eminence point (Figure 2.3).

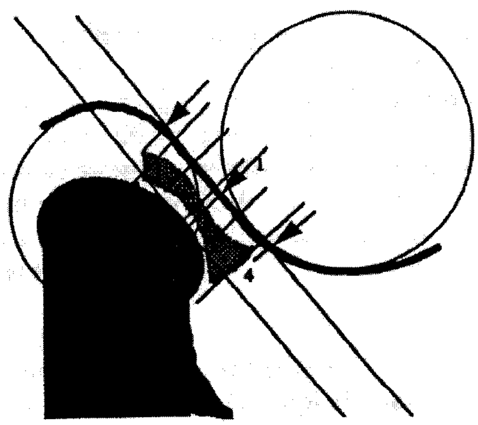

Figure 2.3 [11] **– TMJ disc with respect to eminence reference plane:** Each of the traced points on the articular eminence reference plane for each MRI parasagittal slice was used to reconstruct a "fontal image of the disc and condyle load point" relative to the articular eminence point. Arrows and perpendicular lines indicate the anterior (4) and posterior borders of the disc, the mid point of the disc (1)

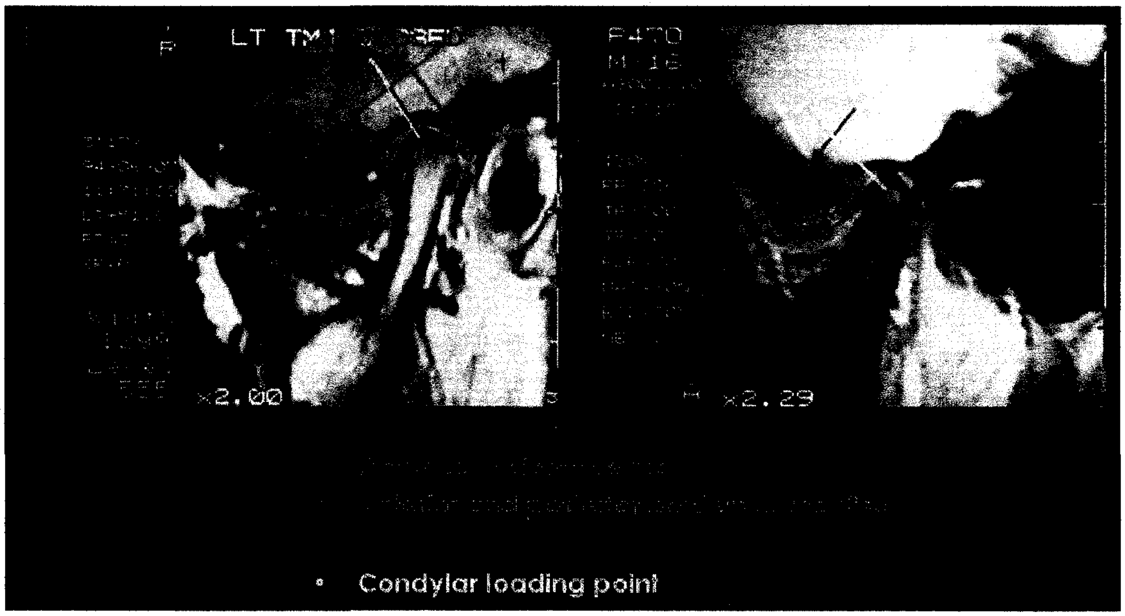

Figure 2.4 – Live tracing: MRI of the left TMJ of the same patient at V1 and V2 (from left to right). Note how the disc (in green) has notably changed its position anteriorly over time. The measured distance between the condylar loading point to the disc mid-point is considered the sagittal disc position (SDP) at V1 or V2. The difference of the SDP at V2 and SDP at V1 is the disc displacement over time (DD-change).

The distance between the disc midpoint and condylar loading point was measured in millimeters to quantify the sagittal disc position (SDP). The difference of such distance measured at V1 and V2 was obtained to quantify the amount of disc displacement change over time (DD-change) (Figure 2.4). These variables were recorded with a negative value in those cases in which the disc had a greater SDP at V1 than at V2; in other words, those cases that had a posterior sagittal change in disc position

Slight magnification was found between in some subjects in the print outs of images at V1 compared to V2. Such difference in size was managed by using the scale provided in each slice. This scale represents 1cm of true size. Therefore, all images were converted to a scale of 1:1 at V1 and V2.

2.2.3 CALIBRATION AND INTEROBSERVER RELIABILITY

The main investigator (PK) received an extensive training involving the evaluation of MRIs of the TMJs. Training was provided by Dr. Brian Nebbe, who produced and analyzed data derived from the initial set of MRIs (V1). Once the training period was completed, 10 randomly selected MRI's from the records pool were used for interobserver calibration. Calibration was performed with the trainer mentioned above and with Dr. Sharon Brooks, a maxillofacial radiologist in the University of Michigan.

It has been demonstrated that the use of this tracing technique can provide reproducible results with very small variability when utilized by observers with different training and backgrounds. This tracing method has demonstrated moderate to substantial agreement between observers in classifying disc displacement status.[8] Once calibration was demonstrated the main investigator proceeded with MRI analysis and data collection.

2.2.4 STATISTICAL ANALYSIS

In order to satisfy the main study objective, a regression analysis was performed to evaluate if there is a difference in the sagittal disc position (SDP) in millimeters over time (from V1 to V2) in each TMJ (right and left). Matched pairs t-test was performed between right and left TMJ to observe if a difference was present between both sides in terms of amount of disc displacement. A comparison of DD-change between right and left joints was performed in this way. For these tests the type I error was fixed to α=0.05.

2.3 RESULTS

The main investigator demonstrated reliability at MRI tracing and measurement. The intraclass correlation coefficient for measuring 10 random subjects three times was 0.991. Data for this analysis is shown in Table 2.2. The intraclass correlation coefficient among all 3 observers for calibration was 0.77.

Subject	Tracing 1	Tracing 2	Tracing 3	Mean	SD
1	0	0.5	0	0.17	0.29
2	7	7	7	7	0
3	4	4	4	4	0
4	8	7	8	7.67	0.58
5	0	0	0	0	0
6	1	1	0.5	0.83	0.29
7	1	1	1	1	0
8	1	1	0.5	0.83	0.29
9	1	1.5	1	1.17	0.29
10	3	3	3	3	0

Table 2.2 – Intra-reliability analysis: Data for intra-reliability analysis indicating means (mm) and standard deviation (SD) for each measurement.

