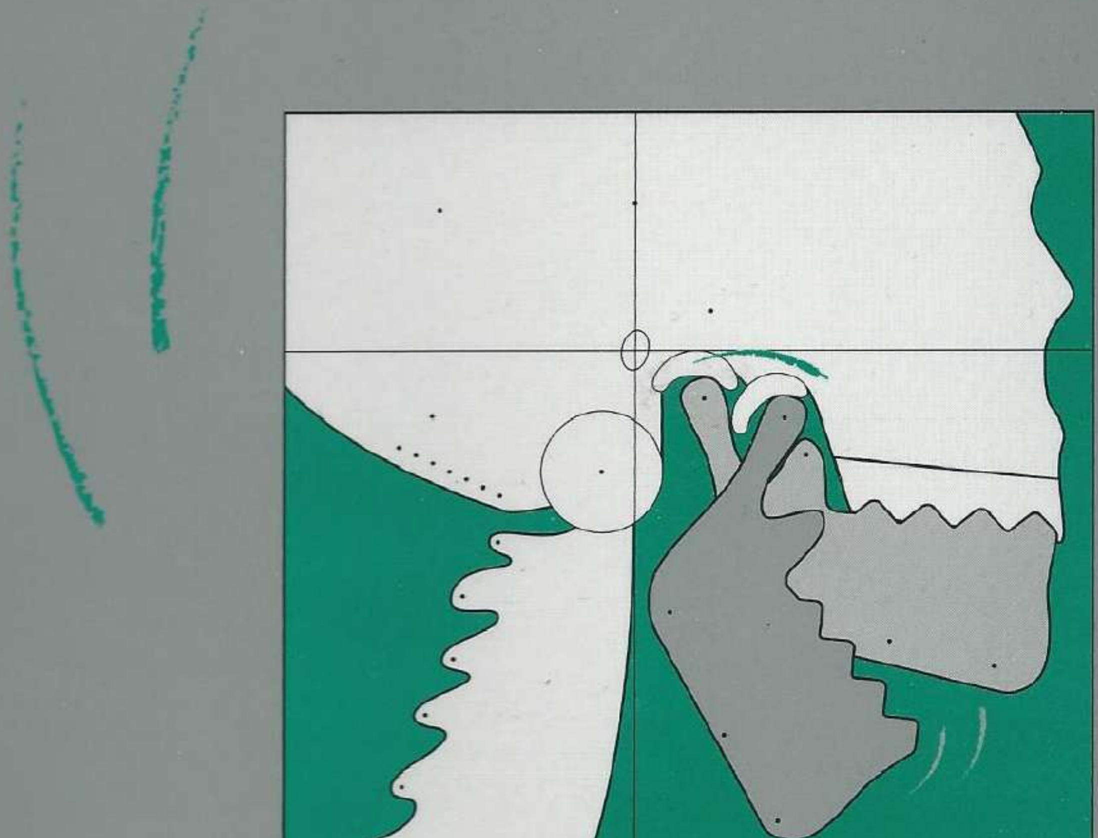
CRANIOMANDIBULAR BORDER CHARACTERISTICS AND OROFACIAL PAIN



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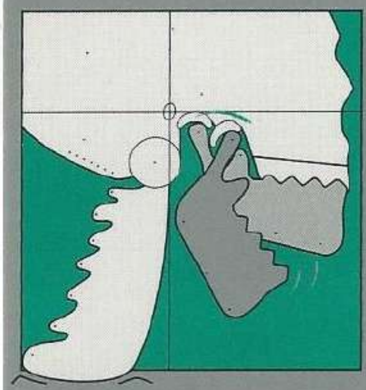

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CRANIOMANDIBULAR BORDER CHARACTERISTICS AND OROFACIAL PAIN

A Clinical and Experimental Investigation

Jules Robert Hesse

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CRANIOMANDIBULAR BORDER CHARACTERISTICS AND OROFACIAL PAIN:

A Clinical and Experimental Investigation

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Ter nagedachtenis aan mijn vader Mr. Harm Hesse

CONTENTS

Chapter 1

INTRODUCTION AND AIM OF THE STUDY

Sore and fatigued masticatory muscles and painful temporomandibular joints (TMJs), altered mobility of the mandible, and TMJ sounds are frequently recognized symptoms and signs of craniomandibular disorders (CMD). Disorders of the masticatory system with concomitant symptoms and signs in the ear and facial regions were first reported by Costen.[1] It was hypothesized that missing molar support was one of the etiological factors of ear and facial pains, as jaw 'overclosure' caused possible TMJ compression. Sensory reactions of the auriculo-temporal nerve branches were considered a result of this abnormal joint loading. For this matter the dental profession had become interested in the effects of structural changes in static jaw relationships (i.e., occlusion) and dynamic jaw relationships (i.e., articulation). Yet, anatomical studies by Sicher[2] and Zimmerman[3] caused some uncertainties about the occlusal theories related to CMD. The latter authors reported that it was impossible for the auriculo-temporal nerve to become compressed by an abnormal condylar position in the glenoid fossa. Later studies however, supported possible anatomical associations between the TMJ and the auriculo-temporal nerve, particularly in conditions of medial disc displacement.[4,5]

While occlusal disturbances were still regarded by many dental researchers as a primary factor related to CMD[6-8], other investigators found no significant correlations between occlusal interferences and CMD symptoms and signs.[9,10] So far it has not been established clearly whether occlusal interferences cause CMD, result from CMD, or should be considered independent variables.

Besides investigations on occlusal relationships, many studies were undertaken during the last decades focusing particular interest on neuromuscular pathophysiology,[11-15] behavioral aspects,[16-19] degenerative TMJ diseases, [20-22] and inflammatory TMJ diseases [23,24] affecting the masticatory system. General agreement however exists concerning the statement that the etiology of CMD is multifactorial and is thought to be composed of predisposing, initiating, and perpetuating factors.[25] The contributing factors are believed to possess behavioral, psychosocial, and physical aspects. Yet, many aspects remain puzzling, and complicate the recognition and the management of CMD patients by a single profession. The generally heterogeneous character of CMD therefore demands a multi-disciplinary approach with regard to diagnosis and treatment.

Today many multi-disciplinary teams managing CMD patients consist of a dentist, a physiotherapist, a psychologist, and less frequently, even incorporate pain specialists from the medical field, with each profession contributing their specific knowledge and skills. Most CMD examination protocols today therefore incorporate questionnaires which pay considerable attention to the medical, psychosocial, and behavioral status of the patient.

Traditionally, the physical examination of CMD patients by the dentist focused mainly on the dental status of the patient. An inspection of active mandibular movements, and the palpation of the masticatory muscles and the TMJs usually completed the clinical examination.[26-29] However, a more extended physical examination of the masticatory system was introduced by Hansson, Wessman, and Öberg.[30] Their clinical assessment included the orthopedic tests: active and passive ranges of mandibular movements, dynamic pain en static pain tests (i.e., provocation tests emphasizing specific joint or muscle pain), and a jointplay test (i.e., traction and translation of the TMJ condyle/disc complex).

Abnormal function is considered to be related to musculoskeletal pain, and the response to a provocation is more or less proportional to the stimulus applied.[31] The detection of the origin of pain and function impairment are the most important objectives in the diagnostic process of musculoskeletal disorders. Patient history and an orthopaedic examination provide the basis for this examination process. Orthopaedic tests have extensively been described in the orthopaedic literature for other joints of the body and are practiced by physiotherapists, chiropractors, orthopaedic doctors, etc.[32-37] However, little detailed information is available regarding the techniques of manual orthopaedic examination and the outcome of the tests with respect to the specific disorders affecting the stomatognathic system. Pain involved with musculoskeletal disorders is generally believed to be associated with tissues related to joints and muscles. Loading the musculoskeletal apparatus will inevitably evoke pain at the site of (or nearby) the injured tissue. The objectives of orthopaedic testing are, to discover by means of provocation testing, from where the joint, muscle, or other soft tissue symptoms arise. Great emphasis is generally put on the outcome of the range of motion and the outcome of pain provocation tests. In evaluating musculoskeletal disorders, therapists have always emphasized the need for quantitative assessment of joint movement and the subjective interpretation of the manner in which joint movements stop at the border position.[35,37,38] Border position characteristics may be assessed by the active (AROM) and passive (PROM) range of motion tests. Moreover, PROM testing may supply the examiner with additional information regarding the sensed 'feel' (i.e., resiliency or stiffness) of the constraining structures prior to the arrest of the movement and the onset of pain. This clinically obtained 'feel' during passive stretching toward the border position of a joint movement is described as 'endfeel'. Several 'normal' endfeels have been described by the previously mentioned authors: 'soft' (at elbow flexion) or 'tissue approximation', 'firm' (e.g., at internal rotation of the femur) or 'capsular feel', and 'hard' (e.g., at elbow extension) or 'bone-to-bone'. Abnormal endfeels were then described as 'less-elastic', 'more-elastic', 'springy block', 'empty', 'premature', and 'extended'. These subjective denotations are however susceptible to variable interpretations and may therefore lead to confounding conclusions. A need for unification and agreement grows as more dentists, physiotherapists, and physicians become involved with the diagnostic procedure incorporating orthopaedic tests in the evaluation of CMD. The assessment of craniomandibular border positions should therefore include objective criteria when examining mobility disorders in CMD patients. Since the orofacial pain symptoms involved with CMD come forth from the musculoskeletal apparatus of the stomatognathic system,[39] the objectives generally persued in an orthopaedic examination seem applicable to the examination of the stomatognathic system. Traditionally, myogenous CMD has been assumed to present with an elastic endfeel and arthrogenous CMD with a stiff endfeel.[30] Craniomandibular (CM) border characteristics obtained through AROM and PROM testing may therefore contribute to the diagnostic separation of CMD patients. The lack of clinical experimental studies on these aspects of craniomandibular function forms the background of this thesis.

The aims of this thesis were firstly, to investigate objective criteria describing craniomandibular border position characteristics, and secondly, to validate the outcome of several orthopaedic pain provocation tests in CMD patients.

In **Chapter 2** a review of the literature on the structure, the function, the various biomechanical constraints, and some important musculoskeletal disorders that influence the range of motion of synovial joints in general, and in particular respect of the craniomandibular articulation is given.
In **Chapter 3** the results of a peripheral joint mobility assessment were compared with the outcome of mandibular border positions in a group of healthy male and female subjects. The concept of endfeel distance is introduced as a quantification of the difference between passive and active range of mandibular motion.
In **Chapter 4** a new technique for measuring craniomandibular border characteristics is tested in a group of healthy male and female subjects.
In **Chapter 5** a comparison between subjective pain report and the outcome

of several orthopaedic tests is investigated in CMD patients with recent pain complaints.
In **Chapter 6** the craniomandibular border characteristics of myogenous and arthrogenous CMD patients are investigated.
In **Chapter 7** a general discussion and conclusions are presented.
In **Chapter 8** a summary of this thesis is given.

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Chapter 2

FACTORS INFLUENCING MANDIBULAR BORDER POSITIONS: A LITERATURE REVIEW

Summary

The literature concerning the various musculoskeletal disorders and biomechanical constraints that influence joint mobility in general, and particularly those influencing the craniomandibular articulation, has been reviewed. Mandibular range of motion (ROM) is affected by similar pathogenic factors influencing peripheral joint ROM. The assumed constraints involved with these border positions are largely based on morphologic and theoretic analyses and they lack direct evidence from living subjects. Future clinical and experimental studies may demonstrate their usefulness in the determination of constraints involved with mandibular border positions.

Introduction

An important clinical feature of musculoskeletal disorders is the marked changes they display in the range of joint motion.[1] Healthy synovial joints normally exhibit proportionally large, and nearly frictionless movements. A normal range of motion (ROM) is determined by several structures: ligaments, capsule, intra-articular structures (i.e., disci, menisci), muscles, subcutaneous tissue, and skin.[2] The ROM is commonly described as the range, measured in degrees of a circle by a goniometer, through which a joint can be extended or flexed.[3] With reference to the craniomandibular articulation (i.e., both TMJs and associated soft tissues), the mandibular ROM is generally expressed in millimeters.[4] In an orthopaedic examination the ROM is assessed quantitatively by measuring the active and passive ranges of motion.[2,5] Active mandibular ROM is achieved by motion imparted by voluntary contraction of the controlling muscles and relaxation of antagonist muscles, whereas passive mandibular ROM is the motion imparted to the craniomandibular articulation, its capsule, ligaments, and muscles by another individual, machine, or outside force.[4]

Qualitative assessment of the ROM is the personal interpretation of an examiner when testing joints passively towards their border positions. The nature of the resistance imparted at the hand of the examiner, when approaching the border position of a joint, is described in terms of a so-called 'endfeel'. Several denotations of endfeels have been proposed for classifying the type of resistance perceived by the examiner during passive ROM assessment.[2,5] Cyriax[5] described the following classification of endfeels: 'bone-to-bone', 'capsular', 'empty', 'spasm', 'springy block', and 'tissue approximation'. Another classification was offered by Evjenth and Hamberg[2] who described a normal endfeel as soft (e.g., tissue approximation at elbow or knee flexion), firm (e.g., capsular/ligamentous stretching at femur rotation), or hard (e.g., bone-to-bone stop at elbow extension). Passive ROM testing can also used in the assessment of ligamentous integrity (e.g., knee instability after cruciate ligament damage) and the determination of an inflammatory process in or around the joint.[6] Both quantitative and qualitative assessment of the ROM are supposed to assist the examiner in identifying the structures that limit a joint's passive ROM.[7] Implicit in the interpretation of these assessments is the assumption that border position constraints can be identified.

The purpose of this review is therefore to discuss the structure, the function, the various biomechanical constraints, and some important musculoskeletal disorders which influence the range of motion of synovial joints in general, and that of the craniomandibular articulation.

Synovial joint

Anatomy

Synovial joints are characterized by wide ranges of almost frictionless movements.[8] The presence of an articular cavity is an important feature of these joints (fig.1). This cavity is enclosed by an intraarticular layer - the synovial membrane - and is filled with a joint lubricating and nourishing fluid synovia.

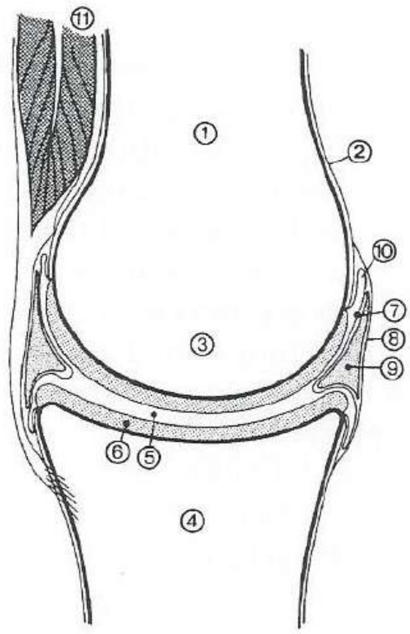


Fig.1 Schematic presentation of a synovial joint:

(1) bone shaft;
(2) periosteum;
(3) condyle (convex);
(4) condyle (concave);
(5) joint cavity;
(6) cartilage;
(7) synovial membrane;
(8) fibrous membrane and capsule;
(9) intra-articular fat pad;
(10) synovial bursa;
(11) muscle with tendon entering the joint capsule and bone.

The mucopolysaccharide content of synovial fluid is thought to be responsible for its efficient lubrication properties.[8] The synovial membrane is well vascularized, innervated, and is attached to the margins of the cartilage covering the bone. A fibrous layer supports the synovial membrane and is often enforced by ligaments and tendons of muscles.

The articulating bones of synovial joints are covered by hyaline cartilage. This type of cartilage is also found in the larynx and certain portions of the bronchial tree of the respiratory tract. Joint cartilage represents a specific and highly differentiated connective tissue, which is lacking blood vessels and nerve endings.[9,10] In contrast to most synovial joints, the sternoclavicular and temporomandibular joints are built with fibrocartilage. According to Gay and Miller[9] this type of cartilage has the same general physical properties as hyaline cartilage, but it is less distensible due to the presence of a higher proportion of dense collagen fibers. The latter authors reported that the tissues of the TMJ are therefore better suited to withstand shearing forces. Some of the body's synovial joints have fibrocartilaginous discoid partitions known as menisci or disci.[8] These structures are not constantly present in some areas (e.g., acromioclavicular joint), whereas they are highly developed and well defined in the knee, TMJ, and sternoclavicular joint. They are firmly attached to the margins of the bone and into the adjacent ligaments and/or capsule.

Capsular and ligamentous constraints

Rozendal[11] listed the following general constraints that guide joint motion and that determine the joint's border positions:

1. The configuration of the articular fossa, condylar head, and intra-articular structures as menisci or disci,
2. the direction and length of the surrounding capsule and ligaments,
3. the direction in which the surrounding muscles pull, their length, and the magnitude of their forces acting upon that joint.

The first two factors are generally considered to be of great importance in maintaining a stable joint position.[12] For example a fully extended knee represents such a ligamentous (i.e., intra-articular cruciate ligaments) determined border position with optimum congruency between the articulating partners. The function of the ligaments is to guide joint motion, to stabilize the joint, and particularly to prevent excessive motion. Excessive range of motion exhibited at different joints of the body has also been recognized as a discrete clinical entity, and is often referred to as the hypermobility syndrome.[13] Others[14,15] have suggested that hypermobile individuals represent an extreme of a normal distribution. According to some researchers physical factors like ballet training and gymnastics are also likely to be of critical importance in developing an increased level of joint mobility.[8,16] The ligaments and tendons consist of dense connective tissue containing few cells and a multitude of parallel collagen fibers. This arrangement of a large number of fiber bundles provides these structures with a high degree of tensile strength.[9] The fact that ligaments may be elongated up to 5 - 8 % of their original length may be assumed to prevent irreversible damage to its structure.[17] A less parallel orientation of fibers is found in capsular connective tissue and therefore allows joint motion to occur in different directions. The third constraining factor is the active and passive influence of muscles restraining border movements. Contraction of an antagonist muscle occurs when a joint is moved rapidly towards a joint's border position.[18] This reflex activity is considered a protective mechanism against excessive joint motion.

Influence of musculoskeletal pathology upon range of motion.