MRIs derived from a total of 94 patients were traced and analyzed. The age range of the subjects was 7 - 17 years at V1 and 10 - 22 years at V2. This group consisted of 60 female subjects and 34 males. The mean female age was 12.45 (SD=1.98; range = 9 to 16) years at V1 and 16.32 (SD=2.31; range = 10 to 22) years at V2. The mean age for male subjects was 12.03 (SD=2.23; range = 7 to

17) years at V1 and 15.53 (SD=2.27; range = 11 to 19) years at V2. The total mean age for both groups was 12.3 (SD=2.07; range = 7 to 17) years at V1 and 16.03 (SD=2.32; range = 10 to 22) years at V2. Demographics of this sample are summarized in Table 2.3.

	N	MAV1	SD	Range	MAV2	SD	Range
Total	94	12.3	2.07	7 - 17	16.03	2.32	10 - 22
Females	60	12.45	1.98	9 - 16	16.32	2.31	10 - 22
Males	34	12.03	2.23	7 - 17	15.53	2.27	11 - 19

Table 2.3 - Demographic table: illustrating the number (N) of patients for the total sample and per gender. The mean age at V1 (MAV1) and at V2 (MAV2) in years are presented with their standard deviation (SD) and range.

The average time between V1 and V2 for all subjects was 3.73 (SD=1.31; range = 1 to 6) years. The average time between V1 and V2 for male subjects was 3.5 (SD=1.10; range = 1 to 6) years. Regarding females, the mean time between V1 and V2 was 3.87 (SD=1.40; range = 1 to 6) years. This is illustrated in Table 2.4.

	Mean time from V1 to V2	SD	Range
Total Sample	3.73	1.31	1 - 6
Females	3.87	1.4	1 - 6
Males	3.5	1.1	1 - 6

Table 2.4 – Time between V1 and V2: Mean time in years between V1 and V2 for the total sample, females and males with its respective standard deviation (SD) and range

An Independent sample t-test was performed to compare genders at V1 to determine if males and females had homogenous baseline SDP in millimeters.

When the right TMJ was analyzed, both gender groups were statistically different (P=0.001). Females showed a greater amount of disc displacement than males at V1. The mean difference between groups was 1.95mm. The same situation was detected for the left TMJ between genders at V1. Females had 1.79mm more disc displacement than males. This difference was also statistically significant (P=0.001).

Since it was noted that males and females presented different baseline scores, it seemed unfair or unrealistic to make a comparison between genders in further analyses. Therefore, all other aspects evaluated were done for each gender separately.

A regression analysis was performed to detect if there was a change in DD-change over time. No specific linear pattern of DD-change was detected for either the right or left joint in both genders. Greatest measurements (greater than -/+ 2mm) in DD-change were observed to occur 3 to 5 years after V1. This is better illustrated in Figures 2.5 -2.8.

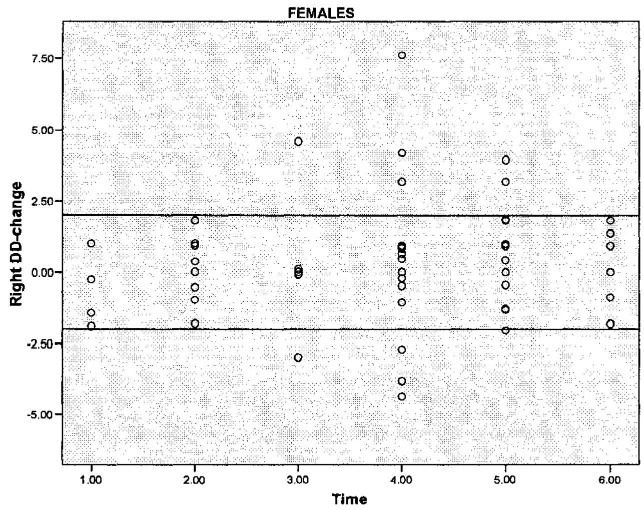

Figure 2.5 – Regression: Regression analysis for the right TMJ of females illustrating the amount of DD-change in millimeters (Right DD-change) against time (in years). Horizontal lines enclose those subjects with a DD-change between -2 and 2mm

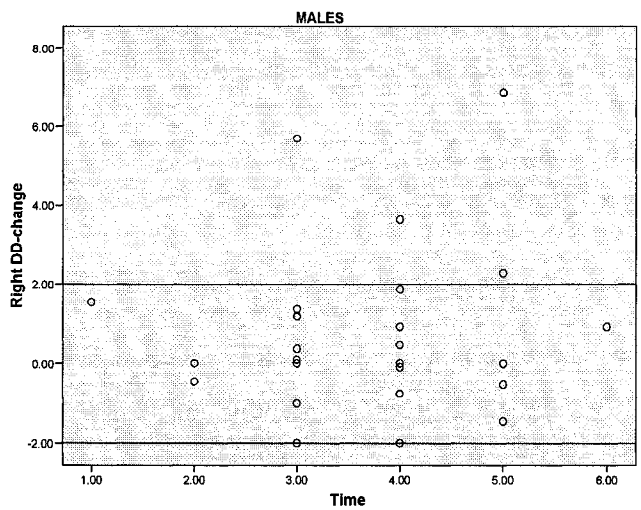

Figure 2.6 – Regression: Regression analysis for the right TMJ of males illustrating the amount of DD-change in millimeters (Right DD-change) against time (in years). Horizontal lines enclose those subjects with a DD-change between -2 and 2mm

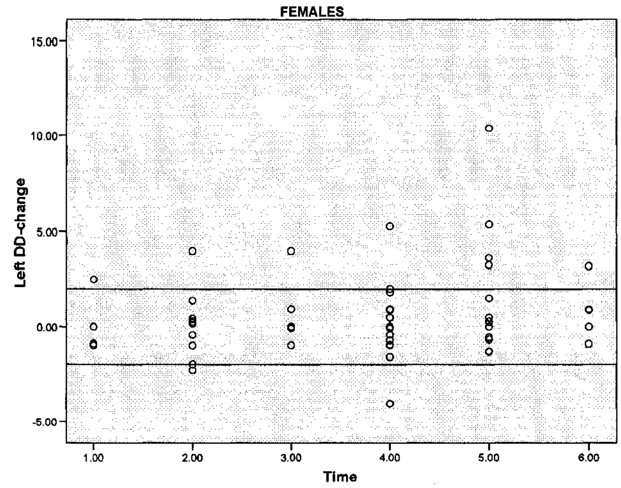

Figure 2.7 – Regression: Regression analysis for the left TMJ of females illustrating the amount of DD-change in millimeters (Left DD-change) against time (in years). Horizontal lines enclose those subjects with a DD-change between -2 and 2mm