Musculoskeletal disorders generally demonstrate marked changes in the range of joint motion (ROM).[1,3,8] It is beyond the scope of this article to review all possible conditions affecting the musculoskeletal apparatus. Nevertheless, the most important factors affecting the musculoskeletal system will be discussed in this review. Restriction of movement is generally caused by articular disorders, non-articular disorders (mostly muscular), or both. For example, an articular restriction of the knee is frequently observed following a traumatic event; this is seen in skiing accidents and after soccer injury. Meniscus damage may have occurred, either in isolation, or in association with ligamentous injury.[19] The knee may be locked disabling full extension of the joint, whereas flexion may be carried out fully. Aside from this impediment, joint effusion may also be held responsible for an additional impediment temporary disabling full range of motion. These mechanical restrictions may both diminish the active and passive ranges of motion.

Joint motion may also be limited due to ligamentous or capsular shortening as a result of an inflammatory swelling of these tissues.[20] The decreased extensibility of these tissues causes both the active and passive ranges of motion to become decreased. Extreme loss of active and passive range of motion can be observed in patients with an fibrous ankylosis of a synovial joint; a pathological deposition of collagen fibers in the joint (i.e., intra-articular adhesions) that often results from a traumatic injury, an infection, or an inflammation of that joint.[21] Passive stretch applied to the joint demonstrates an unyielding firmness and is usually not painful.

In contrast to a loss of joint mobility, joint hypermobility, skin hyperelasticity, and widespread tissue fragility are well known clinical phenomena seen in patients with inherited connective tissue disorders such as the Ehlers-Danlos and Marfan syndromes.[9,10] In particular the Ehlers-Danlos type III, also referred to as benign familial hypermobility, and the Marfan syndromes are recognized for the following clinical findings - redundant joint capsules, tendons and ligaments exhibiting a loose jointedness, hyperextensibility of joints, backward curvature of the legs at the knees (genu recurvatum), flat feet, kyphoscoliosis, and chronic dislocations of the hips, patellas, mandible, and other joints.[22]

A limited ROM is a frequently observed clinical feature in patients with progressed stages of rheumatoid arthritis and osteoartrosis.[23] Rheumatoid arthritis is primarily a disease of the synovium with secondary changes in the articular cartilage,[24] whereas osteoarthrosis (syn. degenerative joint disease or osteoarthritis) is a disease of peripheral and central (e.g., spinal joints) articulations which is characterized by destruction of articular cartilage, thickening and remodelling of subchondral bone and the formation of marginal spurs as well as subarticular bone cysts.[25] The exact aetiology of both diseases are hereto unknown but current hypotheses suggest that both genetic and microbiological factors may be important.[26] Following an acute or chronic inflammation both the synovial lining and the fibrous joint capsule may become contracted and limit active and passive range of motion.

Restriction of the range of joint motion is not necessarily caused by articular impediment, but may be a direct result of a (painful) muscular involvement. Muscle pain (syn. myalgia) may arise from two major types of receptor systems: chemonociceptors and mechanonociceptors, respectively.[27]

The former are responsive to chemical or noxious stimuli, and the latter to mechanical changes in their environment. Skeletal muscle pain is usually associated with exercise or trauma, and is of a temporary nature. Occlusion of intramuscular blood vessels during prolonged muscle contraction is held primarily responsible for ischaemic pain, and secondarily to accumulation of metabolites (i.e., waste products).[27] Protective and restricted movements may be noted during clinical examination of a patient with an acute myofascial pain syndrome.[28] Myofascial pain is assumed to result from trigger-point activity in the muscle and/or its associated fascia due to mechanical overload. A trigger-point is a focus of hyperirritability in one of these structures, which causes pain and tenderness at rest, or with motion that stretches or loads that muscle. Under these circumstances active range of motion may be restricted whereas full range of motion may be obtained by means of passive stretch. Muscle spasm usually implies a reflex contraction of muscles surrounding an injured or inflamed structure. Reflex spasm of the respiratory muscles in the immediate region of the injured area is for instance observed after surgery or trauma to the chest and is a direct result of the pain associated with such conditions.[29] The patient's reaction to the pain may also result in voluntary reduction of muscle movement in the thorax and abdominal area. This phenomenon is generally described as 'muscle splinting'. Muscle cramp is usually distinguished by its acute onset, relatively short duration and its association with powerful muscle contraction. Contracture of muscle is also very painful, but its time course is longer than that of cramp. Both active and passive ranges of motion are notably limited during the inflammatory phase of the disease.

Temporomandibular joint

Anatomy

The craniomandibular articulation comprises two distinct synovial articulations, that is, the two temporomandibular joints (TMJs) connecting the base of the skull with the mandible. The TMJ consists of two highly incongruent partners: the mandibular condyle and the glenoid fossa extending anteriorly to the articular eminence. The incongruence is compensated by the presence of an intracapsular, bi-concave disc, that divides the joint space into two separate synovial joint cavities (fig.2).

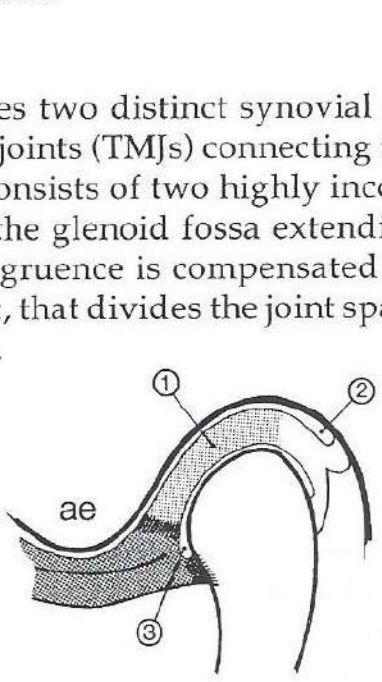


Fig.2 Sagittal presentation of the TMJ.
(1) intra-articular disc
(2) upper joint cavity,
(3) lower joint cavity, and
articular eminence (ae)

The mandibular condyle is elliptic in the horizontal plane. Its convexity is most distinct in anteroposterior direction and slightly rounded in its mediolateral direction. However, the anatomic design has been shown to vary extensively.[30]

The function of the articular disc has been described as space filling, force distributing, and joint stabilizing. However, Osborn[31] hypothesized that the disc was rather a "de-stabilizer" during TMJ function, enabling nearly frictionless movements across the articulating surfaces. The cartilaginous structures of the TMJ are neither vascularized nor innervated. Pain arising from the temporomandibular joint may therefore originate from the synovial and/or fibrous membrane,and the postero-lateral discal and capsular tissues innervated by pain receptors of the auriculo-temporal nerve and branches of the deep temporal and deep masseter nerves of the fifth cranial nerve.[32]

In an anatomical investigation by Dauber[33] a strong connective tissue sheet was found adjacent to the joint capsule medially, posteriorly, and laterally by means of the pterygoid, parotic, and masseteric fasciae. Laterally and medially the disc attachments have been found to insert into the condylar poles by means of the menisco-condylar ligaments,[34] directly to the condylar poles,[30] or directly into the joint capsule by means of the "disco-capsular system".[33]

The TMJ capsule is laterally reinforced by a ligamentous structure, that is, the temporomandibular (TM) ligament.[35,36] The TM ligament is attached above the articular tubercle and runs posteriorly and inferiorly to the posterolateral aspect of the condylar neck (fig. 3).

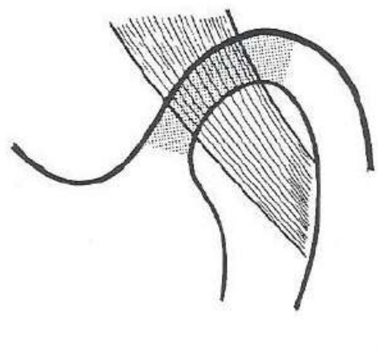
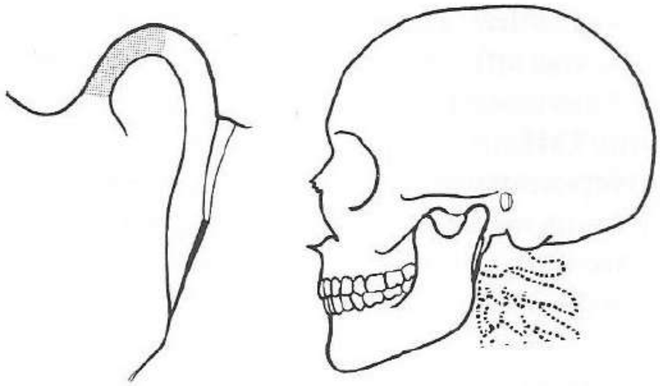


Fig.3 The temporomandibular ligament in a lateral view

Although most anatomy textbooks agree upon the presence and the location of the TM ligament, recent histological investigations by Savalle[38] could not confirm the earlier described precise direction and the distinct anterior thickening of the capsule in all of the studied human cadaver specimens.

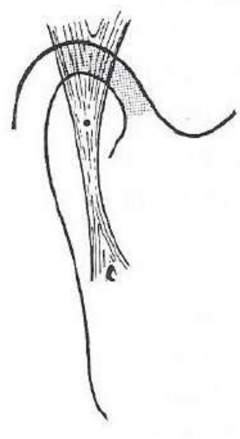
Two distinct extracapsular ligaments, the stylomandibular ligament and the sphenomandibular ligament are often classified as accessory ligaments.[35,36] The stylomandibular ligament is generally described as a reinforced part of a fascial lamella that extends from the styloid process and styloid ligament to the region of the mandibular angle (fig. 4).

Fig. 4 The stylomandibular ligament from a lateral view



The sphenomandibular ligament (fig. 5) is part of the pterygoid fascia complex, but can be identified clearly.[36] This ligament connects the medial side of the mandible with the cranium by running from the lingula above the opening of the inferior alveolar canal to the spine of the sphenoid.

Fig. 5 The sphenomandibular ligament from a medial view



Capsular and ligamentous constraints

The capsule and ligaments of the TMJ are generally considered constraining factors to the border positions of the mandible. A minor role is generally ascribed to the TMJ capsule as a constraining factor, because of its loose arrangement of connective tissue.[32] However, Freesmeyer and Stehle[39] postulated that the posterior fibers of the TMJ capsule may also serve as an additional constraint restricting maximal anterior translation of the condyle.

The superior portion of the bilaminar zone is also assumed to be a constraining factor to some extent during the late phase of translatory movement of the menisco-condylar complex.[39] Its magnitude as a constraining factor to condylar movement is however difficult to interpret.

The TM ligament is generally described as a ligament that controls and limits condylar movements, similarly to that of the collateral ligaments of other joints.[40] Some authors[41,42] stated that the temporomandibular ligament is also capable of preventing posterior movement of the condyle. Nevertheless, Saizar[34] found the more vertical orientation of this ligament's fibers not directly suitable for preventing further retrusive condylar movement in the glenoid fossa. In an earlier study, Boucher[43] found no difference towards the most retruded condylar position after sectioning this ligament. According to Posselt and Thilander[37] the TM ligament's orientation of fibers is capable of preventing a separation between the condyle/disc and temporal fossa, and restricts condylar translation at maximum mouth opening, maximum protrusion, and maximum laterotrusion. In their study unilateral and bilateral anesthesia of the lateral TMJ capsule and temporomandibular ligament increased the active maximum mouth opening by 10% and 15%, respectively. The authors reported no changes regarding the other actively achieved mandibular border positions, which led them to conclude that the lateral joint capsule and the temporomandibular ligament are particularly involved in the maximum mouth opening positions. However, it is not clear from this experiment whether the result was an effect of inhibition of a protective mechanism (i.e., reflex activity of the jaw closing muscles). Nevertheless, from theoretical analyses using a mathematical approach, it has been postulated that the TM ligament controls particularly the condylar movement during the initial phase of symmetrical mouth opening.[39,44-47] The tightening of the ligament supposedly offers a more stable relation between the condyle/disc complex and the posterior slope of the articular eminence during this phase of mouth opening. The authors stated that this ligament becomes a less constraining factor during later phases of mouth opening.

Jaw movement towards full mouth opening causes the stylomandibular ligament to become slack, whereas mouth closure during full protrusion tightens it visibly.[35] Overclosure of the mandible in edentulous subjects may strain this ligament further. The latter author also reported the contralateral ligament to tighten at lateral jaw border positions. However, others have expressed the opinion in recent studies that this ligament has uncertain function.[48,49]

Like the stylomandibular ligament, the sphenomandibular ligament was found to become slack on jaw opening, straight on closure to its normal vertical jaw relation, and even visibly tightened during overclosure of the mandible.[35] Other investigators however ascribed a different role to this ligament. Again, from theoretical analyses using a mathematic approach, it has been assumed that the sphenomandibular ligament controls the late phase of mouth opening.[39,44-47] At present time no consensus exists in the literature regarding the individual or combined tasks of the capsular and ligamentous constraints involved with the border positions of the mandible. According to Sato et al[49] and Hanam[50] controversies exist regarding the anatomy and function of associated TMJ ligaments. Their conclusions were that knowledge of the function of these ligaments is incomplete and is based mainly on theoretical speculations. More direct experimentation was proposed by the latter authors in order to elucidate TMJ capsule and ligament function at border positions of the mandible. Clinical experimentation employing passive ROM tests may provide us with additional information regarding mandibular border position determinants.

Influences of musculoskeletal pathology upon range of motion

Disorders affecting synovial joints in general are observed to affect the TMJ in a similar manner. In craniomandibular disorder (CMD) patients both restricted and excessive mandibular movements are observed.[51] Restricted TMJ mobility is frequently a result of an internal derangement (i.e., permanent disc displacement without reduction), a reduced extensibility of the capsular ligament, or to intra-articular fibrous adhesions.[52] Internal derangement is usually preceded by a history of joint clicking followed by a sudden limitation in the range of mouth opening with a mandibular deflection to the affected side on opening, and is frequently recognized in patients with craniomandibular disorders (CMD).[51] Severe restriction of mouth opening is particularly observed in the acute phase of a disc displacement without reduction with strong restriction of translation of the affected joint.[4] The rotational capacity of the condylar head is then usually unaffected. Restriction of condylar translation may also be a result of capsular inextensibilty or intra-articular adhesion formation following inflammatory conditions, trauma, or surgery.[21,52] Stegenga[52] reported that capsular fibrosis, described as a generalized thickening of the joint capsule, is a common sequela of osteoarthrosis and leads to capsular inextensibility. Moreover, the author reported that the latter condition may contribute to adhesion formation, even when the disc is still in place. Passive stretch at full mouth opening is then usually painless and will demonstrate a decreased and tough endfeel. However, clinical discrimination between the latter two conditions may be difficult. In both cases the vertical and horizontal movements will be reduced as a result of translatory restriction of the condyle. Capsulitis (syn. synovitis) is an inflammatory response to mechanical irritation (e.g., overextension) of the capsular ligament and associated intra-articular attachments, and is tender to passive stretch or manual joint distraction.[52] However, the range of motion is not found to be impeded significanty under this circumstance.

Excessive range of condylar translation anterior to the articular eminence has been described as hypermobility of the TMJ.[53] This condition is also frequently observed in healthy subjects who show no signs of a craniomandibular disorder.[41,53,55] However, this condition may be accompanied by pain, and spasm of either the superior head of the lateral pterygoid muscle or the jaw closing muscles, preventing jaw closure.[44] In a study by Westling[56] the relationship between general joint hypermobility and craniomandibular dysfunction was investigated. She reported a higher prevalence of CMD among females with hypermobility of peripheral joints than in female CMD patients without general joint hypermobility.

With respect to the possible relationship between joint hypermobility and osteoarthrosis both Harinstein et al[57] and Buckingham et al[58] hypothesized a causal relationship between TMJ hypermobility and osteoarthrosis in studies consisting mainly of CMD patients admitted for reconstructive TMJ surgery. However, in recent clinical studies[59,60] no relationship was shown between osteoarthrosis and a generalized joint hypermobility in a CMD patient population that was re-evaluated after a period of 30 years. The authors concluded from their studies that TMJ hypermobility could not be more than a subsidiary factor in the development of osteoarthrosis as the severity of symptoms had progressed only mildly in the elapsed time.

Rheumatoid arthritis is also known to afflict the temporomandibular joint with common symptoms including pain during function, limitation of movement, tenderness on palpation, stiffness, and crepitus.[61] Particularly in early active rheumatoid arthritis there is pain, soft tissue swelling and stiffness, whereas in the late-stage destructive rheumatoid arthritis problems of deformity and loss of range of mandibular motion predominate with relatively little inflammation. Franks[62] reported that 53% of the group of rheumatoid arthritis patients he studied were aware of TMJ symtoms including pain, noise, or altered movement. He reported that none of the subjects however, became aware of TMJ involvement prior to recognizing other joint symptoms.

Limitations in the range of mandibular movements are not necessarily caused by TMJ disease or mechanical impedements. Muscular shortening, as a result of muscle contraction, inflammation, or contracture may be the direct cause of mouth opening restriction. These disorders are analogous to muscle disorders that can occur in other areas of the head, neck, body, and extremities. They include myofascial pain,[27,63] myositis,[64] myospasm,[65] protective muscle splinting,[66] contracture,[67] and muscle neoplasia. In these disorders, mandibular movements usually demonstrate a moderately to severely limited active range of motion. Muscular inhibition as a result of myofascial pain may demonstrate a considerable increase of mouth opening during passive stretch and is denoted as a soft endfeel.[52] However, passive stretch at full mouth opening may demonstrate an unyielding firmness in cases of protective muscle splinting (e.g., acute trismus) and contracture (e.g., chronic trismus). Mouth opening may be extremely limited under these circumstances, whereas the horizontal mandibular movements (i.e., translatory movements of the TMJs) are nearly unaffected.[68] Nevertheless, the overlap of symptoms in the differential diagnosis of muscular disorders affecting TMJ ROM is frequently confusing to clinicians.

In conclusion, craniomandibular disorders are musculoskeletal disorders that display similar disorders that are observed affecting other synovial joints, and as a consequence may display altered ranges of mandibular motion. It may therefore be assumed that the methods used for investigating joint mobility and joint border positions in general are applicable to the craniomandibular system as well. Controversies exist in the literature with respect to the dominance and hierarchy of the various constraints that determine mandibular border positions. The hypotheses offered are mainly based on speculations derived from studies concerned with morphological and theoretical analyses. Future clinical and experimental investigations employing active and passive ROM tests may prove to be useful in the search for mandibular border position determinants.