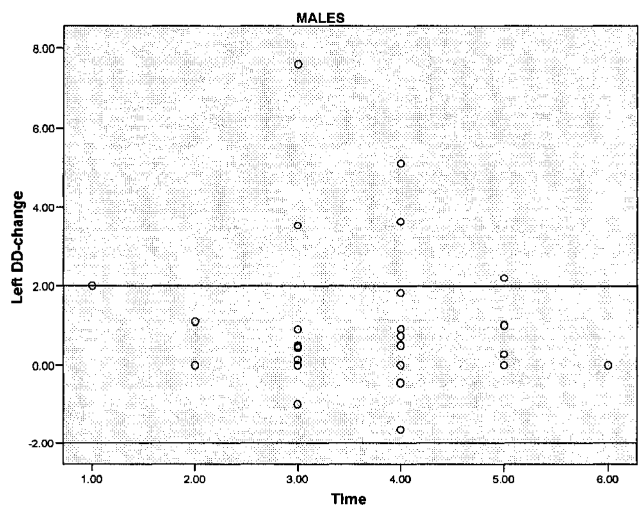

Figure 2.8 – Regression:: Regression analysis for the left TMJ of males illustrating the amount of DD-change in millimeters (Left DD-change) against time (in years). Horizontal lines enclose those subjects with a DD-change between -2 and 2mm

A matched pairs t-test was performed to compare SDP at V1 and V2. Unlike the analysis described above, this test does not consider the time between V1 and V2. Normality assumptions were checked visually using box-plot graphs of the data and Levene's test for equal variances. Normality assumptions of the sample were not completely met, thus non-parametric tests were chosen over conventional matched pairs t-tests for analysis.

No significant difference in SDP between V1 and V2 was found in the right (P=0.37) and left (P=0.25) joints when females were analyzed. Males showed a difference in this regard in the left joint (P=0.003) but not in the right (P=0.26). The mean SDP for the right and left joints are reported in Table 2.5

	SDP	SD	Mean difference
Right V1	2.95	3.24	
Right V2	3.23	3.29	0.28
Left V1	2.69	3.18	
Left V2	3.24	3.72	0.55

Table 2.5 – SDP in females: Mean SDP, standard deviation (SD) and mean difference for the right and left TMJ at V1 and V2 in female subjects

	SDP	SD	Mean difference
Right V1	1	2.13	
Right V2	1.52	2.69	0.52
Left V1	0.9	1.78	
Left V2	1.78	2.89	0.88

Table 2.6 – SDP in males: Mean SDP, standard deviation (SD) and mean difference for the right and left TMJ at V1 and V2 in male subjects

The right and left TMJ were compared in terms of DD-change for males and females separately. No difference (P=0.11) was found in DD-change between the right and the left TMJ of male subjects. Males presented a DD-change of

0.51mm (SD=1.85) for the right TMJ and 0.87mm (SD=1.78) for the left. The same situation (P=0.87) was found for female subjects.

Tables 2.7 and 2.9 illustrate descriptive statistics for the number of subjects who presented posterior and anterior sagittal disc position changes, as well as no change at all, from V1 to V2 in the right and left TMJ respectively. Tables 2.8 and 2.10 present data of those subjects with DD-change greater than 2mm anteriorly or posteriorly.

DD-change	< - 2mm	-2 to -0.1mm	0 mm (no change)	0.1 to 2mm	> 2mm
Females	5	15	13	21	6
Females %	8.33%	25%	21.66%	35%	10%
Males	0	10	11	9	4
Males %	-	29.41%	32.35%	26.47%	11.76%
Total	5	25	24	30	10
Total %	5.3%	26.58%	25.52%	31.91%	10.63%

Table 2.7 – DD-change in the right TMJ: Number and percentage of subjects who had changes in sagittal disc position greater than 2mm in the posterior and anterior directions, and no change in the right TMJ from V1 to V2. Females% and Males% indicate the percentage per gender and not based on the total sample (Total %).

RIGHT	SDP V1 (mm)	DD-change (mm)	Gender
<-2mm	6.36	-4.36	F
	6	-3.83	F
	10	-3	F
	10	-2.73	F
	7.5	-2.05	F
>2mm	-0.45	2.27	M
	0	3.18	F
	0	3.18	F
	-1.36	3.64	M
	3.33	3.94	F
	4	4.18	F
	4.5	4.59	F
	1.82	5.68	M
	-0.5	6.86	M
	1.5	7.59	F

Table 2.8 – True right DD-change: Baseline scores of sagittal disc position (SDP V1) and the amount of sagittal displacement from V1 to V2 (DD-change) for those subjects with measurements <-2mm and >2mm for the right TMJ

DD-change	< - 2mm	-2 to -0.1mm	0 mm (no change)	0.1 to 2mm	> 2mm
Females	2	18	15	16	9
Females %	3.33%	30%	25%	26.66%	15%
Males	0	3	13	13	5
Males %	-	8.82%	38.23%	38.23%	14.70%
Total	2	21	28	29	14
Total %	2.12%	22.29%	29.78%	30.84%	14.88%

Table 2.9 – DD-change in the left TMJ: Number and percentage of subjects who had changes in sagittal disc position greater than 2mm in the posterior and anterior directions, and no change in the left TMJ from V1 to V2. Females% and Males% indicate the percentage per gender and not based on the total sample (Total %).

LEFT	SDP V1 (mm)	DD-change (mm)	Gender
<-2mm	9.55	-4.09	F
	11.13	-2.33	F
>2mm	-0.38	2.20	M
	5	2.50	F
	0.9	3.18	F
	2.22	3.23	F
	1	3.55	M
	2.73	3.64	M
	1.36	3.64	F
	7	4.00	F
	6	4.00	F
	4	5.09	M
	2	5.27	F
	1	5.36	F
	0.9	7.59	M
	5	10.38	F

Table 2.10: - True left DD-change: Amount of DD-change for those subjects with measurements <-2mm and >2mm for the left TMJ

2.4 DISCUSSION

TMJ disc displacement is a condition characterized by a positional change of the articular disc with respect to the condyle and articular eminence. It is possible to observe that in some groups of patients this condition progresses over time but in other groups the condition remains stable. There are no clear parameters that would predict the progression in severity of TMJ disc displacement over time. The current literature lacks MRI retrospective studies evaluating this situation.

This longitudinal study evaluated MRI records of the right and left TMJ of 94 adolescent subjects in two separate visits with approximately 4 years in between. Unlike other studies, our sample was composed exclusively of adolescent patients that were recruited from orthodontic practices.[11]

In this study, males and females subjects were different in terms of baseline measurements of SDP. It is well known in the literature [4] that TMD, in general, is more prevalent among females than males. Although nothing is reported specifically for the amount of disc displacement, our findings show that females showed greater amount of sagittal disc displacement than males at V1. Since genders were shown to be different since baseline scores, further comparisons would not seem of great use. For this reason, the data collected from this study was analyzed separately for each gender.

When looking at these values it is important to take into consideration the presence of measurement error that can have an effect on such means. It was found in this study that the tracing MRI analysis described in Section 2.2.2 [11 15] can introduce some measuring error when is analyzed over time (e.g. from V1 to V2). It is known that when MRIs are repeated over time on the same area (e.g. TMJ) there is a very high chance that the sagittal slices will not coincide exactly at the same point. When an MRI is taken, a cephalostat is not used to position the patient's head. For this reason, there is no orientation in any plane of space, thus there can be a position change due to operator variability and the chances of obtaining the same slices are minimal. Therefore, when the TMJ is sliced from medial to lateral, the sagittal images obtained in such slices will automatically be slightly different from V1 to V2. The same situation would be observed in the images obtained in coronal cuts when the TMJ is sliced in the anterior-posterior direction. This situation would bring mild changes regarding the reference points utilized in this tracing method when the same joint is analyzed in two different occasions.

Another important factor that accounts for this type of error is related to the osseous remodeling changes that occur over time in the articular surfaces of the condyle and articular eminence. Such articular surfaces are constantly experiencing adaptive remodeling,[4 16] and as a consequence their shape changes over time. Since the tracing method utilized in this study involves osseous references, such as the "condylar load reference point",[11 15] it was observed in some cases that this point differed in the same subject from V1 to V2. However, this reference point did not show a sagittal difference greater than +/- 2mm, from V1 to V2, in any subject. In those cases, the disc appeared to be in the same position, with no displacement over time. The sagittal measurement was taken regardless of the change of this reference point and included for the analysis. In all cases this sagittal measurement was not greater than 2mm and, from an imaging perspective, the position of the disc should not be considered different from V1 to V2. The recorded means of sagittal disc displacement in all patients were less than 2mm (less than the observed error) so it can be considered that no significant positional change was observed in the articular disc from V1 to V2.

The fact that the frequency of cases presenting a disc displacement <2mm is greater than those cases with a displacement >2mm, explains why the results of this study indicate that the overall mean displacement is <2mm for both joints. Since cases with a disc displacement greater than 2mm in the anterior or posterior direction are out of the range of the error explained above, it seems safer to consider only such cases as those who experienced a true disc displacement over time.

Regarding intraobserver measurement error, the highest standard deviation was 0.58mm. Thus, it is safe not to consider any disc displacement measurement between -0.58 to 0.58 as a true displacement from a radiological perspective. It is important to remember that the main investigator was blinded through the whole MRI tracing stage. Blinding was directed to the time when the MRI was performed (V1 and V2) but not to the patient. In this way it was possible to clinically identify if there was an obvious sagittal change in disc position (not derived from the errors explained above) in the same patient over time, but not in which time direction (i.e from V1 to V2 or from V2 to V1).

In this study, no specific pattern of changes in SDP was seen over time. DD-change did not show a linear change in any direction between V1 and V2. The time range between visits was from 1 to 6 years. However, a true disc displacement was observed in some subjects (Tables 2.7 – 2.10). The time of V2 for subjects who presented DD-change measurements outside the range of measurement error (-2mm to 2mm) was most commonly observed at the 3rd, 4th or 5th year after V1 (Figures 2.7 – 2.10) for both genders in the right and left joints. A true progression of anterior disc displacement over time was observed in 10.63% of the total sample in the right TMJ and 14.88% in the left TMJ. A posterior sagittal change was observed only in female subjects. Five subjects (5.3%) showed this pattern in the right joint and only 2 (2.12%) subjects in the left joint. This is better represented in Tables 2.7 and 2.9.

No significant difference in SDP between V1 and V2 was found in the right (P=0.37) and left (P=0.25) joints when females were analyzed. Males showed a difference in this regard in the left joint (P=0.003) but not in the right (P=0.26). This difference was an anterior disc displacement of 0.88mm. Even though this was statistically significant, from a clinical perspective this change seems very small and probably not clinically significant. Published literature does not provide an indication of how much disc displacement is clinically significant.

Clinical significance according to DD-change may not occur at 2mm of displacement (which is radiologically significant in this study), but it could at a higher absolute value. This study found DD-change values as high as 10.38mm and 4.36mm for anterior and posterior displacement respectively. Clinical significance of disc displacement depends on the expression of symptoms and signs that may not be dictated by a fixed DD-change value for all patients. This condition most likely has a threshold value for clinical expression that varies according to each individual. Values of posterior and anterior DD-change greater than 2mm are presented in Tables 2.8 and 2.10 for the clinician's interpretation.

These tables (2.8 and 2.10) also illustrate the direction of disc displacement. It is interesting to observe that those subjects who experienced a sagittal disc change in the posterior direction had baseline scores that were considerably greater than those who had an anterior displacement. Since the baseline SDP at V1 was still considerably higher than the amount of posterior sagittal change, the position at V2 was still much greater than 2mm. Therefore, it is the author's opinion that, this change would not seem to be clinically significant enough to be considered as an "improvement".

Most of the studies evaluating longitudinal changes of TMJ disc position with MRI have been performed with the objective of evaluating the efficacy of certain treatment modalities (i.e. occlusal splints, arthroscopy, etc). No longitudinal studies have been performed looking at general changes that might occur over time rather than a "before and after" approach of a specific treatment. One study by de Leeuw at al in 1994 [17] analyzed changes over 30 years in adult patients who had a previous history of degenerative joint disease (DJD) and internal derangement. However, MRIs of the TMJs were performed after 30 years and not at the initial assessment. Therefore an imaging comparison over time was not possible. The authors did not observe a significant clinical difference between the sample of subjects with a TMD history and the age-matched controls. On the other hand, imaging changes were easily evidenced in those patients with internal derangement and DJD. This raises the question again of when imaging changes are indicative of clinical significance, and furthermore, what MRI findings can be considered a "threshold" for an internal derangement to become clinically significant. The literature suggests that when this condition becomes symptomatic and clinically obvious, not only the amount of displacement is involved, but also other conditions within the TMJ such as degenerative changes and joint effusion (an excessive amount of fluid in the joint) are present.[18, 19]

In clinical practice patients often want to know if their condition will become more severe over time and what factors could worsen the problem. The clinician should be aware that although this might be a possibility, there is no clear evidence to indicate this in a definitive way. Patients must be instructed to follow conservative treatment and should also be informed what the current research is indicating in regard to this field.