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Chapter 3

MANDIBULAR BORDER POSITIONS AND THEIR RELATIONSHIPS WITH PERIPHERAL JOINT MOBILITY

SUMMARY

Peripheral joint mobility was assessed in a group of fifty-one dental students using a modification of the Carter and Wilkinson Index. Mandibular border positions were measured both actively and passively with the aid of a millimeter ruler. The purpose of the investigation was to study possible relationships between generalized joint (hyper)mobility and (hyper)mobility of the temporomandibular joints. Only a few weak correlations were found between the mandibular border position measurements (active and passive mouth opening, active and passive, left and right, laterotrusions and active protrusion) and the peripheral joint mobility measurements. Differences between the sexes were illustrated in peripheral joint mobility with females showing a greater joint mobility than males, especially when only the passively measured joints were considered. The mandibular border positions were significantly correlated with each other ($p<0.05$ - $p<0.001$) for the males, but few and then only weak relationships between these measurements could be found for the females in this group. The concept of temporomandibular joint 'end-feel distance' in relation to joint mobility is discussed.

INTRODUCTION

Generalized joint hypermobility is a recognized clinical diagnostic entity and has been named the 'hypermobility syndrome' by Kirk, Ansell & Bywaters.[1] Biro, Gewanter & Baum[2] claimed that this syndrome is not sufficiently recognized in the United States as a source of musculoskeletal disorders. Kirk, Ansell & Bywaters,[1] Bird, Tribe & Bacon[3] and Scott, Bird & Wright[4] even suggested that premature osteoarthrosis may be a direct consequence of joint hypermobility.

Carter & Sweetman[5] and Beighton & Horan[6] suggested that congenital influences are of critical importance in the development of joint laxity. Beighton, Solomon & Soskolne[7] also pointed to differences in racial predisposition in developing hypermobility. Sports like athletics and ballet training may be looked upon as functional factors which can be of critical importance in acquiring hypermobile joints.[8]

Clinically, little attention has been drawn to the relationship between hypermobility and the function of the stomatognathic system. Schultz[9] introduced the concept of temporomandibular joint hypermobility to the dental literature using palpation of these joints as a diagnostic tool. He noted its association with symptoms of stomatognathic dysfunction. Boering[10] found no relationship between hypermobility of the temporomandibular joints measured on radiographs as excessive condylar translation and hypermobility patients, he did notice a trend of increased temporomandibular joint mobility. Katzberg et al[11] found through arthrotomographic studies that patients who had temporomandibular joint disc displacement with reduction showed hypermobility of the condyle on the symptomatic side. Orthopaedic testing of joint mobility involves measurements of joint border positions.[12] In trying to correlate temporomandibular joint hypermobility with general joint hypermobility the use of mandibular border position measurements appeared appropriate. Therefore, the aim of this study was to investigate the relationship between mandibular border positions and the mobility of several peripheral joints.

Subjects and methods

Fifty-one dental students, fifteen females and thirty-six males, between the ages of 22 and 37 years with an average age of 25.8 were tested for temporomandibular joint and peripheral joint mobility. Each individual was screened according to a fixed protocol after informed consent. A physiotherapist (J.R.H.) measured the mobility of the peripheral joint. Subsequently one dentist (R.S.M.) performed all measurements on the mandibular border positions. Peripheral joint mobility was measured by the following tests, which are a modification of the tests used by Carter & Wilkinson.[12] Each subject was assigned a mumerical score between 0 and 24 (fig.1) The active test represents the possibility of the subject to reach a border position on the basis of his own muscle force. The passive test is performed using a manual force to extend the active border position until no further movement can be obtained without pain being reported by the subject.

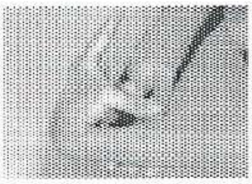
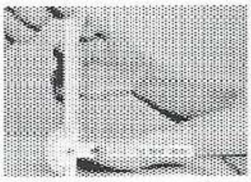
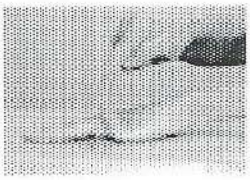
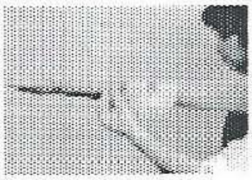
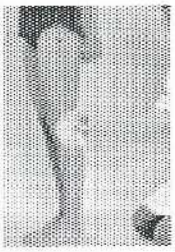
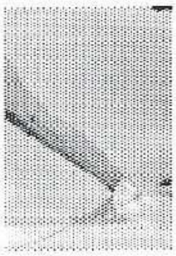
		Ability	Score	Right	Left
	a. Passive opposition of the thumb	Before // Beyond // Contact	0 1 2		
	b. Passive hyperextension of the MCP II-IV	<45° 45°-90° >90°	0 1 2		
	c. Passive hyperextension of the MCP V	<45° 45°-90° >90°	0 1 2		
	d. Active hyperextension of the elbow	180°-170° <170°	0 2		
	e. Active hyperextension of the knee	180°-170° <170°	0 2		
	f. Active dorsi-flexion of the ankle	90°-75° <75°	0 2		
		Subtotal	+		
		Total	+		

Fig. 1. Peripheral joint mobility index (modified after Carter & Wilkinson, 1964).

The total score for a subject represents the sum of the following parameters:
a) passive apposition of the thumb towards the flexor aspect of the fore arm;
b) passive hyperextension of the metacarophalangeal joints (MCP II-IV) measured with the forearm and the palm of the hand on the table;
c) passive hypertension of the little finger (MCP V) following the same procedure as in b);
d) active hyperextension of the elbows during full external rotation of the shoulder joint;
e) active hypertension of the knees, while standing;
f) active dorsiflexion of the ankles, performed standing with a straight knee.

The individual scores were recorded using standard goniometers. Before measurement, each test was demonstrated to the subject. Then the subject was asked to perform the test. During this trail the investigators verbally motivated the subject to attempt to reach the border position of the different joints. Subsequently, the test was repeated and the measurement recorded. The mandibular border positions were registered during active and passive opening, right laterotrusion, left laterotrusion and active protrusion. The mouth opening was measured as the distance in millimetres between the incisal edges of the upper and lower left central incisors, including the vertical overbite. The passive mouth opening was performed by expanding the active opening with the examiner's middle finger and thumb on the lower and upper incisors. The passive movement was expanded until resistance prevented further movement. The difference in millimetres between active and passive border positions is referred to as the 'endfeel' distance. During laterotrusion the subject was instructed to move his jaw maximally to the right and to the left, just avoiding tooth contacts. Both excursions were also tested passively by fixating the subjects head against the body of the examiner using one hand and then expanding the laterotrusion by a laterally directed manual force exerted by the other hand of the examiner. A vertical line had been drawn on the upper and lower left incisors close to the midline, with the teeth contacting in intercuspal position. This line was used as the reference for all laterotrusive measurements. Finally, the examiner instructed the subject to protrude the mandible. In order to measure the protrusion, a fine vertical line had been drawn on an antagonist pair of premolars on each side, again with the teeth in intercuspal position. During maximum protrusion, the horizontal distance was then measured between the vertical lines. Thus all movements to border positions, except protrusion, were performed actively and passively. Protrusion was only measured actively.

Statistical testing of the data employed linear correlation analysis, the *t*-test and the paired *t*-test. Values of $P<0.05$ were considered to be statistically significant.

Results

Peripheral joint mobility

The passive measured joints, thumb, fingers (MCP II-IV) and little finger (MCP V), were significantly more mobile in the female group than in the male group (Table 1). For the actively measured joints - elbow, knee and ankle - no differences in mobility were found between the two groups. Analysis of the total peripheral joint mobility scores revealed significant difference showing more mobile joints in the female group than in the male group.

Table 1. Peripheral joint mobility correlations, average scores and their standard deviations

	Passive Testing			Active Testing			
	Thumb	MCP II-IV	MCP V	Elbow	Knee	Ankle	T.Sc.
Males	1.1±1.5	0.6±0.8	1.5±0.8	0.6±1.3	0.7±1.5	2.1±1.9	6.5±4.1
	*	***	***	n.s.	n.s.	n.s.	*
Females	2.1±1.7	1.6±0.8	2.3±0.6	0.7±1.4	0.5±1.4	1.9±1.9	9.1±3.9

T.Sc. = total peripheral score; * $P<0.05$; *** $P<0.001$; n.s. = not significant

Table 2. Mandibular border position pair correlations

Mandibular border position pairs	Males	Females
Pas.mo./Pas.RLT.	**	n.s.
Pas.mo./Pas.LLT.	**	n.s.
Pas.RLT./Pas LLT.	***	*
Pas.mo./Act.prot.	***	n.s.
Act.mo./Act.RLT.	*	*
Act.mo./Act.LLT.	**	n.s.
Act.RLT/Act.LLT.	***	*
Act.mo./Act.prot.	***	n.s.

Act.mo. = active mouth opening; Pas.mo. = passive mouth opening; Act.RLT. = active right laterotrusion; Pas.LLT. = passive left laterotrusion; Act.prot. = active protrusion; * $P<0.05$; ** $P<0.01$; *** $P<0.001$; n.s. = not significant.

Mandibular border positions

All the mandibular border position pairs investigated were related to one another in the male group with levels of statistical significance varying from weak to strong ($p<0.05$ to $p<0.001$, Table 2). In contrast, the females displayed only a few weak correlations between the mandibular border positions. The mean values of mandibular measurements are shown in Table 3.

Table 3. Mean values of mandibular border positions and their standard deviations

Mandibular border positions	Males (mm)	Females (mm)
Act.mo	53.6 $\pm$ 7.4	50.7 $\pm$ 7.2
Pas.mo.	55.7 $\pm$ 8.2	53.8 $\pm$ 6.8
Act.RLT.	10.2 $\pm$ 2.3	10.3 $\pm$ 3.4
Pas.RLT	11.5 $\pm$ 2.1	12.2 $\pm$ 3.5
Act.LLT.	10.5 $\pm$ 2.7	10.0 $\pm$ 2.8
Pas.LLT	11.8 $\pm$ 2.7	11.7 $\pm$ 3.1
Act.prot.	9.0 $\pm$ 2.8	9.1 $\pm$ 1.8

Act.mo. = active mouth opening; Pas.mo. = passive mouth opening; Act.RLT. = active right laterotrusion; Pas.LLT. = passive left laterotrusion; Act.prot. = active protrusion; mm = millimetre

Mandibular border positions and their 'endfeel' distances

For the male group the active and passive mouth opening revealed positive correlation with the 'endfeel' distance of mouth opening. For the female group this was not the case. 'Endfeel' distance of mouth opening was greater ($p<0.05$) for women (3.13 mm, SD 2.19 mm) than formen (2.13 mm, SD 1.3 mm).

Correlations between lateral 'endfeel' distances and laterotrusion border positions were few and weak for both sexes. The 'endfeel' distances of right and left laterotrusions were related for women but not for men. Relationships between endfeel distance of mouth opening and the endfeel distance of the laterotrusions were not found for either sex (Tables 4 and 5).

Discussion

The results concerning the mobility of the peripheral joints support the findings of others that women are generally more mobile than men.[7,13] This increased mobility in women is best displayed in the passively measured joints: the thumb and the fingers.

Table 4. Mandibular border positions and their relations with peripheral joint mobility

	Males			Females		
Parameter	T.Sc.	T.P.Sc.	T.A.Sc.	T.Sc.	T.P.Sc.	T.A.Sc.
Act.mo.	*	n.s.	n.s.	n.s.	*	n.s.
Pas.mo.	*	n.s.	n.s.	n.s.	*	n.s.
EF.mo.	*	*	n.s.	n.s.	n.s.	n.s.
Act.RLT.	**	*	n.s.	n.s.	n.s.	n.s.
Pas.RLT.	*	*	n.s.	n.s.	n.s.	n.s.
EF.RLT	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Act.LLT.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Pas.LLT.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
EF.LLT	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Prot.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

T.Sc. = total peripheral score; T.P.Sc. = total passive score; T.A.Sc. = total active score; EF.mo. = endfeel mouth opening; EF.RLT = endfeel right laterotrusion; EF.LLT = endfeel left laterotrusion; Prot. = active protrusion; *$P<0.05$; **$P<0.01$; n.s. = not significant.

Table 5. Correlations between mandibular border position pairs and 'endfeel' distances for the male and the female group.

Mandibular border position pairs and 'endfeel' distances	Male	Female
Pas.mo./EF.distance	***	n.s.
Act.mo./EF.distance	**	n.s.
Pas.RLT./EF.RLT.	n.s.	n.s.
Act.RLT./EF.RLT.	*	n.s.
Pas.LLT./EF.LLT.	n.s.	*
Act.LLT./EF.LLT.	n.s.	n.s.
EF.RLT./EF.LLT.	n.s.	*
EF.mo./EF.RLT.	n.s.	n.s.
EF.mo./EF.LLT.	n.s.	n.s.

*$P<0.05$; **$P<0.01$; ***$P<0.001$; n.s. = not significant.

No differences in mobility between the sexes were revealed in the actively measured joints: the elbows, the knees and the ankles. Therefore, these findings support the use of passive measurement for diagnosing hypermobility of the peripheral joint.

The relationships between maximal mandibular movements have been investigated by Agerberg.[14] He used a similar technique of border position measurement with a millimetre ruler, which he found to be statistically reliable. However, in his study he employed only active mandibular movements to border positions. Our findings regarding the intra-individual active and passive mandibular border position correlations are surprising regarding sex distribution. For the men the statistically significant correlations between all pairs of border positions tested, indicate the consistency of these relationships. The results therefore verify the use of prediction ellipses in calculating mandibular border positions in men, as suggested by Agerberg.[14] Because few and then only weak correlations were found in the female group, our results do not support the general use of prediction ellipses for women.

The failure to find any strong correlations between anthropological measurements and the movements of the mandible[14,15] indicate that the limits of these movements may be determined by other factors such as the properties of the jaw muscles and the peri-articular tissues. These properties with a possible bias in their dominance for different sexes may therefore be responsible for the differences in intra-individual border position correlations between men and women found here.

The 'endfeel' at the end of a joint movement is elastic and pain free in all healthy joints.[16-18] Although endfeel is essentially qualitative in a clinical orthopaedic testing, we attempted to quantify it for the mandibular border positions. The purpose in doing so was to investigate the possibility that it could give an indication of the temporomandibular joint mobility.

The endfeel distance of mouth opening was significantly larger for women than for men. This may reflect the fact that female joints are generally more elastic than male joints. The results appear to be in agreement with figures calculated from the results of Pullinger et al.[15] No significant differences were found for the endfeel distances of laterotrusions between men and women. However, there was a trend of greater values for women. In this respect the finding that the endfeel distance of mouth opening is strongly correlated to the mouth opening for men and women is interesting in view of the high prevalence of women amongst patients with TMJ dysfunction.

Few, and then only weak, correlations were found between mandibular border positions, their endfeel distances and peripheral mobility measurements. This lack of correlation underlines the importance of further investigations of local factors as aetiology for hypermobility of the temporomandibular joints. The mechanisms underlying the differences between the sexes found here also require further study.

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Chapter 4

PASSIVE MOUTH OPENING TEST IN HEALTHY SUBJECTS: AN EXPERIMENTAL INVESTIGATION.

Summary

Passive mouth opening was investigated in healthy young subjects in an experimental setting. In a pilot study the active and passive border positions of mouth opening were investigated under EMG control, and with the help of two separate recording devices enabling the registration of force and displacement, simultaneously. Two protocols ('A' and 'B') of passive testing were investigated. The outcome of the pilot study indicated the use of the passive test protocol ('B') that evoked the least muscle interference, and the use of a more practical and stable force transducer. In the following study an improved and less laborious force/displacement recording device was used in a group of 40 healthy young subjects. No difficulties were observed with relaxation of the muscles or force application during the passive mouth opening tests with the execution of protocol 'B' and the improved experimental design. A stretching sensation at the TMJ reported by most subjects supports the idea that the TMJ capsule and ligament serve as a constraint at the border of passive mouth opening. Higher applied forces (Fmax) were needed to achieve the passive border position of mouth opening in the male subjects ($p=0.005$). Craniomandibular (CM) stiffness was calculated from the force/displacement recordings of the males and the females and demonstrated higher values of CM-stiffness at the middle (S2; $p<0.05$) and upper (S3; $p<0.05$) sections in the male subjects.

Introduction

Musculoskeletal disorders have a marked influence on human joint function. The range of joint motion is frequently limited as a result of (intra-)capsular, ligamentous, and muscular disorders.[1] The identification of individuals exhibiting these disorders is based largely on medical history and clinical examination. The orthopaedic evaluation, as an important part of the clinical examination, employes provocation tests which are used to recognize and differentiate between the various musculoskeletal disorders. The objectives of diagnostic orthopaedic testing are to determine from which tissues (i.e., joint, muscle, or other soft tissues) the symptoms arise.

Following a (socio-)medical history and a general inspection, the examiner usually starts the examination by observing the patient's active joint movements in all possible directions. Active range of motion (AROM) indicates the patient's ability and willingness to perform the movement requested, possible mechanical (i.e., muscle, joint, or other soft tissues) impediments, muscle weakness, or pain.[2] Left/right differences between peripheral joints are generally considered the best yardstick for AROM comparison.[3]

During the passive range of motion (PROM) test the examiner requests the patient to relax the muscles, and subsequently increases the range of motion with a manual force to the new border position, thereby eliminating the effects of conscious control and muscular effort.[4] These border positions are dictated by specific anatomical constraints. These constraints are determined by the design of the joint, and the capsular, the ligamentous, and the muscular structures surrounding it. The dominance of the different constraints that come into play throughout the full range of motion, changes constantly until the border position has been reached. In order to determine as accurately as possible the nature of the anatomical constraints, a PROM test is ideally carried out throughout the full range of motion.[4] Reflex muscle activity, as an involuntary active constraint, may also come into play as an additional mechanism for the prevention of joint damage when the joint is threatened with movement beyond its passive border position.[5] Firing of mechanoreceptor and nociceptor (i.e., pain) organs imbedded in the joint capsule, the ligaments and tendons (i.e., ligamento-muscular reflex) at the joint site, and in the muscles spanning the joint are directly responsible for this muscle action.[6]

The nature of the sensation imparted at the hand of the examiner during the final phase of PROM testing, e.g., beyond the AROM border position, is called "endfeel". Cyriax[4] described several endfeel sensations as "bone-to-bone", "spasm", "capsular feel", "springy block", "tissue approximation", and "empty feel", each representing different detectable sensations to the examiner. These qualitative descriptions are supposed to assist the examiner in making a clinical distinction between the different (intra-) capsular, and muscular disorders (e.g., muscle splinting, muscle contacture). Nevertheless, these qualitative descriptions of the different endfeels are susceptible to variable interpretation.

AROM and PROM tests have also become incorporated in the diagnostics of craniomandibular disorders (CMD).[7-10] McCarroll et al[11] (Chapter 3) introduced the concept of endfeel distance (EFd), a quantitative measurement representing the difference between the passive mandibular border position and the patient's active mandibular border position. In a group of 51 healthy young dental students (36 males, 15 females) a difference was shown between the passive maximum mouth opening (PMMO) and the active maximum mouth opening (AMMO). The EFd was significantly larger in females (3.13 mm) than in males (2.13 mm). In McCarroll's study[11], PMMO was obtained only beyond the AMMO border position, and not throughout the full range of movement to the passive border position of mouth opening. Early and intermediate (i.e., predominantly muscular) constraints controlling this movement are therefore excluded from this passive test procedure. On the other hand, PMMO testing throughout the full range of motion may enable the examiner the recognition of these constraints. Moreover, no recordings were made of the applied forces during these PMMO tests. Low interexaminer reliability PMMO values have been demonstrated, and are attributed to possible differences in force application, even when executed by experienced examiners.[12] So far, no experimental studies regarding passive mandibular movements to the passive border positions are available at the present time.

Clinicians employing passive mouth opening tests should be aware of the above mentioned influences such as the choice of protocol and the amount of force applied, and as a consequence may observe variable test results. Data collection by means of more objective tools may improve our understanding of the various factors involved with these tests. The purpose of this study was therefore to investigate border characteristics of passive (PMMO) mouth opening in healthy subjects in an experimental setting.

Methods

Pilot investigation

In a pilot investigation, prior to this study, the active (AMMO) and passive (PMMO) border positions of mouth opening were investigated under EMG control, and with the help of two separate recording devices enabling the registration of force and displacement simultaneously. In particular the method of execution of the PMMO test was of interest to us. A group of 12 healthy dental students (6 males; 6 females) between the ages of 19 and 26 years old (average age 22.6 years) participated in this pilot investigation. After informed consent, the subjects were given a thorough explanation about the nature of the experiments.

The examination took place in the department's electrophysiologic laboratory. Each subject was seated comfortably in an upright position in a dental chair. The head was supported by two adjustable cups, placed directly under the back of the head. Before positioning and securing thecups, the subject was asked to open the mouth maximally a number of times to ensure the possibility for freedom of movement. After the cups were secured, small head movements were still possible.

Mandibular movements were recorded by means of a so-called "floating circle principle" target tracker, an optoelectronic device equipped for monitoring mandibular movements relative to the maxilla, and which had been used in previous studies conducted at our department.[13] The mandibular excursions were observed from a lateral view point. Four photovoltaic cells, two for the maxilla and two for the mandible, were attached to two small metal bars. The bars were mounted on special, individually designed clutches glued to the buccal surfaces of the maxillary and mandibular central incisors with histoacryl(R) (B. Braun Melsungen AG, Germany). The bars were shaped in such a way that lip closure, occlusion, and articulation were minimally disturbed. Four circular light spots, generated on the screen of an oscilloscope, were projected on the four photocells by means of an optical lens. Using the floating circle principle, each circular spot on the screen was made to follow the position of the particular photo cell on which it was projected. In this way the horizontal and vertical outputs of the oscilloscope reflected the displacements of the photo cells on the central incisors of the subjects. The recording system had an average linear accuracy of 2%. For the recordings of the forces applied during the PMMO tests, a small force transducer based on strain gauges and with a sensitivity of 0.15 V/N (Volt/Newton) was used. The force transducer was fitted with an acrylic mould for stable and perpendicular positioning on the lower incisors in an attempt to ensure axial loading (fig. 1).

The electromyographic (EMG) activity of three masticatory muscles (left anterior temporal, left superficial masseter, and anterior suprahyoid muscle complex) was recorded using bipolar surface electrodes of a silver-amalgam composition with a 3 mm diameter and 14 mm inter-electrode distance. The electrodes were placed by palpation of the muscles in the main direction of the muscle fibers. The EMG signals were amplified 3000 times and fed into root mean square (RMS) converters showing the amplitude (RMS value) of the signal. The signals from the EMG root mean square converters, the jaw tracking device, and the force transducer were fed into a personal computer after digitizing with a sample frequency of 150 Hz and a 12-bit resolution.

PMMO according to protocol 'A'

When executing protocol 'A', which was similar to the protocol[11] used in Chapter 3, the examiner requested the subject to open the mouth maximally, whereafter the force transducer was placed on the lower central incisors (fig. 1).

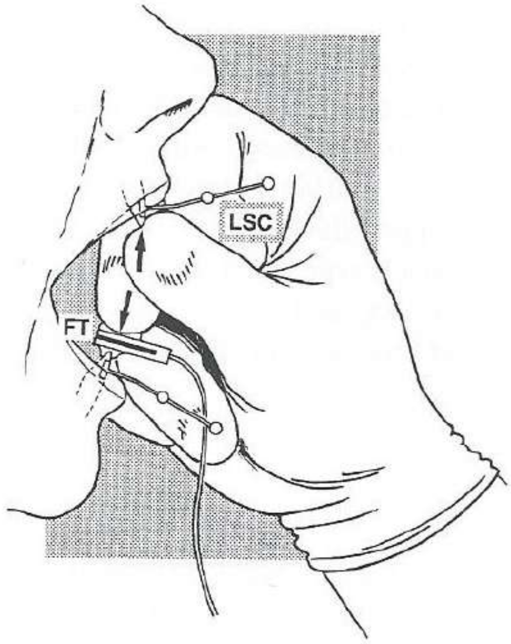

Fig. 1. Passive mouth opening testing with the use of a small force transducer (FT) placed on the central-mandibular incisors. Four light-sensitive cells (LSC) mounted on clutches attached to the buccal surfaces of the maxillary and mandibular cuspid and incisor regions.

The subject was then instructed to relax the muscles as much as possible. Next, the PMMO was executed in an attempt to ensure axial loading of the lower middle incisors. Each recording automatically began when the external force exceeded 1 kilogramforce or 9.8 Newton (N). The speed of loading towards the PMMO position was kept slow and as constant as possible in order to minimize muscle activity. Each trial was stopped when no further movement was felt and/or discomfort or pain was reported by the subject. Directly following each PMMO trial the examiner recorded whether or not any muscle action was sensed during the test. During the test, muscle action, either counteracted or supportive, could be sensed as either an irregular, resisted movement or decreased resistance. Shortly after the trial had ended a graphic display of the force, the displacement, and the EMG recordings of each single trial was shown to the examiner on the monitor, and not to the subject.

PMMO according to protocol 'B'

Employing protocol 'B', the subject was requested to open the mouth slightly, enabling the examiner to place the thumb an the force transducer against the upper and lower middle incisors. Prior to, and during each trial the subject was instructed to relax the jaw muscles. The force transducer was manipulated in such a way by the examiner that mouth opening was executed along a vertical line over a period of 8 to 10 seconds. Again, each trial was stopped when no further movement was felt and/or discomfort or pain was reported by the subject. Each recording automatically began when the external force exceeded 1 kilogramforce or 9.8 Newton (N). The speed of loading towards the PMMO position was kept slow and as constant as possible in order to minimize muscle activity.

When protocol 'A' was executed, a clear 'take-over' effect was observed during the PMMO trials in 8 of the 10 subjects (fig. 2a). This effect occurred when the subject was instructed to relax the muscles at the AMMO border position, and the examiner subsequently attempted to increase the mouth opening to the PMMO border position. The elastic tension build up in the mouth closure muscles probably temporarily exceeded the externally applied force of the examiner. Moreover, the subjects reported difficulties in relaxing particularly the muscles of the supra-hyoid complex, which was sensed by, and later shown to the examiner as an increased and irregular EMG activity of this group of muscles.

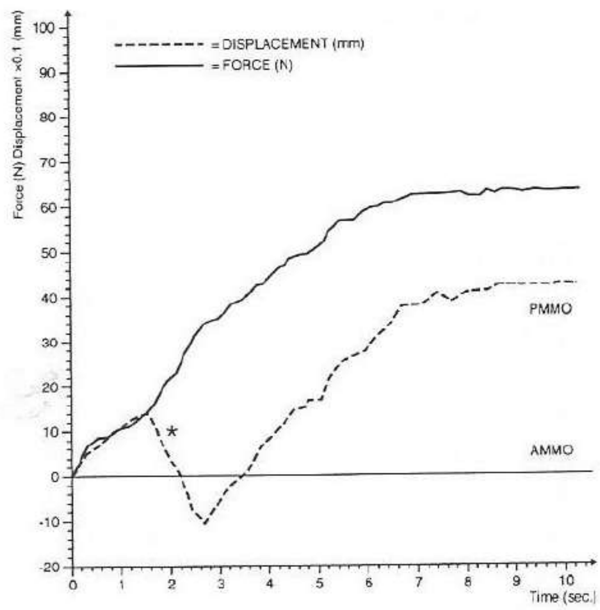

Fig. 2a. Force and displacement curves shown during a single passive mouth opening trial employing protocol 'A'. The displacement curve clearly exhibits a 'take-over' effect(*). N=Newton; mm=millimetre; T=time in seconds; AMMO=active maximum mouth opening; PMMO=passive maximum mouth opening.

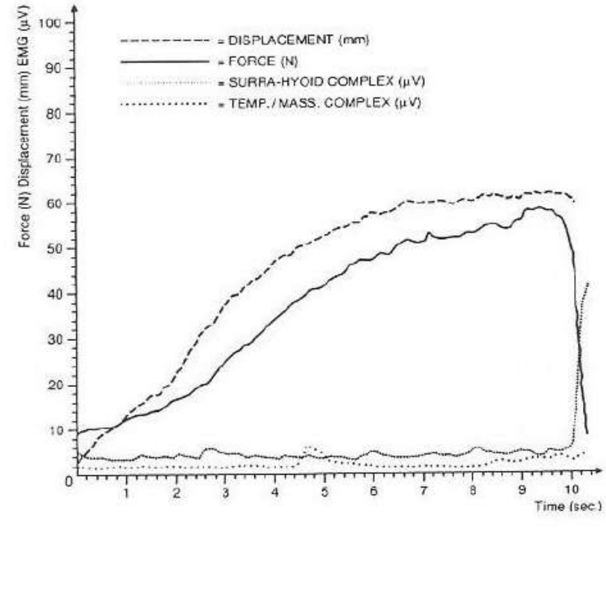

Fig. 2b. Force and displacement curves shown during a single passive mouth opening trial employing protocol 'B'. No 'take-over' effect or increased levels of EMG activity was observed during the execution of this protocol. EMG=electromyography; μV=microvolt.

The execution of PMMO according to protocol 'B' revealed minimal interfering EMG activity. The 'take-over' effect (fig. 2a), as demonstrated in most subjects with protocol 'A', was no longer observed. Moreover, no difficulty with relaxation was reported, nor demonstrated by means of EMG activity monitoring (figure 2b). The latter two corresponding findings therefore precluded the necessity of EMG recordings during PMMO testing. Three of the 12 subjects demonstrated smaller PMMO values as compared to their AMMO values. The handling of the force transducer, that is, the stabilization and the axial loading of the lower middle incisors, proved difficult during the execution of high external forces. Thus, the outcome of this pilot investigation demonstrated two important aspects of PMMO testing in an experimental setting: the choice of PMMO protocol 'B' and the use of a more practical and stable force transducer.

Based on the findings observed in the pilot investigation, an improved and less laborious method capable of simultaneously recording force and displacement was used.

A different group consisting of 20 healthy male students (29.1 ± 4.5 years) and 20 healthy female students (29.1 ± 3.4 years) participated in this study. After informed consent, each individual was examined for signs and symptoms of CMD according to a screening protocol described by Bezuur et al.[14]

Again, the experimental part of the study took place in the department's electrophysiologic laboratory. All subjects were seated comfortably in an up-righted dental chair with the back of the head well supported. The experimental set-up included a personal computer, a modified electronic caliper (fig. 3) and an analog/digital conversion unit. Instead of recording the jaw movements by means of a 'floating circle' target tracker, a calliper with a double prism (Mitutoya no. 5222161) was modified to accommodate both a force transducer and a displacement transducer.

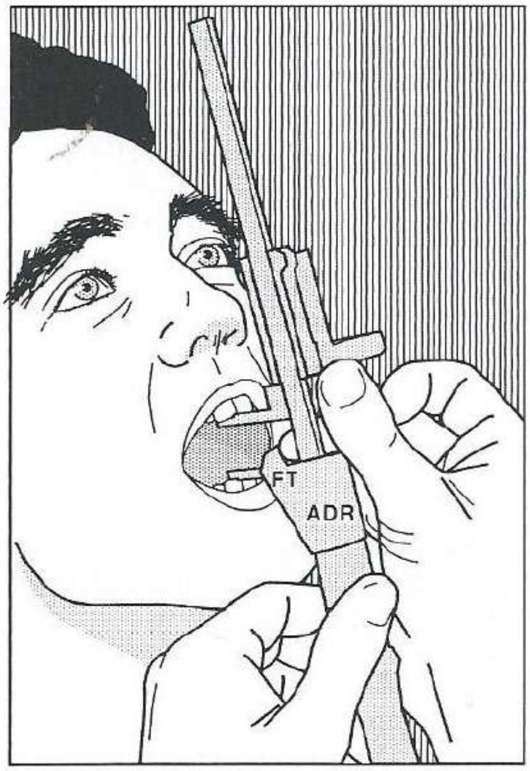

Fig. 3. Passive mouth opening testing using a modified caliper fitted with an analog displacement recording (ADR) device and a force transducer (FT).

The force transducer had a range from 0 to 80 Newton (N) with a linear variation less than 5 %. The analog displacement transducer (Philips - pr 9314/20) had a recording range of 40 millimetres (mm) with a linear variation less than 1 %. The calliper was adjustable to measure three ranges of mouth opening: 20 - 60, 30 - 70, and 40 - 80 mm.

To calculate and visually display the force/displacement relationship as a craniomandibular (CM) stiffness curve, the vertical axis represented the applied force ranging from 9.8 to 100 Newton, and the horizontal axis represented the displacement ranging up to 80 millimeters. For the calculations, the vertical axis ranging from 9.8 Newton to the maximum applied force (Fmax) was divided into three equal parts: S1, S2 and S3, representing the initial (i.e., the lower), the middle, and the final (i.e., the upper) section of the curve , respectively. At each section of the curve, the average CM stiffness was calculated as the slope of the force/displacement (FD) relationship based on linear approximation to the FD curve according to the least squares method (fig. 4).

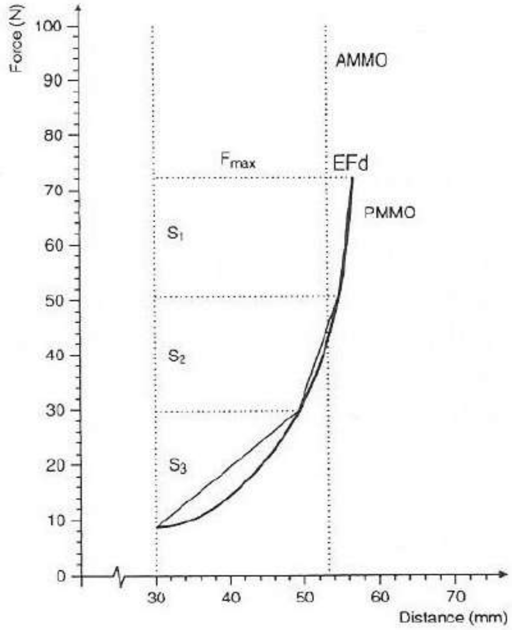

Fig. 4. Example of the calculation of CM stiffness at sections S1, S2, and S3 of a force-displacement curve of one subject. AMMO=active maximum mouth opening; PMMO=passive maximum mouth opening; Fmax=maximum applied force; EFd=endfeel distance; N=Newton

Statistical testing of the data employed the t-test, the paired t-test, and linear regression analysis. Values of $p<0.05$ were considered to be statistically significant.

RESULTS

No symptoms or signs of CMD were found in the 20 male and 20 female subjects during the screening examination.

The AMMO and PMMO values for the males were 54.7 ± 5.1 mm and 56.9 ± 5.3 mm, and for the females 52.2 ± 3.8 mm and 55.9 ± 3.4 mm, respectively. In contrast to some of the findings in the pilot study, none of the 40 subjects demonstrated smaller PMMO values than their AMMO values.

A 'stretching' sensation directly anterior to the external ear canal was reported in all (92.5%) but 3 male subjects, who did not report any stretching sensation at this region nor at any other region.

Table 1 shows the values of the endfeel distance (EFd), the maximum applied force (Fmax), and the craniomandibular (CM) stiffness at the sections S1, S2, and S3 for the male and the female subjects.

Table 1. The average values and standard deviations of the endfeel distance (EFd), the maximum applied force (Fmax), and the craniomandibular (CM) stiffness (sections S1, S2, and S3). mm=millimetre; N=Newton; N/m=Newton/metre. $^{*}p<0.05$; $^{**}p<0.01$

		EFd (mm)	Fmax (N)	S1 (N/m)	S2 (N/m)	S3 (N/m)
males	(n=20)	3.0 ± 1.1	44.6 ± 7.2	1758 ± 1052	3966 ± 1639	6239 ± 1693
females	(n=20)	3.8 ± 1.4	37.1 ± 2.1	1562 ± 759	3174 ± 731	5362 ± 828

The mean values and their standard deviations of the endfeel distance (EFd) recorded in the male group (3.0 ± 1.1 mm) was not different from the EFd value (3.8 ± 1.4 mm) found in the female group (t-test; p=0.07). The average Fmax values were higher in the male subjects (t-test; p=0.005). A higher stiffness was found in the male group at the sections S2 and S3 (t-test; p<0.05). In both groups a significant increase of CM stiffness was found in the sections S1 through S3 (paired t-test; p<0.01).

The results of the craniomandibular (CM) stiffness recordings at the sections S1, S2, and S3 of the male and female subjects are displayed in figure 5.