2.5 CONCLUSION

A progression of disc displacement over time was observed in 10 to 14% of the total sample. No changes were observed in most of the sample. This can be considered as suggestive, but not definitive, evidence that disc displacement progresses over time.

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chapter 3: RESEARCH PROJECT

Clinical factors associated with sagittal changes in temporomandibular joint disc position over time in adolescents: A retrospective study

chapter 3: RESEARCH PROJECT

Clinical factors associated to sagittal changes in temporomandibular joint disc position over time: A retrospective study

3.1 INTRODUCTION

The masticatory system is often affected by a wide family of conditions known as Temporomandibular Disorders (TMD). Such conditions can be due to articular or muscular problems or due to a combination of both. TMD are present in approximately 40 to 60% of the general population.[1] [2] In many cases, the temporomandibular joint (TMJ) disc does not sit in a physiologic position with respect to the articular surfaces of the condyle and the fossa; this creates a mechanical problem defined as disc displacement or internal derangement. When a disc is displaced from its natural position, the biomechanics of the TMJ become affected, creating a wide spectrum of signs and symptoms such as clicking, difficulties with jaw function and pain.[3]

The discal ligaments, the tonicity of the lateral pterygoid muscle and the morphology of the disc provide intra-articular stability of the disc.[4] The ligaments of the articular disc not only hold the disc in a physiologic position but also regulate the amount of disc movement during jaw function. When the normal anatomy of the disc becomes altered or the ligaments holding the disc in a physiologic position become elongated, the disc is displaced from its normal position on the condyle. Most commonly the disc becomes displaced anteriorly rather than posteriorly and such displacement can also present a medial or lateral orientation. Once this situation is established and the disc is completely dislocated anteriorly, it acts as a mechanical interference to the condylar opening movement, which becomes limited. This condition is known as disc displacement without reduction or closed lock.

An anterior TMJ disc displacement is thought to have a multifactorial etiology. Macrotrauma, microtrauma, age, gender, hormones, history of orthodontic treatment, among others, have been proposed.[4] It is well proposed in the literature [4] that trauma to the face can create the onset of TMJ disc displacement through a dislocation of the disc from its physiologic position. However, nothing has been said related whether the precedent of facial trauma can indicate, not only the onset but also a progression of such condition over time.

Clinical signs and symptoms of TMJ internal derangement include click sounds at opening and/or closing, pain in TMJ area, limited range of opening, and deviation or deflection of the mandible during mouth opening. Patients often report difficulties with mastication and other jaw movements. In many occasions, patients with disc displacement not only present with joint noises but also with pain.[4] It is well known that the presence of sounds (TMJ clicking) has a high correlation with MRI findings of disc displacement. The literature suggests that the presence of pain is related to the presence of inflammation and breakdown of the articular surfaces of the TMJ, [4 5] but not necessarily with the presence of disc displacement per se.[6] However, nothing is reported regarding the presence of TMJ pain as a clinical predictor for a progression of disc displacement over time.

MRI studies have demonstrated that approximately 30% of disc displacement is present in asymptomatic individuals.[7-9] On the other hand, it has been reported that approximately 86% of individuals with TMJ symptoms present a disc displacement.[8] Therefore, it is not an uncommon clinical situation to find in an orthodontic practice.[10]

Magnetic resonance imaging is considered a reliable and valid imaging method to visualize the position of the articular disc within the TMJ.[11 12] Unlike other imaging methods such as axially corrected tomography and computed tomography, MRI provides information regarding the soft tissue components of the TMJ. MRI is non-invasive and pain free.

Although it is commonly assumed that TMJ disc displacement progresses with time, there are no MRI longitudinal adolescent studies evaluating this situation. Furthermore, the association of such progression over time has never been evaluated in a longitudinal fashion with potential clinical factors. The clinician often faces questions from patients who ask what factors can influence the progression of such disc displacement over time.

The objective of this study was assess if clinical symptoms, such as TMJ pain, and, the presence of an etiological factor such as history of facial trauma could give some indication in terms of a progression of disc displacement over time.

3.2 METHODS AND MATERIALS

3.2.1. SAMPLE

The University of Alberta Human Ethics Research Board approved the protocol of this study (Appendix 1). The sample of records for this study was obtained from a longitudinal study performed by Nebbe et al in 1998.[10 13] A total of 194 pre-orthodontic adolescent subjects from the city of Edmonton and surrounding areas were recruited for Nebbe's study from 1995 to 1997. These subjects were recruited from private practices and the University of Alberta Orthodontic Graduate Clinic. At the first visit (V1), a set of clinical records was obtained from these patients, including MRI and axially corrected tomography of the TMJ, a lateral cephalogram, a panoramic radiograph, a posterior-anterior cephalogram and a hand wrist film. Clinical signs and symptoms of TMD were also recorded. The same sample of subjects was re-called in 1999 and 2000 to obtain a second set of records. Out of the original 194 patients, 116 returned for the new set of records.

The screening for the present study consisted of the 114 patients who returned for a second visit (V2). Cases involving orthognathic surgery were not included in the study. In addition, those cases with poor quality images or when at least one image was missing were not considering for tracing either. The number of subjects for MRI tracing consisted of 94 adolescent subjects with age ranging from 7 to 22 years. For this study, a portion of these 94 patients had available data for clinical factors. This fraction was considered as the final sample for this study and is reported according to the number subjects considered for each variable in tables 3.2, 3.3 and 3.4 in the Results section.

3.2.2 MRI ANALYSIS

The MRI equipment utilized at V1 was a Shimadzu 1.0 Tesla magnet with a 3-inch receiver coil. All images were T1 weighted pulse sequences of 500TR ms/ 20 TE ms.[14-16] This MRI equipment was replaced in 2000 and a small number of the follow-up images were taken with a Siemens Magnetom-Symphony Maestro Class (serial #14330, year 1999).

The tracing method for sagittal disc displacement utilized in this study is the same described in section 2.2.2 of chapter 2. The main investigator was calibrated for MRI analysis as indicated in section 2.2.3 of chapter 2.