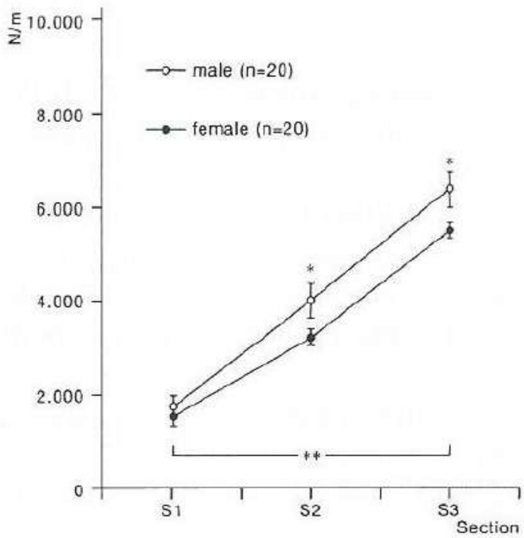

*Fig. 5. Mean values and standard errors of the mean (SEM) of the CM stiffness recordings at the sections S1, S2, and S3 for the males and the females. N/m= Newton/meter (*p<0.05 - **p<0.01)*

No correlations were found between the EFd values and CM-stiffness values at either single or combined sections of S1, S2, and S3.

Discussion

Active mouth opening capacity is regarded by most clinicians managing CMD patients as one of the most objective indicators of the TMJ and masticatory muscle status.[15] Recording mandibular border positions by means of active and passive movement tests has been advocatedin previous investigations.[7,11,16,17,18] The use of a simple ruler for the recording of linear active mouth opening is considered a reliable clinical procedure with good intra- and interobserver consistency.[19,20,21,22] For this matter an electronic caliper modified with a force transducer was used in this experimental investigation.

PMMO testing performed either clinically or experimentally precludes subjects or patients with partial (incisor region) prosthetics or full dentures. Under these circumstances the premolar regions of the upper and lower jaw may serve as locations for force application by means of a bi-manual 'scissor-like' manipulation technique, enabling a clinical execution of the PMMO test. Also, subjects with a history of recurrent condylar luxation (i.e., a hypermobile TMJ condition) should be excluded from PMMO testing since additional provocation may worsen this condition unnecessarily.

The results of the AMMO and PMMO measurements of this study do not differ from the AMMO and PMMO values reported in Chapter 3 (t-test; p=0.3 and p=0.2, respectively). The different methods (i.e., clinical vs experimental) and protocols ('A' vs 'B') used therefore do not seem to influence the outcome of these tests. In contrast to the results of the AMMO and PMMO measurements observed in the pilot study, no subjects in this study demonstrated smaller PMMO values than their AMMO values. This supports the suggestion that the smaller PMMO values found in the pilot study are probably due to the unstable positioning of the force transducer on the lower incisors.

No difference was shown between the EFd values of Chapter 3 and this study for the females (t-test;$p=0.3$). The EFd values obtained in females seem therefore independent of the employed protocol. The male subjects of this study demonstrated higher EFd values (3.04 ± 1.1 mm) than the EFd reported in Chapter 3 (2.13 ± 1.3 mm) for the males (t-test; $p<0.05$). In a few male subjects the applied force was probably not sufficient to reach the border position since no pre-auricular stretching sensation was reported. Most subjects (92.5 %) reported a pre-auricular stretching sensation at the site of the TMJ. Although the constraints at maximum mouth opening are hereto not determined properly (Chapter 2), the indicated location seems to support the idea that the TMJ capsule and its lateral ligament are possible constraining factors at the border position of PMMO.[23] Others[24,25,26] hypothesized that the sphenomandibular (SM) ligament is particularly involved as a constraining factor at the border positon of mouth opening. It seems however less likely that ligamentous strain from the SM ligament is indicated by the subject at the site of the TMJ.

The higher applied Fmax values observed in the male subjects may be attributed to their larger muscles.[27] In other investigations the passive resistance to movement also increased with knee and finger joint size,[28] and the circumference of the thigh muscle.[29] The differences in Fmax values observed between both sexes as well as the variance of these values within the groups dotherefore not justify any standardization of forces.

The experimental set-up of this study enabled the simultaneous recording of force and displacement, and thereby offered an additional parameter: craniomandibular (CM) stiffness. Qualitative descriptions (e.g., 'capsular feel', 'bone-to-bone', 'tissue approximation', etc.) of passive range of motion (PROM) testing supposedly assist the examiner in making a clinical distinction between the various constraining tissues involved.[2,4] These descriptions however imply that the examiner can actually recognise variations in stiffness. Nevertheless, an attempt to identify objectively stiffness during PMMO testing has so far not been performed. In sections S2 and S3 a difference in CM stiffness was found between the male and the female subjects (t-test;$p<0.05$). The failure to find such a difference in CM stiffness at the section S1 may be due to the fact that the passive (e.g., mainly muscular) resistance met during the initial phase of mouth opening does not differ yet between the sexes.

No relationship was shown between the EFd and CM stiffness at either single, or combined sections of S1, S2, or S3 for both the males and the females. Particularly the absence of this relationship between EFd and the CM stiffness at the section S3 hampers the qualitative interpretation of the stiffness description, such as 'capsular feel' or 'bone-to-bone', at the border position of mouth opening.

In conclusion, the results of active (AMMO) and passive (PMMO) mouth opening measurements are only slightly influenced by different methods of execution. In experimental studies where stiffness is also to be measured, the choice of a PMMO protocol that evokes the least muscular activity is advocated. However, in clinical practice EMG control seems superfluous during PMMO testing as activity of jaw related muscles can be noticed by the examiner. Standardization of force application in PMMO testing is not justified because of the observed variance in forces within both groups. Moreover, different standards of force application would be neccessary for both sexes. The experimental method of PMMO testing investigated in this study may offer additional information in future investigations with respect to the diagnostic separation between CMD patient subgroups.

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Chapter 5

SUBJECTIVE PAIN REPORT AND THE OUTCOME OF SEVERAL ORTHOPAEDIC TESTS IN CMD PATIENTS WITH RECENT PAIN COMPLAINTS

Summary

A comparison between subjective pain report and the outcome of the combined dynamic and static pain tests, and several other orthopaedic tests was investigated in craniomandibular disorder (CMD) patients with recent pain complaints and in control subjects. Thirty two CMD patients who clearly reported pain at the masticatory muscle region or at the temporomandibular joint region by means of a Symptom Report Questionnaire (SRQ), participated in the study. The investigators performing respectively the symptom report interview and the clinical tests were blinded to each other. A high correspondence was shown between the patients reporting joint or muscle pain (by means of SRQ), and the classification into arthrogenous and myogenous pain patients, based on the outcome of the dynamic and static pain tests ($p=0.0003$). The outcome of 4 other orthopedic tests: passive maximum mouth opening (PMMO; $p=0.0001$), palpation of the TMJ and the masticatory muscles ($p=0.0002$), TMJ-play ($p=0.0001$), and TMJ-compression ($p=0.0138$) demonstrated significant differences between the patients reporting joint and muscle pain.

Introduction

Sore and fatigued masticatory muscles, painful TMJs, altered mobility of the mandible, and TMJ sounds (i.e., clicking or crepitus) are frequently recognized symptoms and signs of craniomandibular disorders (CMD). Most CMD patients seek help from their dentist especially for their facial pain complaints. Because facial pain can arise from any nociceptive innervated structure in the facial area, both the masticatory muscles and the TMJs may be involved with painful symptoms in CMD.

In an attempt to determine which tissues are painful in a musculo-skeletal disorder an extended clinical examination of muscles and joints is generally carried out with the help of orthopaedic tests. Several authors from the field of physical therapy have described clinical diagnostic tests for the recognition and evaluation of abnormal joint and muscle functions.[1,2,3] Although most clinicians limit their clinical examination of the stomatognathic system to the observation of active mandibular movements and the palpation of the masticatory muscles and the TMJ's [4,5,6] a more extended clinical examination of the masticatory system was introduced by Hansson, Wessman & Öberg.[7] Since then other authors have employed similar orthopedic tests in their clinical examination protocol.[8,9]

The results of the combined dynamic and static pain tests, as part of the extended clinical examination, are used to distinguish a myogenous or an arthrogenous origin of the facial pain.[7] However, verification of this procedure is hampered by the absence of a "gold standard" with respect to the determination of the pain location. Patients, who experience (semi-) recent musculo-skeletal pain are believed to be able to fairly accurately describe the location of their pain.[10,11,12] The local character of the injury is an essential aspect of recent musculoskeletal pain and helps the patient to pinpoint the location of the pain. Both Bell[11] and Stacey[12] state that, in contrast to recent pain conditions, the patient's ability to accurately localize a chronic pain condition, is often limited. Therefore, in this study the pain location indicated by CMD patients with recent pain complaints was used as a standard to be compared with the pain location outcome of the dynamic and static pain tests.

An extended clinical examination also usually includes palpation of the masticatory muscles and the TMJ's, the execution of active and passive mandibular movements, the joint play test and the joint compression test. Some of these tests are pain tests (palpation and compression test), others are used to test the mechanical characteristics of muscular or joint structures. However, also during these latter tests the patient may experience pain. Therefore, in this study the indicated location of pain during palpation, mandibular movements, joint play and joint compression, was also studied in relation to the reported pain location in the CMD group with recent pain complaints.

The aim of this study was therefore to compare the subjective pain location reported by a CMD patient group with the pain location indicated by several orthopedic tests: the dynamic and static pain tests, passive maximum mouth opening, palpation, TMJ-play, and TMJ-compression. The latter tests were also applied in a control group.

Materials and methods.

After giving informed consent, 43 CMD patients (35 women; 32.2 ± 4.6 years and 8 men; 29.2 ± 5.1 years) and 22 control subjects, matched for age and sex, participated in this study. All subjects were screened for CMD symptoms and signs by an independent dentist using the protocol by Bezuur, Hansson and Wilkinson.[13]

The dentist and the physiotherapist, performing a symptom report questionnaire (SRQ) and a clinical examination, respectively were well-trained and experienced clinicians in the field of CMD. The SRQ always took place first. The patients were requested not to disclose any information concerning their pain complaint and/or the nature of the disorder to the physiotherapist. Both the SRQ and the clinical examination took place on the same day. The control subjects only underwent the clinical examination performed by the physiotherapist. During the entire examination the subject was seated comfortably in an uprighted dental chair with the head well supported.

Symptom report questionnaire (SRQ)

The SRQ started by asking the patient about the reason for seeking help and about the duration of the complaint. The patient was requested to be as accurate as possible regarding the location, the intensity and the nature of the pain sensed in the facial, head, and neck areas. The following questions were used for the recording of the patient's primary pain complaints:

1. Do you sense any pain directly in front of the ear canal?
2. Do you sense any pain in the cheek region?
3. Do you sense any pain in the region of the temples?
4. Do you sense other localized facial pains?
5. Are there any neck pains?
6. Do you suffer from regular headaches? (i.e., more than 2 times per week)
7. Is the main indicated pain always experienced at the same location?

Affirmation of question 1 was interpreted as pain originating from the TMJ and these patients will be referred to as joint pain patients. Affirmation of questions 2 and 3 was interpreted as pain coming respectively from the masseter and temporal muscles and these patients will be referred to as muscle pain patients. Affirmation of the questions 1, 2, and 3 indicated that the patient sensed pain in both the muscles and the joint. The remaining questions (4 through 7) were used for additional information, and not for the interpretation of joint or masticatorymuscle pain in this study.

Clinical examination

At the start of the clinical examination a brief explanation was given to the patient by the physiotherapist concerning the 5 orthopaedic tests that were included in this examination. The patient was requested to report the location and the severity of the pain directly following each test.

The outcome of the combined dynamic and static pain tests was used to make a diagnostic separation between an arthrogenous or a myogenous pain.[7,14] During both tests the subject's head was stabilized by the examiner during intentional opening, closing, left and right laterotrusion, and protrusion. Gradual application of force by the examiner was required as the patient was asked to move the mandible against the resistance supplied by the hand of the examiner. The dynamic pain test requires only a slight resistance to the patient's mandible during active movements in all directions. The static pain test, however, requires heavy manual resistance executed by the examiner. No TMJ movement should take place during the static pain test, so pain symptoms suggest strong participation of the masticatory muscles. The dynamic test will evoke responses in both the TMJ and the masticatory muscles. The origin of either joint or muscle pain is interpreted according to the difference in severity of the pain reported by the subject during the two tests. More pain during the dynamic test indicates primarily an arthrogenous pain, while an equal amount of pain or more pain during the static test indicates primarily a myogenous pain.

Apart from the dynamic and the static pain tests, four additional orthopedic tests were also used: the passive maximum mouth opening test (PMMO), palpation of the TMJ and the masticatory muscles, the TMJ-play test and the TMJ-compression test.

The passive mouth opening (PMMO) test is used to test whether muscles or joint tissues limit the maximum mouth opening. The test was executed according to the method described by McCarroll et al.[15] Except for a stretching sensation just anterior to the ear canal (i.e., at the TMJ site) healthy individuals report no pain when the PMMO test is executed.[16]

For palpation of the lateral aspect of the TMJ condyle, the masseter muscle (deep and superficial portions) and the temporal muscle (the anterior, middle, posterior portions) a pain-pressure threshold meter (Model PTH-AF2, Pain Diagnostics and Thermography, Great Neck, NY) was used. The surface area (0.5 cm2), the pressure, and the speed of applied pressure (0.5 kg/ cm2/s) during palpation were standardized according to a protocol described by List, Helkimo, and Falk.[17] Test-retest reliability of pain-pressure threshold meters has recently shown to be excellent.[18]

The TMJ-play test is a manual technique, which is performed in order to detect mechanically (i.e. joint surface irregularities, loss of range of motion, etc.) related disorders of the TMJ.[7,19,20] The test is performed by the examiner and includes two components: traction (i.e., separation of the condyle/disc complex from the temporal component) and translation of the condyle/ disc complex along the temporal component in an antero-medial direction. Each side was tested separately, while the patient was instructed to keep the facial and jaw muscles asrelaxed as possible.

TMJ-compression employs a manual technique similar to the TMJ-play test. However, the condyle is now being pressed with moderate force in a postero-cranial direction towards the temporal fossa. This test is not expected to stress the extra-articular tissues of the TMJ, but will mainly load the posterior portion of the disc and the temporal fossa. The posterior and lateral discal and capsular tissues are well innervated by pain receptors of the auriculotemporal nerve, and branches of the deep temporal and deep masseter nerves of the fifth cranial nerve.[21] No TMJ pain is elicited during this test in healthy individuals.[8,22,23] In a condition of a recent disc displacement without reduction, the retro-discal tissue becomes prone to compression between the condyle and the temporal fossa. Since this tissue is well innervated with pain receptors this compression may evoke pain in this condition.

A history of clicking and intermittent locking in patients who show a clearly diminished mouth opening and a deviation of mouth opening towards the affected side, is considered indicative for a disc displacement without reduction. A limited laterotrusion towards the contra-lateral side, a deviation towards the affected side during protrusion and a limited translation of the condyle/disc complex in the antero-medial direction during the TMJ-play test support this diagnosis.[24-26]

Statistical testing of the data employed the chi-square test and the Fisher exact test. Values of $p<0.05$ were considered to be statistically significant.

Results

The examined group consisted of 43 patients (35 women and 8 men). The average duration of the facial pain and masticatory dysfunction was reported by the patients as 4 ± 0.5 (SD) months.

Based upon the outcome of the Symptom Report Questionnaire the 43 CMD patients could be sub-divided into three groups. Twelve patients (8 females, 4 males) reported to have only pain directly in front of the ear canal and were categorized as joint pain patients. Twenty patients (19 females and 1 male) reported to have only pain in the cheek region and/or the temporal region and were categorized as masticatory muscle pain patients. Eleven patients (8 females and 3 males) reported pain both at the joint site and at the cheek and/or temporal region. As the patients in the latter group did not clearly indicate to have either muscle or joint pain, they could not be used as a standard for the location of pain and were therefore excluded from this study. Finally, thirty two patients (joint pain group, n=12; masticatory muscle pain group, n=20) participated in this study.

When the joint pain and masticatory muscle pain patients, classified according to the symptom report questionnaire (SRQ), were also classified as myogenous or arthrogenous pain patients on the basis of the results of the dynamic and the static pain tests, a high correspondence was found between the two classifications (p=0.0003). Nine of the 12 joint pain patients were classified as having arthrogenous pain, whereas 18 of the 20 muscle pain patients were classified as myogenous pain patients (Table 1).

Table 1. The correspondence between the numbers of joint and muscle pain patients, as classified by the Symptom Report Questionnaire (SRQ), and the numbers of arthrogenous and myogenous pain patients, as classified by the outcome of the combined dynamic and static pain tests (p=0.0003).

dynamic/static pain test outcome:	Joint(n=12)	Muscle(n=20)
ARTHROGENOUS	9	2
MYOGENOUS	3	18

In Table 2 the numbers of joint pain and masticatory muscle pain patients and the numbers of controls who indicated pain at the muscles or at the TMJ during the additional orthopedic tests; the PMMO test, the muscle and joint palpation test, the TMJ-play test, and the TMJ-compression test, are shown. In case the patient indicated pain both in the joint and in the muscles the patient was asked to indicate which pain was worse.

The controls reported no pain at all during the additional orthopedic tests. When testing possible associations between the indicated location of pain during the orthopaedic tests and the classification of the patients into muscle or joint pain patients the (3 X 2) chi-square test could not be used. For the subtables in table 2 not all the expected values exceeded 1.0. For the PMMO test and the TMJ-play test the rows 'muscle' and 'none' were therefore combined. For the palpation test the row 'none' was omitted and for the joint compression test the row muscle was omitted. Then the (2 x 2) Fisher exact test was used for the subtables in Table 2.

Table 2. The differences between the numbers of joint pain and muscle pain patients, as classified by the SRQ, and the numbers of patients indicating the pain location (TMJ, muscle, or none) during the PMMO test ($p=0.0001$), the palpation test ($p=0.0002$), the TMJ-play test ($p=0.0001$), and the TMJ-compression test ($p=0.0138$). The indicated location of pain (TMJ, muscle or none) during several orthopaedic tests for the joint pain and muscle pain patients and control subjects.

Pain location indicated during test:	**Joint**(n=12)	**Muscle**(n=20)	**Contr.subj.**(n=22)
(a) PMMO			
TMJ	10	1	-
muscle	-	3	-
none	2	16	22
(b) Palpation:			
TMJ	8	1	-
muscle	3	18	-
none	1	1	22
(c) TMJ-play:			
TMJ	10	1	-
muscle	-	4	-
none	2	15	22
(d) TMJ-compression:			
TMJ	4	-	-
muscle	-	-	-
none	8	20	22

A significant association between the rows and colums was found for all the orthopaedic tests. The joint pain patients indicated pain at the TMJ during the PMMO test, whereas the musclepain patients had pain in the muscles or no pain at all (Table 2a, $p<0001$). The joint pain patients indicated pain during palpation of the TMJ, whereas the muscle pain patients had pain during palpation of the muscles (Table 2b, $p=0.0002$). The joint pain patients indicated pain at the TMJ during the TMJ-play test and the muscle pain patients had pain in the muscles or no pain at all during this test (Table 2c, p=0.0001). During the TMJ-compression test the joint pain patients experienced pain at the TMJ and the muscle pain patients had no pain (Table 2d, p=0.0138).

Of the three joint pain patients, who were classified as myogenous patients in Table 1, two patients indicated no pain during the PMMO test, the TMJ-play test, and the TMJ-compression test, and indicated pain at the deep masseter muscle during palpation. Thus, the results of these orthopedic tests point to a muscle pain location, which is in accordance with the results of the dynamic and static pain tests. The third patient had a disc displacement without reduction. The PMMO test, the TMJ-play test, and the TMJ-compression test evoked pain at the TMJ in this patient, while pain was reported during palpation of the deep portion of the masseter adjacent to the affected joint. Thus, apart from the muscle palpation results, the pain results of the additional orthopedic tests point to a patient with joint pain. This is in accordance with the patient's own report and in contrast with the results of the dynamic and static pain tests.

Of the two muscle pain patients, who were classified as arthrogenous pain patients in Table 1, one patient clearly indicated TMJ pain during the PMMO test, the palpation test, and the TMJ-play test, and no TMJ-compression pain. Thus the results of these orthopedic tests indicate, that this patient was a joint pain patient, in accordance with the dynamic and static pain tests results. In the other patient, pain was evoked in the deep portion of the masseter muscle during palpation and during the TMJ-play test. Thus, the pain results of the additional orthopedic tests point to a muscle pain patient, in accordance with the patient's own report.

Discussion

The main reason for CMD patients seeking help is pain.[27] In order to install proper treatment, the tissues from which the pain originates need to be determined as precisely as possible. For this reason an extended clinical examination of the muscles and joints is generally carried out with the help of several orthopaedic tests. The dynamic and static pain provocation tests, as part of the clinical examination, play an important role in the clinical examination since they give an indication of the origin of pain to be mainly myogenous or arthrogenous.[7,14] In order to verify this indication, the results of the dynamic and static pains tests should preferably be compared with the results of a 'gold standard' for the location of pain. Unfortunately, this standard does not exist. Since CMD patients with recent pain complaints can fairly accurately report the location of pain[11] this reported pain location was used as a standard in this study. Of the 43 CMD patients with recent pain symptoms only the 32 patients who clearly reported pain at the temporomandibular joint or at the masticatory muscles were used for the comparison between the location of reported pain and the location of pain indicated by the dynamic and static pain tests.

The classification of the patients, based upon the answers of the Symptom Report Questionnaire (SRQ), into joint pain and muscle pain patients corresponded well with the diagnostic classification of arthrogenous and myogenous pain patients ($p<0.0003$). In only 5 (16%) of the 32 patients there was a disagreement between the two classifications. There was also a clear pattern in the location of pain indicated by the muscle or joint pain patients during the additional orthopedic tests (Table 2). Joint pain patients indicate pain at the TMJ during the PMMO test, the joint palpation test, the joint play test and sometimes during the joint compression test. Muscle pain patients indicate pain in the muscles or no pain during the PMMO test and the joint play test; they indicate pain in the muscles during muscle palpation and no pain during the compression test. If this pattern is used to modify the classification into muscle or joint pain patients (two patients, originally classified as joint pain patients are then classified as muscle pain patients and one muscle pain patient is then classified as joint pain patient), there was even a higher correspondence between the SRQ classification and the classification based upon the dynamic and static pain tests. For only 2 (6%) patients there remains a disagreement between the two classifications schemes.

During the PMMO test (Table 2a) three muscle pain patients reported pain at the deep portion of the masseter. Stretching of this portion of the masseter muscle is likely to be reponsible for this pain indication. Anatomical overlap, as demonstrated by the presence of masseter and temporal muscle fibers running into the TMJ capsule, may also be responsible for the pain report adjacent to the TMJ.[28]

Although at a high significance level ($p=0.0002$) the joint pain patients showed pain during palpation of the TMJ and the muscle pain patients pain during palpation of the muscles (Table 2b, $p=0.0002$) there were three joint pain patients who predominantly indicated pain in the muscles during palpation. The joint and the surrounding muscles form a functional unit. If the joint is dysfunctioning, this may eventually spread to the surrounding tissues, the muscles. Sensory and anatomical overlap may also be held responsible for this clinical finding. Palpation of the TMJ and the masticatory muscles is a clinical instrument adopted by many clinicians today and also advocated by the American Academy of Orofacial Pain (AAOP) in their guidelines.[23] However, the results of this study indicate that palpation must be considered with caution in the evaluation of CMD patients with joint or muscle pain, as it may lead to erroneous conclusions.

Four muscle pain patients indicated pain at the deep portion of the masseter muscle during the TMJ play test. Translation of the lateral pole of the condyle in antero(-medial) direction may cause friction, and thus pain, at the deep masseter muscle during this test. Again, anatomical and sensory overlap, as indicated earlier in this study, may also be responsible for this finding.

Four joint pain patients indicated TMJ pain during the TMJ compression test. One patient was diagnosed as having an anteriorly displaced disc without reduction. Intra-articular inflammation of the TMJ may then be held responsible for the occurrence of pain during this test.[22,23] The origin of the TMJ pain in the other three patients is unclear. Since the capsule of the joint is not stressed during this test, capsular pain is less likely to be provoked during this test. The value of this test should be further investigated in CMD patients clearly subdivided for different inflammatory TMJ conditions. Further studies are needed to investigate the outcome of this test procedure among CMD patients with more chronic pain conditions.

Conclusion

The high correspondence between the classification of CMD patients with recent pain complaints into patients who reported joint or muscle pain and into arthrogenous or myogenous patients based upon the outcome of the dynamic and static pain tests, supports the usefulness of these latter tests in discriminating the location of pain. However, since static provocation tests are considered to evoke pain in the musculo-tendinuous apparatus the interpretation of the results of the static provocation test may be confounded when the TMJ is sensitive to compression. Therefore, an additional TMJ-compression test is needed for the correct interpretation of the origin of pain.

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Chapter 6

PASSIVE MOUTH OPENING TEST IN MYOGENOUS AND ARTHROGENOUS CMD PATIENTS: AN EXPERIMENTAL INVESTIGATION.

Summary

The purpose of this study was to compare active maximum mouth opening, endfeel distance, and craniomandibular (CM) stiffness values of three craniomandibular disorder (CMD) patient subgroups and the control group used in Chapter 4. The CMD patient subgroups consisted of myogenous pain patients, and arthrogenous pain patients with a 'closed lock' (CL) and arthrogenous pain patients without a 'closed lock (no-CL)'. Both the myogenous pain patients and the CL patients showed great differences with the control group on all parameters ($p<0.05$ - $p<0.001$). However, the no-CL patients revealed no statistical differences with the control group on any of the investigated parameters. The subjective endfeel classifications 'more-elastic', 'firm', and 'less-elastic', given to each patient were related to the endfeel distance (EFd) and the craniomandibular (CM) stiffness values. A 'more-elastic' endfeel corresponded well with higher EFd and lower CM stiffness values, whereas a 'less-elastic endfeel corresponded well with lower EFd and higher CM stiffness values, respectively.

Introduction

Patients with craniomandibular disorders display a variety of symptoms and signs like fatigued and sore masticatory muscles, painful temporomandibular joints (TMJs), altered TMJ mobility, and TMJ sounds. Similar to the clinical examination of patients with musculo-skeletal disorders, CMD-patients are often evaluated with the help of orthopedic tests.[1-5] The evaluation of the outcome of pain provocation tests in CMD patients was performed by means of electromyography by Naeije & Hansson.[6] In their study the diagnostic separation into myogenous and arthrogenous CMD patient subgroups was supported by the higher RMS (root mean square) values found in the myogenous patient group as compared to the arthrogenous patient group. On average the myogenous patient group was capable of stronger voluntary muscle contractions of the jaw closure muscles.

The active and passive ranges of joint motion, including the endfeel, play an important role in the orthopaedic examination protocol. Endfeel is the nature of the resistance (i.e., resilience) felt by the examiner just prior to the border of a passive joint movement. This clinical 'feel' associated with joint movement is considered of great diagnostic and therapeutic significance.[7,8,9] Evjenth and Hamberg[10] gave descriptions of normal tissue resilience as 'soft' (e.g., tissue approximation at elbow flexion), 'firm' (e.g., capsular/ligamentous stretch at femur rotation), or 'hard' (e.g., bone-to-bone stop at elbow extension). The latter authors also described abnormal endfeel descriptions as 'less-elastic' (e.g., shortened connective tissue), 'more-elastic' (e.g., shortened muscles), 'springy block' (e.g., rebound by torn meniscus), and 'empty' (e.g., due to bursitis, neoplasm). Each of these different sensed endfeels is supposed to indicate the possible dominance of a specific tissue towards a joint's border position. Although no consensus exists as to which particular ligamentous structures are involved with the border of mouth opening, it is generally accepted that the mouth opening is constrained by ligaments (Chapter 2). For this matter the denotation 'firm' was used to describe a normal endfeel at the border of mouth opening. As opposed to the 'firm' endfeel denotations, the denotations 'less-elastic' and 'more-elastic' could then be used respectively to describe a less resilient and more resilient endfeel.

Describing endfeel as a qualitative parameter in various CMD patient subgroups ('normal' or 'deviating'), lead to low inter-examiner reliability values.[5] For this matter, in Chapter 3 the concept of endfeel distance (EFd) was introduced. The EFd found at the border of mouth opening is the difference between passive maximum mouth opening (PMMO) and active maximum mouth opening (AMMO). In a group of healthy students a difference in average EFd was found between the men (mean value 2.13 mm) and the women (mean value 3.13 mm). Recording the endfeel distance added an objective aspect to the clinical endfeeldenotations. An increased EFd of more than 5 mm was found by Schokker[11] in recurrent headache patients with muscular CMD symptoms.

In a previous study (Chapter 4) the active and passive ranges of mouth opening were investigated in a group of healthy male and female subjects with the aid of an electronic caliper capable of recording force and displacement simultaneously. Craniomandibular (CM) stiffness was calculated from the relationship between force and displacement during passive mouth opening to the border.

The purpose of this study was to compare the AMMO, EFd and CM-stiffness values of three female CMD patient subgroups. The subgroups consisted of myogenous pain patients, and arthrogenous pain patients with, and arthrogenous pain patients without a 'closed lock' (i.e., an anterior disc displacement without reduction).

SUBJECTS AND METHODS

After informed consent 59 female CMD patients (30.4 ± 5.1 years) participated in this study. The clinical examination followed a standardized protocol,[3] and was carried out by two identically trained, but independently working dentists. The 20 healthy female subjects who participated in a previous study (Chapter 4) served as control subjects for this study.

Clinical examination

The examination started with a full (socio-) medical history in order to rule out the presence or influence of congenital, developmental and post-traumatic disorders, or systemic and inflammatory diseases. In order to rule out any gross pathology an orthopantomogram was taken of each patient as a standard X-ray procedure. Inspection of the facial, head, and neck areas preceded the functional examination. During the entire examination the patient was seated comfortably in an uprighted dental chair with the head well supported.

The following parameters were included in the examination: active and passive ranges of mandibular motion, jointplay tests for both TMJs, and the dynamic and static pain joint/muscle tests. The maximum ranges of mandibular motion were executed actively for mouth opening, laterotrusion, and protrusion according to the method described in Chapter 3. Asymmetrical and clearly restricted mandibular movements occurring during the active excursions were noted. The endfeel distance was recorded for vertical mouth opening only and measured with the help of a millimeter ruler as the difference between the passive and active maximum mouth opening including a correction for vertical overlap. In addition, the examiner was requested to give an interpretation of the sensed resistance (i.e., endfeel) at the border of passive mouth opening according to the denotations used by Evjenth and Hamberg.[10] The normal endfeel could be denoted as 'firm'. Abnormal endfeel sensations, as opposed to 'firm', were described as either 'less-elastic' or 'more-elastic'.[10] Passive translatory motion of the condyle/disc complex was carried out by means of a jaw manipulation technique, known as temporomandibular 'jointplay'.[1,12,13] Each joint was examined for range of motion and pain occurring during translatory motion.

The examination was completed with two pain provocation tests: the dynamic and the static pain tests.[1,6] During both tests the subject's head is kept well fixated by the examiner during intentional opening, closing, left and right laterotrusion, and protrusion. Gradual application of force by the examiner is required as the patient is requested to move the mandible against the hand of the examiner. The dynamic pain test requires only slight resistance to the patient's mandible during active movements in all directions. The patient is asked to overcome the manual resistance of the examiner from slight mouth opening toward all border positions of the mandible. In contrast to the dynamic pain test, the static test requires heavy manual resistance executed by the examiner. Temporomandibular joint movement is avoided during this test, thereby emphasizing strong participation of the masticatory muscles. The origin of either joint or muscle pain was based on the difference in the amount of pain reported by the subject during the dynamic and static pain tests.

Patients with a past history of joint clicking and intermittent locking, who were now displaying a limitation of mouth opening and a deviation towards the affected joint were considered having a 'closed lock'. A limited laterotrusion towards the contra-lateral joint as well as a deviation towards the affected side during protrusion was considered additional affirmative information for this condition. A clearly diminished translatory movement of the condyle/disc complex in anteromedial direction experienced during jointplay testing was also considered indicative for a closed-lock. The clinically diagnosed closed lock conditions were confirmed by means of magnetic resonance imaging (MRI).

At the end of the clinical examination the patient was requested not to disclose any information about the outcome of the examination or reveal any information concerning the patient's complaint to the next examiner, the physical therapist.

Experimental examination

Later, on the same day, a physical therapist performed an experimental examination for craniomandibular stiffness according to the earlier introduced protocol (Chapter 4). The experimental part of the study took place in the department's electrophysiologic laboratory. All subjects were seated comfortably in an up-righted dental chair with their head well supported.

The patients were examined according to protocol 'B' described in Chapter 4. During the passive mouth opening test, each subject was asked to open the mouth only slightly, enabling the examiner to place the beaks of a caliper against the ridges of the upper and lower incisors. While the subject was requested to relax the masticatory muscles as much as possible, the examiner extended the mouth opening along a vertical line toward full mouth opening. Each recording lasted for a period of 8 to 10 seconds and was automatically started when the applied force exceeded 9.8 N. The speed of loading was kept slow and as constant as possible to minimize masticatory muscle activity. Each trial was stopped when the subject reported clearly increasing pain in the masticatory muscles, TMJs, or at any adjacent site. The maximum applied force (Fmax) was recorded at each successive trial.

No EMG recordings were taken, since active muscle participation by the subject could be clearly sensed by the examiner during the trial (Chapter 4). During each recording the average stiffness was calculated in three equal sections of the CM-stiffness curve: S1, S2 and S3, representing the initial (i.e., the lower), the middle, and the final (i.e., the upper) section of the curve. Because the parameter endfeel distance (EFd) probably coincides for the greater part with the final pathway of mouth opening, the S3 section of the CM stiffness curve was used for further evaluation.

Statistical testing of the data employed the t-test, Pearson's product/moment correlation test, and ANOVA testing according to Welch.[14] Differences between the myogenous patients and the closed lock patients with respect to the control group were tested one-sided, while the no-closed lock patients were tested two-sided. Values of $p<0.05$ were considered to be statistically significant.

Results

Clinical examination

Based upon the outcome of the clinical examination, 41 patients reported mainly myogenous origin of pain (30.1 ± 10.3 years) and 18 patients reported mainly arthrogenous origin of pain. The latter group was further divided into a group of 10 arthrogenous pain patients (29.6 ± 8.9 years) with a unilateral closed lock and 8 arthrogenous pain patients (30.4 ± 5.5 years) without a closed lock.

In the myogenous pain patients almost half were given the denotation 'firm' endfeel and the other half 'more-elastic' (Table 1). A 'less-elastic' endfeel denotation was given to all arthrogenous pain patients with a closed lock (CL). In the arthrogenous pain patients without a closed lock (no-CL) almost half was denoted as 'firm' and the other half as 'less-elastic' .

Table 1. Distribution of endfeel (EF) denotations of the three CMD patient subgroups. CL=closed lock; no-CL=no closed lock.