3.2.3 EVALUATION OF POSSIBLE FACTORS AND SYMPTOMS ASSOCIATED WITH TMJ DISC DISPLACEMENT

Possible associated factors with sagittal changes in disc position over time were considered. Clinical documentation (clinical history and exams) obtained by Nebbe et al [17] during V1 was analyzed and compared against the mean sagittal disc displacement from V1 to V2 (DD-change). The main purpose of this part of the study was not to find a cause-effect relationship, but simply, an association between the presence of clinical factors at V1 and progression of disc displacement.

The following symptoms and demographical factors collected at V1 were considered for analysis and recorded for the right and left joints:

1. Gender
2. Capsular TMJ pain upon palpation (P-pal)
3. Pain during mouth opening (P-op)
4. History of facial trauma (HT)

Except for gender, these factors were recorded as a positive or a negative report. For statistical purposes, the sample was classified in 2 groups according to the presence or absence of the factor being evaluated (P-pal, P-op and HT) at V1.

3.2.4 STATISTICAL ANALYSIS

MANOVA was planned to evaluate if DD-change in the right and left joints was significantly increased in groups of positive report of P-pal, P-op and HT. A

3.3 RESULTS

The main investigator demonstrated to be reliable at MRI tracing and measurement. The intraclass correlation coefficient for measuring 10 random subjects three times was 0.991. Data for this analysis is shown in Table 3.2. The Intraclass Correlation Coefficient among all 3 observers for calibration was 0.77.

Subject	Tracing 1	Tracing 2	Tracing 3	Mean	SD
1	0	0.5	0	0.17	0.29
2	7	7	7	7	0
3	4	4	4	4	0
4	8	7	8	7.67	0.58
5	0	0	0	0	0
6	1	1	0.5	0.83	0.29
7	1	1	1	1	0
8	1	1	0.5	0.83	0.29
9	1	1.5	1	1.17	0.29
10	3	3	3	3	0

Table 3.1 – Intra-reliability analysis: Data for intra-reliability analysis indicating means (mm) and standard deviation (SD) for each measurement.

Data for this study consisted in recorded clinical factors such as gender, P-pal, P-op and HT at V1. The sample size is illustrated in tables 3.2, 3.3 and 3.4.

		P-pal (left TMJ)		
		No	Yes	Total
P-pal (right TMJ)	No	36	11	47
	Yes	9	17	26
	Total	45	28	73

Table 3.2 -Sample size for P-pal: Crosstab representing the number of subjects who had a negative (No) and positive (Yes) report of P-pal in the right and left TMJ

		P-op (left TMJ)		
		No	Yes	Total
P-op (right TMJ)	No	42	10	52
	Yes	9	11	20
	Total	51	21	72

Table 3.3 – Sample size for P-op: Crosstab representing the number of subjects who had a negative (No) and positive (Yes) report of P-op in the right and left TMJ

	HT
No	47
Yes	22
Total	69

Table 3.4 - Sample size for HT: Number of subjects who had a negative (No) and positive (Yes) report of HT

As it can be observed in Tables 3.2, 3.3 and 3.4, each of these variables (P-pal, P-op and HT) was divided in groups according to positive and negative responses. In the same way females and males were compared for baseline measurements of SDP at V1 (see Results section in chapter 2), groups of negative and positive responses were compared for each variable. Due to the unbalanced number of subjects between groups, non-parametric tests were used. Unlike gender, these groups appear be homogenous at V1 in terms of

SDP. Therefore, a fair comparison can be performed between them for further analyses over time.

In order to demonstrate if TMJ pain and facial trauma were related to a progression of disc displacement, a MANOVA was performed to evaluate the association of clinical factors (P-pal, P-op and HT) at V1 and DD-change in the right and left joint as response variables. This was performed for females and males separately. Some of these factors showed a significant difference between groups in terms of DD-change. Therefore, ANOVA was performed to look in more detail to right and left joints separately.

Female groups of negative and positive reports of P-pal, P-op and HT were compared in terms of DD-change in the right TMJ and left TMJ separately. No difference was found between groups in this regard. The same situation was found when the same analysis was applied to male individuals. This is better illustrated in tables 3.5 – 3.8.

	P value	DD-change	SD
P-pal (Yes)	0.12	1.17	
P-pal (No)		0.96	
P-op (Yes)	0.72	0.50	
P-op (No)		0.76	
HT (Yes)	0.075	1.27	
HT (No)		-0.01	

Table 3.5 – Right DD-change in females:: Mean DD-change in the right TMJ of females with positive (Yes) and negative (No) reports of P-pal, P-op.

	P value	DD-change	SD
P-pal (Yes)	0.37	0.22	
P-pal (No)		0.91	
P-op (Yes)	0.39	0.9	
P-op (No)		0.24	
HT (Yes)	0.54	0.81	
HT (No)		0.32	

Table 3.6 – Left DD-change in females: Mean DD-change in the left TMJ of females with positive (Yes) and negative (No) reports of P-pal, P-op

	P value	DD-change	SD
P-pal (Yes)	0.64	1.06	
P-pal (No)		0.71	
P-op (Yes)	0.2	1.51	
P-op (No)		0.26	
HT (Yes)	0.15	1.15	
HT (No)		0.26	

Table 3.7 – Right DD-change in males: Mean DD-change in the right TMJ of males with positive (Yes) and negative (No) reports of P-pal, P-op

	P value	DD-change	SD
P-pal (Yes)	0.12	1.4	
P-pal (No)		0.44	
P-op (Yes)	0.57	0.72	
P-op (No)		1.13	
HT (Yes)	0.36	1.21	
HT (No)		0.64	

Table 3.8 – Left DD-change in males: Mean DD-change in the left TMJ of males with positive (Yes) and negative (No) reports of P-pal, P-op

When such groups where compared regarding the left TMJ of males, a significant interaction between HT and P-pal was found to be significant (P=0.033). Patients with a positive report of both, P-pal and HT, showed a significantly higher DD-change than those subjects with a negative report of at least one of these two variables. This is illustrated in Figure 3.1

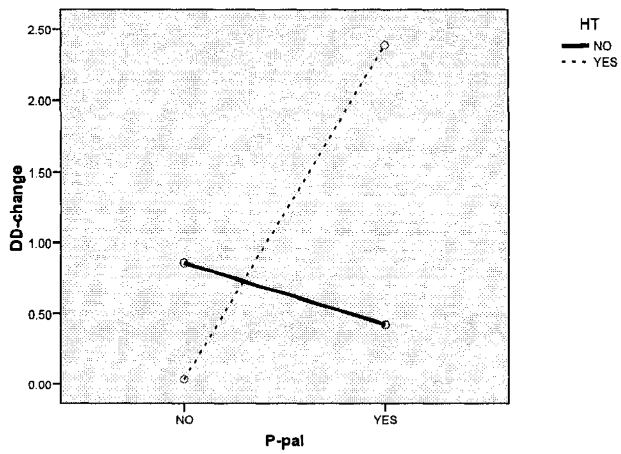

Figure 3.1 - Interaction between P-pal and HT in terms of DD change in the left TMJ of male subjects. "YES" indicates groups of positive reports and "NO" indicates groups of negative reports,

3.4. DISCUSSION

The sample for this study was composed exclusively of adolescent patients that were recruited from orthodontic practices.[13]

In this study, we were interested in evaluating if the sagittal change of disc displacement over time was related to the presence of TMJ pain and history of facial trauma. Therefore, factors such as TMJ pain upon palpation (P-pal), TMJ pain upon opening (P-op) and history of facial trauma (HT) were considered for this study. It is important to note that these results do not imply a causal relationship between a clinical factor and DD-change

None of these factors showed a clear association with a progression of anterior disc displacement over time in the right and left TMJ in both genders.

The literature refers to TMJ pain as a factor that is associated with the presence of inflammation within the joint cavity and with the integrity of the articular surfaces.[4] [5] Examples of this problem acute conditions such as capsulitis, retrodiscitis, acute trauma[4] and other problems that can become chronic such as degenerative joint disease or osteoarthritis.[5] Disc displacement is due to an abnormal position of the disc with respect to the condyle, leading to non-physiological motion of the joint. This problem is purely mechanical and does not necessarily involve inflammation in every case. The literature suggests that in some occasions the abnormal functioning created by a disc displacement can lead to a breakdown of the articular surfaces (degenerative joint disease), creating inflammation and pain.[5] Our study did not find a relationship between change is sagittal disc position over time and TMJ pain upon palpation and opening. This can be related to the fact that our sample was composed of adolescent subjects who rarely present degenerative joint disease and have a greater capacity to adapt to mechanical changes.

In the literature facial trauma is considered a possible etiological factor for the onset of internal derangement by several authors. [4] [18] [19] Facial trauma has been supported in the literature and in clinical experience as triggering factor for this condition. However, nothing is said regarding the progression of such condition over time after is established. In this study we did not find an association between history of facial trauma and a progression of disc displacement over time. It is important to note that only a positive or negative report of past facial trauma was recorded at V1. The nature, severity and direction of trauma was not recorded at V1 for the subjects in this study. Facial trauma should be considered as one of many predictors for the diagnosis of disc displacement.

The literature provides different views when it comes to the correlation of clinical symptoms and radiological findings in MRI. While some studies support the view that the clinical exam and history are highly correlated to MRI findings in regards to internal derangement [9 20 21] others support that the clinical history and examination only are unreliable for a complete diagnosis of the TMJ status.[6 22-25] It is important to remember that MRI studies have detected disc displacement in approximately 30% of asymptomatic subjects.[7-9] At the same time, approximately 86% of subjects with TMJ symptoms presented a disc displacement when their joints were evaluated through MRI.[8]

Our negative finding between the presence of pain and the progression of disc displacement is in agreement with other studies. Emshoff et al[6] performed a study investigating whether the presence of pain in a group of subjects with unspecific diagnosis of TMD may be linked to MR imaging findings of internal derangement. TMJ pain had no effect on prevalence of MR imaging diagnoses of internal derangement. This is supported by another MRI study[26] in which 51 subjects diagnosed with disc displacement with and without reduction were evaluated clinically and with MRI. In this study, the presence of pain was not found to be a characteristic symptom of any type of disc displacement.

Although this study did not detect a direct association between report of TMJ pain upon palpation and amount of disc displacement over time, our findings suggest that a combination of history of facial trauma and the presence of pain upon palpation may be related to an increased amount of disc displacement over time. As it is observed in Figure 3.1, subjects who had a positive report of both, pain upon palpation and history of facial trauma, had greater amount of disc displacement than those who had a negative report of at least one of these two variables. This should be interpreted with caution and should not be used to make general conclusion because it is based only in findings related to the left TMJ of male subjects. A significant interaction of these two factors was found neither in female subjects nor in the right joint of males. If anything, this finding only reflects the multifactorial basis that is necessary for the clinical expression of TMD symptoms.

It is well known, that other TMJ symptoms not considered in this study such as closed lock are good clinical predictors for an MRI diagnosis of disc displacement. Another study performed also by Emshoff et al[27] showed that when it comes to disc displacement without reduction, clinical findings, such as closed lock, are often sufficient to be accurate for this particular diagnosis. Sato et al [28] followed subjects with a diagnosis of disc displacement without reduction for approximately 2 years with MRI and clinical examinations of the TMJs. Sato's group found that those displaced discs without reduction did not improve over time. Deformity of the disc anatomy was observed to continue over time without correlations to the clinical symptoms, which were measured to decrease as the condition became more chronic.

The results of this study suggest that there is no definitive evidence to state the presence of TMJ pain upon palpation, TMJ pain upon opening and history of trauma are related to a change in the sagittal disc position over time.

In clinical practice patients often want to know if their condition will become more severe over time and what factors could worsen the problem. The clinician should educate the patient about the multifactorial nature of this problem. The presence of pain or a positive report of facial trauma does not appear to be related to a progression in the severity of this condition. Patients must be instructed to follow conservative treatment and should also be informed what the current research is indicating in regard to this field.

3.5 CONCLUSION

- There is no evidence to state that a sagittal change in disc position will be better predicted by the clinical presence pain upon palpation and pain upon jaw opening.
- Positive reports of history of facial trauma does not appear to be related to a progression of disc displacement over time

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chapter 4: GENERAL DISCUSSION AND RECOMMENDATIONS

chapter 4: GENERAL DISCUSSION AND RECOMMENDATIONS

4.1 GENERAL OVERVIEW OF THE STUDY AND CLINICAL IMPLICATIONS

TMD, including different types of internal derangements, affect approximately 30% of the population.[1] This condition is seen not only in patients who experience symptoms and seek treatment but also in a good proportion of asymptomatic individuals. It is commonly believed in clinical practice that TMJ disc displacement can progress into a more severe stage and even to disabling symptoms.[2]

No single etiological factor has been identified as a definitive triggering factor for the establishment of disc displacement in the TMJ. It is rather believed to be a problem of multifactorial etiology in most cases, except for those few cases in which an acute traumatic situation appears to be the obvious cause of the problem. Demographic, environmental and genetic factors play a role in the onset of this condition.