	CMD patients		
	myogenous	arthrogenous	
EF	(n=41)	CL (n=10)	no-CL (n=8)
'more-elastic'	20	-	1
'firm'	17	-	3
'less-elastic'	4	10	4

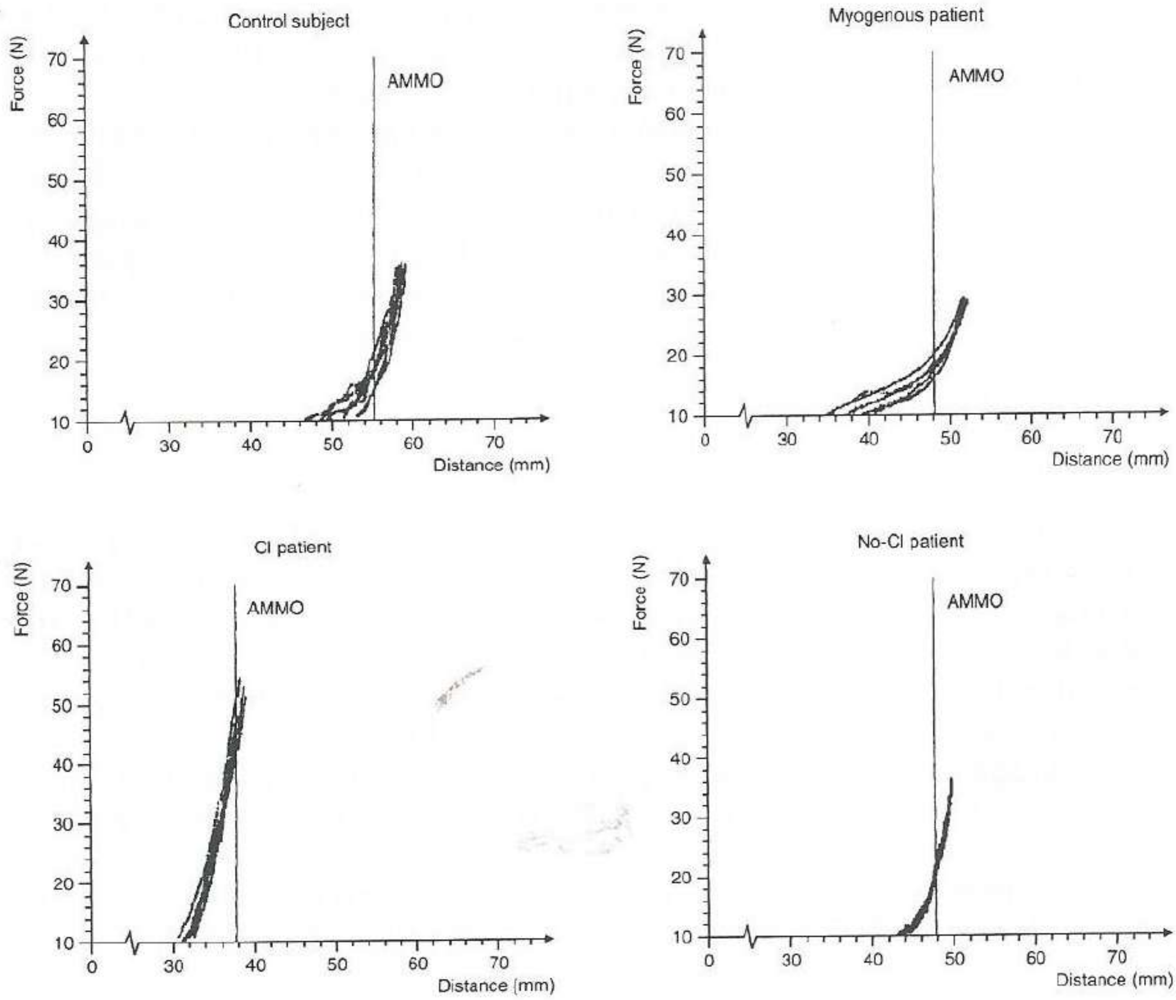

Figure 1. Craniomandibular (CM) stiffness recordings of a control subject, a myogenous, and two arthrogenous pain patients (CL & no-CL). AMMO=active maximum mouth opening; PMMO=passive maximum mouth opening; N=Newton; mm=millimetre.

Experimental examination

Examples of the craniomandibular (CM) stiffness recordings of a myogenous pain patient, two arthrogenous (i.e., CL and no-CL) pain patients, and a control subject are shown in figure 1.

The results of the experimental recordings of the CMD patient subgroups and the control group are shown in Table 2 and figure 2.

Table 2. Mean values and standard errors of the mean (S.E.M.) of the CM stiffness recordings of the CMD patient subgroups and the control group. AMMO=active maximum mouth opening; EFd=endfeel distance; CM=craniomandibular; Fmax=maximum applied force; CL=closed lock; no-CL=no closed lock; mm=millimetre; N/m=Newton per metre; N=Newton.

	CMD patients			Controls
	Myogenous	Arthrogenous		
	(n=41)	CL(n=10)	no-CL(n=8)	(n=20)
AMMO(mm)	45.4 ± 1.3	38.0 ± 3.2	49.6 ± 1.7	52.3 ± 0.9
EFd(mm)	6.7 ± 0.3	2.3 ± 0.3	4.1 ± 0.2	3.8 ± 0.3
CM(N/m)	4461 ± 361	8559 ± 550	6726 ± 748	5362 ± 185
Fmax(N)	31.0 ± 1.3	38.9 ± 1.3	38.5 ± 2.2	37.1 ± 0.5

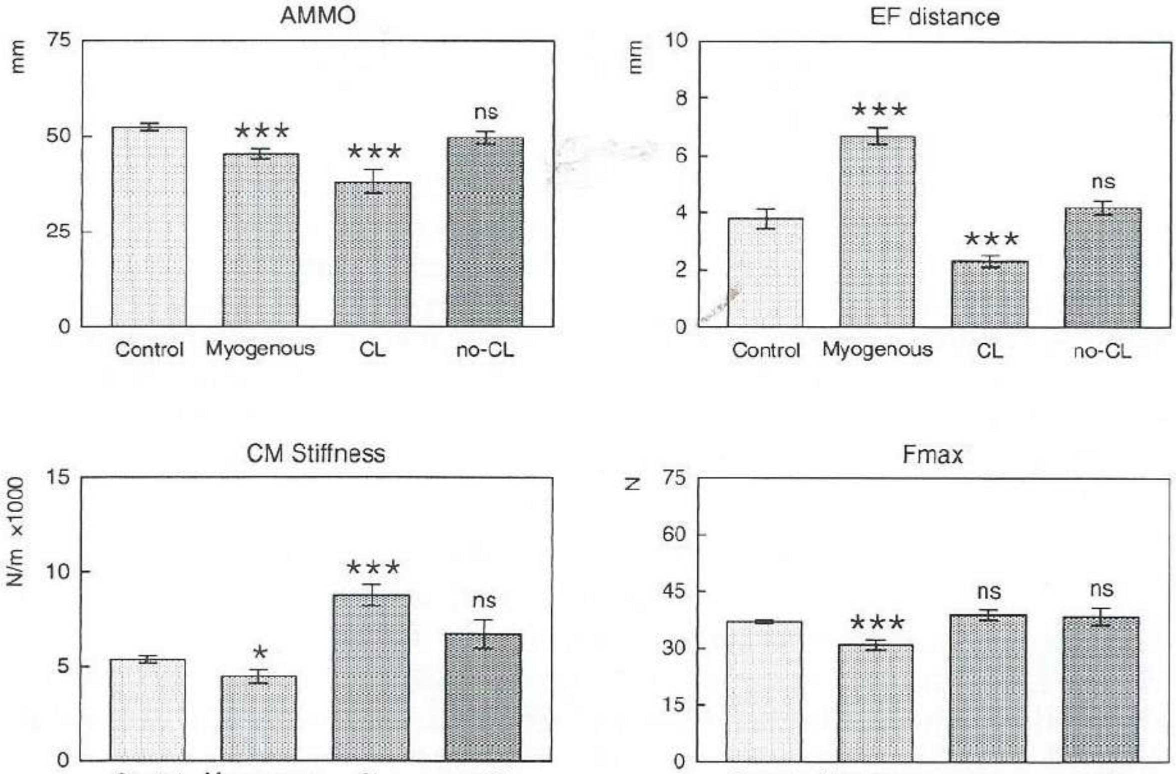

*Figure 2. Mean values and standard errors of the mean (s.e.m.) of the experimental recor-dings of the CMD patient subgroups and the control group. AMMO=active maximum mouth opening; EF=endfeel; CM=craniomandibular; Fmax=maximum applied force; mm=millimetre; N/m=Newton per metre; CL=closed lock; no-CL=no closed lock. *p<0.05; ***p<0.001; n.s.=not significant.*

Except for Fmax in the CL group, both the myogenous pain patients and the closed lock patients showed statistical differences with the control group ($p<0.05$ to $p<0.001$) on all parameters. The no-CL patients revealed no statistical difference with the control group on any of the tested parameters.

In figure 3 the clinical endfeel (EF) denotations 'more-elastic', 'firm', and 'less-elastic' are presented in relation to the parameters endfeel distance (EFd) and craniomandibular stiffness recorded in the CMD patient subgroups.

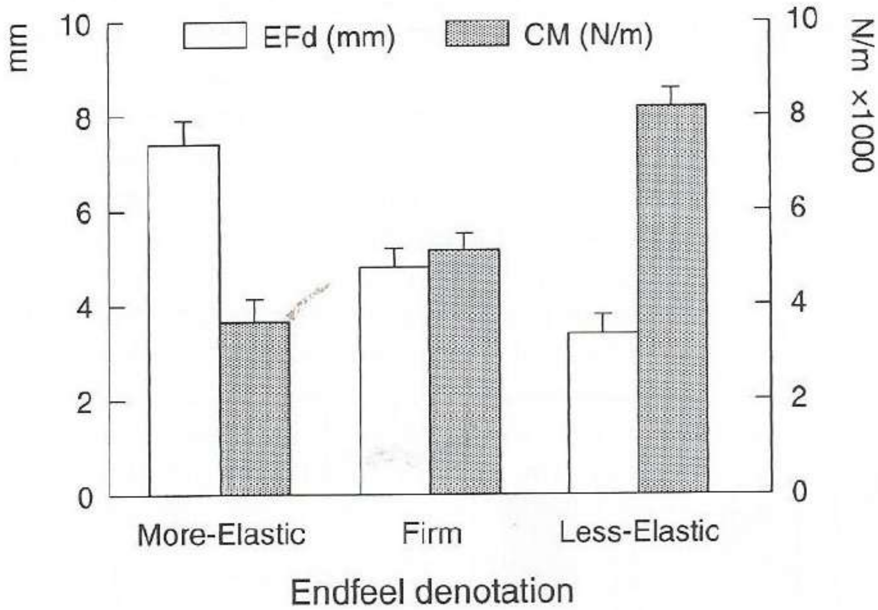

Figure 3. The endfeel denotations 'more-elastic', 'firm', and 'less-elastic' are shown in relation to the mean values and standard error of the mean of the parameters endfeel distance (EFd) and craniomandibular (CM) stiffness. N/m=Newton per metre; mm=millimetre.

The CM stiffness values ($p<0.05$ - $p<0.001$) and the EFd values ($p<0.05$ - $p<0.001$) of the patients with the endfeel denotations 'more-elastic', 'firm', and 'less-elastic' differed significantly. Lower values of CM stiffness and higher EFd values were found in the group with the 'more-elastic' endfeel denotation, whereas higher values of CM stiffness and lower EFd values were observed in the group given the 'less-elastic' endfeel denotation.

Discussion

Active (AMMO) and passive (PMMO) maximum mouth opening, the endfeel (EFd), and craniomandibular (CM) stiffness values were investigated in three CMD patient subgroups, and compared with a control group from a previous study (Chapter 4).

In general endfeel denotations were not found to distinguish the diagnostic groups of CMD patients investigated. The finding that endfeel tended to be more elastic in predominantly muscle disorder patients supports the impression by Stegenga et al[15] that endfeel can be denoted as 'soft' in CMD patients with muscle disorders. In the no-CL group no consistent endfeel sensation was found, making it difficult to achieve clinical diagnostic implications for these denotations. In the arthrogenous pain patients with a closed lock (CL) however, the endfeel denotation was consistently described as 'less-elastic'.

The active maximum mouth opening (AMMO) was significantly smaller in the myogenous pain patients ($p<0.01$). Similar values of active maximum mouth opening were found by Seligman & Pullinger[16] in CMD patients with predominantly pain in the masticatory muscles, despite the fact that they used a different diagnostic procedure: muscle palpation. The range of active movement may be restricted as a result of nociceptive stimuli in the muscle itself or at nearby site.[17] Insufficient blood supply to the muscle, as a result of prolonged contractions (i.e., tooth clenching or grinding), may lead to ischaemic pain, and thus result in shortening and 'stiffening' of the muscles. However, it is not clear whether active contraction or an increased resistance to elongation (i.e., 'stiffening') of the muscle itself prevents full lengthening of these tissues. The above mentioned muscle problems probably also explain the larger endfeel distance values ($p<0.001$) found in this patient group. The lower Fmax values ($p<0.001$) found during PMMO tests indicate the masticatory muscles of myogenous CMD patients to be more sensitive to passive elongation than the muscles of healthy individuals. That the maximum applied force (Fmax) during the PMMO test was lower probably also accounts for the lower CM stiffness values found.

The lower EFd ($p<0.001$) and higher CM stiffness ($p<0.001$) values found in the closed lock group confirm the suggestion that displaced discal tissues directly limit condylar movements in these patients. Other (extra-)capsular tissues and muscles are probably less involved with this arrest of movement during passive mouth opening.

The no-CL group failed to show significant differences with the control group on all parameters (AMMO, EFd, CM stiffness). Similar AMMO values were found in studies by Seligman & Pullinger[16] and Dijkstra et al[18] who reported that even patients with severe TMJ osteoarthrosis and degenerative joint disease can show 'normal' mouth opening values. Although irregular mandibular movements and TMJ crepitus were noted in the no-CL group during mouth opening, neither the masticatory muscles, nor the articulating TMJ structures seem to influence the studied parameters significantly.

The subjective endfeel classifications 'more-elastic', 'firm', or 'less-elastic' are supported by the relationships with the EFd and the CM stiffness values (fig. 3). A 'more-elastic' endfeel corresponded well with lower CM stiffness and higher EFd values, whereas a 'less-elastic' endfeel corresponded well with higher CM stiffness and lower EFd values, respectively. Since the endfeel distance is a quantitative parameter and easy to use in the clinical situation, it is probably the best parameter to test the craniomandibular border characteristics. However, both the CM stiffness, the subjective endfeel denotations, and the endfeel distance show considerable overlap between the three CMD patient subgroups used in this study.

In conclusion, the endfeel distance test is a quantitative and easy performed test for CM stiffness. Therefore it is suggested to incorporate this test in a standard CMD examination protocol.

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GENERAL DISCUSSION AND CONCLUSIONS

Craniomandibular disorders (CMD) comprise a number of symptoms and signs including painful masticatory muscles and temporomandibular joints (TMJs), limited jaw mobility, and joint sounds.[1] Restricted mandibular mobility is commonly accepted as one of the main signs of CMD, and so it is an important variable in evaluating the functional state of the stomatognathic system.[2] The measurements of jaw mobility or range of craniomandibular motion have shown good intra- and interexaminer reliability.[3] The assessment of craniomandibular range of motion (ROM) has therefore become an important adjunct in the diagnostic process of CMD. Nevertheless, craniomandibular mobility tends to vary among healthy male and female subjects and this makes it difficult to construct cut-off values that reflect normalcy in mandibular mobility.[2] However, in that study Szentpetery only assessed mandibular mobility by means of active ROM testing. The borders of the craniomandibular articulation may not have been achieved fully, since active ROM generally depends on the subject's willingness and ability to perform the requested movement. Adding the passive ROM examination, which excludes active muscular participation of the subject, has demonstrated less variation in the assessment of craniomandibular border constraints,[4] although contrary results have also been reported.[3] The quantification of the border characteristics such as stiffness and endfeel distance, obtained by passive ROM testing were of interest to us.

Pain assessment in CMD patients also remains a difficult topic. The patient's pain report and appreciation of pain are important adjuncts in the clinical evaluation of CMD. Symptom reports, coupled with clinical examination findings, provide the data base on which diagnostic and treatment decisions are made.[5] Pain and function impairment in CMD patients originates from the masticatory muscles, the TMJs, or both. These structures are therefore subjected to loading (i.e., provocation) during an orthopaedic examination. The object of orthopaedic testing is to determine from which tissues the CMD symptoms arise. However, confusing overlap of pain responses during orthopaedic testing often complicates the diagnostic process. No 'gold standard' exists with respect to the diagnostic separation of the various CMD subgroups.[1] Therefore continuous refinement of clinical assessment methods in CMD patients is necessary in order to improve diagnostic separation and proper treatment choice.

The aims of this thesis were therefore to investigate objective criteria describing craniomandibular border characteristics, and to validate the outcome of orthopaedic pain provocation tests in CMD patients.

According to most anatomy textbooks craniomandibular border positions are determined by ligamentous constraints. The descriptions regarding the topography of the various ligaments are fairly consistent. Most studies on ligamentous constraints of the craniomandibular articulation are based on morphological observation,[6,7] or on theoretical analysis of mathematical models.[8-11] However, no consensus exists regarding the precise determination of which ligaments constrain horizontal (i.e., laterotrusion and protrusion) and vertical (i.e., mouth opening) mandibular movements. This provided the basis for the literature review presented in Chapter 2. This lack of consensus was recently supported by a review by Sato et al.[12] Clinical and experimental studies focusing on craniomandibular border characteristics seemed therefore an appropriate subject matter for further investigaton into the constraints on craniomandibular movement and are presented in theChapters 3,4, and 6.

The absence of objective criteria in the assessment of craniomandibular border characteristics (i.e., active and passive ROM, and their difference expressed quantitatively in terms of displacement) was a starting point for our studies. These studies were based upon the premise that craniomandibular border characteristics can be assessed reliably with the help of simple recording devices. In the study presented in Chapter 3 peripheral joint mobility and mandibular border positions were assessed and investigated for possible relationships in a group of healthy young subjects. Only few and weak correlations were shown between peripheral joint mobility and mandibular border positions. The females demonstrated a greater peripheral joint mobility than the males, which is in agreement with other studies.[13,14] In a recent study by Dijkstra et al[15] similar findings were reported. Endfeel distance (EFd), as the difference measured between the passive and active range of mandibular motion, had hereto not been reported. A significant difference was shown between the EFd values between the males (2.13 mm) and the females (3.13 mm) at the border of mouth opening. Measurements of the active and passive range of lateral movement were found to be less reliable when compared with the measurements obtained during active and passive mouth opening.[4] The observed differences regarding the EFd values at the border of mouth opening inspired further investigation into the relationship between the active and passive borders of mouth opening in an experimental setting (Chapters 4 and 6).

Muscle relaxation is an important prerequisite for passive testing since it aims at the evaluation ofthe inert structures throughout the range of motion and at the border position of the examined joint. The resiliency of the inert structures at joint borders can be sensed and described by the examiner in terms of a certain degree of elasticity. However, the sensation imparted at the hand of the examiner during passive joint testing is limited to subjective description only and is subject to inter-examiner variation. Despite this important shortcoming, therapeutic decisions are generally made on the outcome of these endfeel tests.[16] EFd and stiffness (e.g., the resistance to passive movement), representing objective parameters during the passive mouth opening test, were investigated in a group of healthy male and female subjects (Chapter 4). In a pilot study the active and passive border positions of mouth opening were investigated under EMG control, and with the help of two separate recording devices enabling the registration of force and displacement simultaneously.