In the day-to-day clinical practice patients who present with disc displacement with or without reduction are often informed about the nature of this problem. These patients usually want to be informed by the clinician if the disc displacement will get worse over time on its own and if there are any specific factors that would make the disc displacement more severe. Patients are instructed regarding self-care and conservative treatment to relief pain, when present. Information is usually provided about the possible associated factors that are known in general. There is no clear evidence in the literature to demonstrate that this condition progresses over time.

In this longitudinal study, the MRIs of 94 adolescent subjects were carefully analyzed at two different times (V1 and V2) with a period of approximately 4 years in between. The TMJs evaluated in such MRIs were traced to obtain the main outcome measure, which was the amount of sagittal disc displacement from V1 to V2. Demographic factors such as gender and age were recorded for each subject. Clinical records of some of these subjects were also available and assessed for the presence of certain symptoms often seen in cases with disc displacement such as history of facial trauma, pain upon palpation and pain upon jaw opening. The behavior of these symptoms at V1 and V2 was also recorded to assess the different changing patterns that subjects presented over time. History of facial trauma was also considered. No evidence for a change in sagital disc position over time was observed in the sample as a whole mean. A true displacement was observed only in approximately 11% to 15% of the whole sample. Neither TMJ pain nor history of facial trauma appeared to be related to an increased change of sagittal disc position over time.

Regarding clinical implications of these results, this study provides the first evidence based information to state that it is erroneous to assume that a displaced disc will always progress into a more severe situation. This could happen in some patients, but it should not be considered a rule for prognosis in clinical practice. We can perhaps, assume more safely that patients, who present disc displacement, may have an 11%-15% chance of progressing into a worse disc position. This study did not show an association of disc displacement with TMJ pain and history of trauma, in clinical practice it is difficult to point into a specific symptom or etiologic factor that would clearly predict the severity of a displaced disc. This reflects the multifactorial etiology of TMD. TMJ pain appears to be related mainly to inflammation and effusion within the joint cavity [3 4] rather than with a specific amount of disc displacement purely as a mechanical problem. History of facial trauma is well documented as factor related to the onset of disc displacement,[5] but not necessarily related to its progression over time.

The literature is divided when it comes to correlations between MRI findings and clinical symptoms.[3 6-13] Furthermore, there is no information in the literature about what MRI findings can be predictable for clinical significance of a TMJ disc displacement. It is often seen in clinical practice that some patients with full disc displacement have no symptoms, while others with minor displacement are symptomatic. In fact, there are a number of studies showing that approximately 30% of the population has an asymptomatic disc displacement.[8 14-16] In addition it is also well known that when it comes to TMJ problems, adaptive capacity and dysfunction have a great role to play and differs from individual to individual.

4.2 LIMITATIONS

The main limitation of this study is related to the amount of missing data regarding clinical symptoms. Not all clinical records were available for all the subjects whose MRIs were successfully traced and analyzed. The primary objective of this study was to analyze the amount of sagittal disc displacement from V1 to V2 in order to see if there was a progression of this condition over time. The secondary objective of this study was to evaluate if TMJ pain and history of trauma were associated to it. At the end, the results of the study were able to answer our main research objective. The second objective was also addressed but due to the decreased sample size, conclusions should be interpreted with caution.

Another important limitation of this study is related to the interpretation of the measuring error related to the amount of sagittal disc displacement from V1 to V2. As explained in Chapter 2, the initial method developed by Nebbe et al in 1998 [17] did not account for the changes that the reference points could suffer over time. These reference point utilized in the MRI tracing analysis are located on osseous surfaces, which are susceptible of remodeling changes over time that occur normally in all patients. Once it changes, the measurement to the middle of the disc will also change. Another variation of the location of such reference points between V1 and V2 is related to the lack of accuracy of MRI equipments to obtain the same sagittal slice when the imaging of the same TMJ is performed at two different times. In this study a range of -2mm to 2mm was observed for disc displacement in the sagittal plane. For this reason, those measurements located within this range could equally indicate a sagittal position of the disc or a measurement error.

Finally, it is important to consider in this section that the main objective of this study was the evaluation of changes in disc displacement in a sagital plane only. Therefore, no inferences can be made regarding the rotational component that is often observed in the disc displacement. Further research, looking on how the rotational components of the disc displacement behave over time is recommended for completeness of this topic.

4.3 RECOMMENDATIONS FOR FUTURE RESEARCH

The etiology for the onset of TMJ disc displacement is complex and not understood in many cases. The literature shows extensive research that has been done in order to understand the different etiological factors that may be related to the onset of TMJ disc displacement. Many epidemiological studies are available showing the prevalence of this condition in the population and how clinical findings correlate to what is seen on the corresponding MRI.

The results of all these studies are very variable, leaving the field with the knowledge that is difficult to correlate clinical findings to MRI evaluations. Many studies try to correlate clinical symptoms and MRI findings of "internal derangement". It is important to remember that internal derangement is an unspecific diagnostic term that involves disc displacement with and without reduction. The correlation between clinical findings to what is seen on diagnostic images may differ greatly. For example, it appears that a when a disc is displaced without reduction, the clinical symptoms such as closed lock, are usually easier to use as a predictor compared to what it may be seen on an MRI. However, a less clear trend for symptoms is clinically observed for those discs that are displaced and still reduce. Many of these cases present symptoms such as pain or click and many others are asymptomatic. It is strongly recommended for future research that the authors clearly differentiate and specify the diagnosis to be considered for investigation. Furthermore, if more studies are to be performed regarding correlations of clinical findings and MRI, it may be better to focus on disc displacement with reduction due to the amount of variability of symptomatic and asymptomatic subjects presenting with this condition. It would be of great help to find a measurement of sagittal disc displacement that could be considered as a mean "cut-off" point for clinical significance. This would be of great help to interpret the amount of error that can occur when MRIs are analyzed over time, especially in those cases with reduction in which the amount of change does not appear to be significant.

As mentioned before, the results of this study did not show evidence for a clear trend on the progression of sagittal TMJ disc displacement over time. Since this is the first retrospective study evaluating the progression of sagittal disc displacement over time, the authors encourage future similar projects in order to compare results and begin building a distribution curve with our data. These would provide a clearer understanding on this topic and would facilitate clinical interpretation.

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appendix: University of Alberta Human Ethics Research Board approval