In this study two protocols for passive testing ('A' & 'B') were investigated. Good agreement was shown between the examiner's sensed muscular activity of the subject and the muscle activity as displayed by means of EMG recordings. This agreement precluded the necessity of EMG recordings during passive testing. The results of this study also indicated the use of protocol 'B', since it caused the least muscular interference. In protocol 'B', passive mouth opening started from a point close to occlusion. The subjects were then instructed to relax the muscles as well as possible and the examiner executed the passive test until the mandibular border position was reached. This execution closely resembled the passive testing generally employed in clinical orthopaedics. Also, the use of a more practical and stable force transducer was stressed. In this study an improved and less laborious force/displacement recording technique was used in a group of healthy subjects. A 'stretching' sensation was reported by nearly all subjects at the site of the lateral pole of the condyle during passive mouth opening to the border. This finding supported the hypothesis that the TMJ capsule and lateral ligament serve as a constraint at the border of mouth opening. It is less likely that the reported strain would originate from other ligamentous structures than those indicated at the TMJ location. The results of the simultaneously recorded force and displacement measurements demonstrated higher applied forces in the male subjects to achieve the border of mouth opening. The high variation of the applied forces (Fmax) makes standardization of force application not justified. Craniomandibular (CM) stiffness was calculated from the force and displacement recordings and demonstrated higher values in the male subjects. In a study by Such[17] et al higher stiffness values were found in larger knee joint with larger thigh muscles when compared with smaller knee joints and smaller thigh muscles. However, it must be realized that the different experimental designs employed make comparison with the craniomandibular articulation difficult. Whether the incorporation of the parameter CM stiffness in the diagnostic process contributes to further objective separation of CMD patient subgroups is investigated in Chapter 6.

A comparison between subjective pain report and the outcome of the combined dynamic and static pain provocation tests, and several other orthopaedic tests was made in CMD patients with recent (average 4 months) pain complaints (Chapter 5). A group of thirty-two CMD patients who clearly reported pain at the masticatory muscle region or at the TMJ region by means of a Symptom Report Questionnaire (SRQ), participated in this study. A high correspondence was shown between the patients reporting joint or muscle pain (by means of the SRQ), and the classification into arthrogenous and myogenous pain patients, based on the outcome of the dynamic and static pain provocation tests. These findings are in line with the earlier reported agreement between self-reported pain and clinical data in CMD patients.[5,18] Lobbezoo et al[3] reported a poor agreement between self-reported pain and clinical data, which may be attributed to the longer duration of orofacial pain symptoms (average 2.5 years) in their patient material as compared to the duration of orofacial pain in our material. This underlines the possible disturbing influences of chronic pain and its psychological adjuncts on the diagnostic separation. The prevalence of pain during the TMJ-play test, during PMMO testing, and during palpation of the TMJs showed statistical differences between the myogenous and the arthrogenous pain patients. However, weak differences were shown between both groups when palpating the masticatory muscles. Muscles, painful to palpation, seem therefore not an exclusive symptom of either of the patient groups. Muscle palpation must therefore be considered only an additional test with weak discriminatory power. In patients who are diagnosed having a closed lock condition, the static pain provocation test may cause pain in the TMJ as a result of the accompanying compression during this test. Since static provocation tests are considered to evoke pain in the musculo-tendinuous apparatus the interpretation of the results of the static provocation test may be confounded when the TMJ is sensitive to compression. Therefore, an additional TMJ-compression test is needed for the correct interpretation of the origin of the pain.

The parameters AMMO, PMMO, EFd, and CM stiffness as a quantitative representation of the craniomandibular border characteristics were discussed in Chapters 3 and 4. These parameters were also investigated in a CMD patient population and the results of this study are presented in Chapter 6. After diagnostic separation, according to the earlier described assessment process (Chapter 5), into myogenous and arthrogenous pain patients with and without a closed lock, the values of the parameters AMMO, EFd, and CM stiffness were calculated and compared with the values from the control group presented in Chapter 4. Both the myogenous patients and the arthrogenous patients with a closed lock showed great differences with the control group on all the tested parameters. However, the arthrogenous pain patients without a closed lock condition revealed no statistical differences with the control group on any of the tested parameters. Apparently the structures determining the craniomandibular border characteristics were not affected in this particular arthrogenous CMD group. The clinical significance of the 'feel' sensed at the border of a joint movement has been reported in the orthopaedic literature.[16] In a recent investigation by Lobbezoo-Scholte et al[3] low interexaminer reliability values were found with respect to the subjective denotations for maximal passive mouth opening. In their study the examiners were given the choiceof the endfeel denotation 'normal' or 'deviating'. However, these subjective denotations of endfeel were not further explained, nor linked to any particular joint or muscle related CMD. In our study we used the endfeel classification 'firm', as proposed by Evjenth & Hamberg,[19] and 'less-elastic' and 'more-elastic' as the deviant classifications of endfeel, respectively. It was of interest to us to investigate the relationship between these subjective denotations, and the outcome of the EFd and CM stiffness recordings. The subjective endfeel classifications 'more-elastic', 'firm', and 'less-elastic' were related to the EFd and CM stiffness values. A 'more-elastic' endfeel corresponded well with higher EFd and lower CM stiffness values, whereas a 'less-elastic' endfeel corresponded well with lower EFd and higher CM stiffness values, respectively. Since the endfeel distance is a quantitative parameter and easy to use in the clinical situation, it is probably the best parameter to test the craniomandibular border characteristics. However, both the CM stiffness, the subjective endfeel denotations, and the endfeel distance show considerable overlap between the three CMD subgroups used in this study.

Conclusions:

1) The endfeel distance test is a quantitative and easy performed test for CM stiffness. This test should therefore be incorporated in a standard CMD examination protocol.
2) The high correspondence between the classification of CMD patients with recent pain complaints into patients who reported joint or muscle pain and into arthrogenous or myogenous patients based upon the outcome of the dynamic and static provocation tests, supports the usefulness of these latter tests in discriminating the location of pain.

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SUMMARY

In Chapter 1 an introduction and a brief overview are given with respect to the etiology, symptomatology, and diagnosis of CMD. While occlusal disturbances are still regarded as possible etiological factors by many, the musculoskeletal aspects of CMD have become more recently an important focus of attention of other disciplines than the dental profession. Physiotherapists in particular, but also physicians such as orthopedic specialists and rheumatologists have become involved with the management of CMD. The importance of orthopedic testing is stressed as the incorporation of this test procedure has shown its value in the diagnostic procedure in determining more precisely muscle and joint related tissues affecting joint range of motion. The need for more objective criteria in the evaluation of craniomandibular range of motion determinants in control subjects, and myogenous and arthrogenous CMD patients is discussed.

In order to understand the various factors involved with the border positions of the mandible, detailed information is needed about the anatomic structures restricting the range of motion of the craniomandibular articulation (i.e., both TMJs and related soft tissue structures). In Chapter 2 the literature is reviewed concerning the various anatomical, biomechanical, and pathogenic factors involved with synovial joint range of motion (ROM) in general, and those factors possibly influencing craniomandibular ROM. Craniomandibular disorders (CMD) are musculoskeletal disorders that display similar changes in joint and muscle functions observed in other synovial joints. It may therefore be assumed that the methods used for investigating joint mobility (i.e., ROM) in general are applicable to the craniomandibular system as well. The literature is not consistent with respect to which constraints (i.e., capsular and ligamentous) are specifically involved with the border positions of the mandible. The assumed constraints involved with border positions are largely based on morphologic and theoretic analyses, and they lack direct evidence from living subjects. Further clinical and experimental studies are needed to investigate the border position determinants of the craniomandibular articulation in control subjects and CMD patient subgroups.

In Chapter 3 the results of a study on the mobility of finger, wrist, elbow, knee, and ankle joints, and the border positions of the mandible in a group of fifty-one dental students (15 females and 36 males) are presented. The purpose of this study was to investigate possible relationships between generalized joint mobility and mobility of the temporomandibular joints. The following mandibular border positions were recorded actively and passively: mouth opening, and left and right laterotrusions. Protrusion was measured

only actively. Only a few and weak correlations were found between the outcomes of the mandibular border position measurements and the peripheral joint mobility measurements. Differences between the sexes were illustrated in peripheral joint mobility with females showing a greater joint mobility than males, especially when only the passively measured joints were considered. The mandibular border positions were significantly correlated with each other ($p<0.05$ - $p<0.001$) for the males, but few and then only weak relationships between these measurements could be found for the females in this group. The concept of 'endfeel distance' was introduced as the difference between passive and active maximum mouth opening, exhibiting a greater distance (i.e., expressed in millimetres) for the females than for the men. The differences between the sexes found in this study were a starting point for further investigations.

Passive mouth opening to the border position was investigated in young healthy subjects in an experimental setting (Chapter 4). In a pilot study, prior to this study, the active and passive border positions of mouth opening were investigated under electromyographic (EMG) control, and with the help of two separate recording devices capable of registering force and displacement simultaneously. Two protocols ('A' and 'B') of passive mouth opening testing were used. When executing protocol 'A', the subject was requested to open the mouth maximally, whereafter he was instructed to relax the muscles. Next, the examiner extended the mouth opening further to the border position. In protocol 'B' the subject was requested to open the mouth slightly and subsequently relax the muscles. The examiner then increased the mouth opening throughout the remaining range of motion until the border position was reached. The outcome of the pilot study indicated the use of the passive test protocol ('B') that evoked the least muscle interference, and the use of a more practical and stable force transducer. In the following study an improved and less laborious force/displacement recording device was used in a group of 40 healthy young male and female subjects. No difficulties were observed with relaxation of the muscles or force application during the passive mouth opening tests with the execution of protocol 'B' and the improved experimental design. Most subjects reported a stretching sensation at the site of the temporomandibular joint (TMJ) at the border of passive mouth opening, and which was interpreted as a strain coming forth from its capsular and ligamentous apparatus. Higher applied forces (F_{max}) were needed to achieve the passive border position of mouth opening in the male subjects subjects ($p<0.01$). Craniomandibular (CM) stiffness was calculated from the force/displacement recordings of the male and female subjects. Male subjects demonstrated higher values of CM-stiffness at the middle (S2; $p<0.05$) and upper (S3; $p<0.05$) sections.

A comparison between subjective pain report and the outcome of the combined dynamic and static pain tests, and several other orthopaedic tests was investigated in CMD patients with recent paincomplaints and control subjects (Chapter 5). Thirty two CMD patients who clearly reported pain at the masticatory muscle region or at the TMJ region by means of a Symptom Report Questionnaire (SRQ), participated in this study. The investigators performing respectively the symptom report interview and the clinical tests were blinded to each other. A high correspondence was shown between the patients reporting joint or muscle pain (by means of the SRQ), and the classification into arthrogenous and myogenous pain patients, based on the outcome of the dynamic and static pain tests ($p=0.0003$). The outcome of four other orthopaedic tests: passive maximum mouth opening (PMMO; $p=0.0001$), palpation of the TMJ and the masticatory muscles ($p=0.0002$), TMJ play ($p=0.0001$), and TMJ compression ($p=0.0138$) demonstrated significant differences between the patients reporting joint and muscle pain. The results of this study support the usefulness of the static and dynamic pain provocation tests. However, since static provocation tests are considered to evoke pain in the musculo-tendinuous apparatus the interpretation of the results of the static provocation test may be confounded when the TMJ is sensitive to compression. Therefore, an additional TMJ-compression test is needed for the correct interpretation of the origin of pain.

In Chapter 6 the values of parameters active maximum mouth opening (AMMO), endfeel distance (EFd), and CM stiffness of three CMD patient subgroups were compared with the corresponding values obtained from a control group (Chapter 4). The CMD patient subgroups consisted of myogenous pain patients, and arthrogenous pain patients with a 'closed lock' (CL; disc displacement without reduction), and arthrogenous pain patients without a 'closed lock' (no-CL). Both the myogenous pain patients and the arthrogenous pain patients showed great differences on all investigated parameters ($p<0.05$ - $p<0.001$). However, the athrogenous pain patients without a 'closed lock' (no-CL) revealed no statistical differences with the control group on any of the investigated parameters. The subjective endfeel classifications 'more-elastic', 'firm', and 'less-elastic', given to each patient as a denotation of the endfeel during PMMO testing prior to the diagnostic separation, demonstrated their inversed relationship with the EFd and CM stiffness values. A 'more-elastic' endfeel corresponded well with higher EFd and lower CM stiffness values, whereas a 'less-elastic' endfeel corresponded well with lower EFd and higher CM stiffness values, respectively. Except for the denotation 'less-elastic' to the CL patient group, the other endfeel denotations did not support the diagnostic separation of the CMD patients.

SAMENVATTING

In hoofdstuk 1 is een kort overzicht gegeven over de etiologie, de symptomatologie, en de diagnostiek van craniomandibulaire dysfunktie (CMD). Terwijl occlusale stoornissen nog steeds door velen als een mogelijke oorzaak van CMD worden beschouwd, krijgen juist de musculoskeletale aspecten van CMD de laatste tijd meer aandacht, ook van disciplines buiten de tandheelkundige professie. Fysiotherapeuten in het bijzonder, maar ook medici zoals orthopedisch chirurgen en rheumatologen, zijn tegenwoordig betrokken bij de diagnostiek en de behandeling van CMD. Het belang van orthopedische testen in het diagnostisch proces wordt benadrukt daar deze testen hun waarde aangetoond hebben bij de herkenning van spier- en gewrichtsafwijkingen. De behoefte aan objektieve criteria bij de evaluatie van craniomandibulaire bewegingsuitslagen van proefpersonen, en van myogene of arthrogene CMD patienten wordt besproken.

Ter verkrijging van een beter begrip van de faktoren, die bepalend zijn voor de grensposities van de onderkaak is gedetailleerde informatie nodig van de anatomische structuren die mogelijk betrokken zijn bij deze posities. In hoofdstuk 2 is een literatuuronderzoek beschreven betreffende de verschillende anatomische, biomechanische, en pathofysiologische faktoren die van invloed kunnen zijn op de bewegingsuitslagen van synoviale gewrichten in het algemeen, en op die van van het craniomandibulaire systeem in het bijzonder. Craniomandibulaire dysfunkties zijn musculoskeletale stoornissen die vergelijkbaar zijn met die van andere synoviale gewrichten. De onderzoeksmethoden die in het algemene orthopedische onderzoek worden toegepast zijn daarom ook toepasbaar op het kauwstelsel. Er is geen overeenstemming in de literatuur betreffende de vraag welke strukturen (b.v., ligamenten, kapsel, etc.) specifiek betrokken zijn bij het begrenzen van de onderkaakposities. De meeste veronderstellingen zijn gebaseerd op morphologische en/of theoretische analyses en missen ondersteunende klinische bewijsvoering. Verdere klinische en experimentele studies zijn nodig om meer inzicht te krijgen in de faktoren die van belang zijn bij bepaling van de grensposities van de onderkaak in gezonde proefpersonen en in CMD patienten.

De resultaten van een studie naar de mobiliteit van vinger-, pols-, elleboog-, knie-en enkelgewrichten en de mobiliteit van de craniomandibulaire (CM) articulatie (i.e., beide kaakgewrichten) in een groep van 51 tandheelkunde studenten (15 vrouwen; 36 mannen) zijn beschreven in hoofdstuk 3. Het doel van deze studie was de mogelijke relaties te onderzoeken tussen perifere gewrichtsmobiliteit en de mobiliteit van de CM articulatie. De volgende grensposities van de onderkaak werden aktief en passief geregistreerd: de mondopening en de laterale excursies naar links en naar rechts. Protrusie werd alleen gemeten na aktief bewegen. Slechts enkele zwakke correlaties werden gevonden tussen de uitkomsten van de perifere gewrichtsmobiliteit en de uitkomsten van het bewegingsonderzoek van de onderkaak. Sexe verschillen werden gevonden tussen de uitkomsten van de perifere gewrichtsmobiliteit, waarbij vrouwen met name bij het passief uitgevoerde bewegingsonderzoek een grotere mobiliteit vertoonden. Binnen de mannen correleerden de verschillende grensposities van de onderkaak ($p<0.05$ - $p<0.01$); met betrekking tot deze grensposities werden slechts enkele, zwakke relaties gevonden binnen de vrouwen. Het concept 'eindgevoelafstand', als het verschil tussen de maximale passieve en aktieve mondopening uitgedrukt in millimeters, werd geintroduceerd. De eindgevoelafdstand was groter bij de vrouwen ($p<0.05$).

In een experimentele voorstudie met 12 gezonde proefpersonen werden twee protocollen ('A'& 'B') voor de uitvoering van het passieve bewegingsonderzoek naar de maximale mondopening uitgetest (Hoofdstuk 4). Dit onderzoek werd uitgevoerd onder elektromyografische (EMG) controle en met behulp van twee instrumenten voor de gelijktijdige registratie van zowel de kracht als de verplaatsing. Tijdens de uitvoering van protocol 'A' werd de proefpersoon gevraagd de mond maximaal te openen, waarna deze werd geinstrueerd de spieren te ontspannen. Direkt hierna werd de mondopening door de onderzoeker passief verder doorgevoerd. Tijdens de uitvoering van protocol 'B' werd de proefpersoon gevraagd de mond in geringe mate te openen en vervolgens gevraagd de spieren te ontspannen. Vervolgens werd de mond verder passief door het resterende trajekt geopend tot aan de grenspositie. De uitkomst van dit onderzoek indiceerde het gebruik van protocol ('B'), daar de minste EMG aktiviteit werd uitgelokt. Tevens werd het gebruik van een meer praktische en stabiele krachtmeter voorgesteld. In de hierop volgende studie werd gebruik gemaakt van een verbeterde en minder bewerkelijke kracht- en verplaatsingsregistratiemethode in een groep van 40 gezonde proefpersonen (20 mannen en 20 vrouwen). Tijdens deze metingen werden geen problemen met de ontspanning van spieren waargenomen. De meeste proefpersonen rapporteerden een duidelijk rekgevoel ter plaatse van het kaakgewricht tijdens het passieve bewegingsonderzoek. Dit rekgevoel werd geinterpreteerd als een belasting van het kaakgewrichtskapsel en/of het laterale ligament van het kaakgewricht. In de groep mannen moest een gemiddeld hogere kracht worden aangewend bij het bereiken van de maximale mondopening ($p<0.01$). De craniomandibulaire (CM) stijfheid werd berekend aan de hand van de uitkomsten van de kracht- en de verplaatsingsregistraties. De mannen demonstreerden hogere CM stijfheidswaarden dan de vrouwen ($p<0.05$).

De relatie tussen subjektieve pijnrapportage en de uitkomst van de gecombineerde dynamische en statische pijntesten en verschillende andere orthopedische testen werd onderzocht in een groep CMD patienten met recente pijnklachten (Hoofdstuk 5). In deze studie participeerden 32 CMD patienten die duidelijk pijn rapporteerden in de regio van de kauwspieren of in de regio van de kaakgewrichten aan de hand van een Symptoom Rapportage Vragenlijst (SRV). Het SRV onderzoeksgedeelte en het klinische gedeelte zijn blind ten opzicht van elkaar uitgevoerd. Een duidelijke overeenkomst is aangetoond tussen de patienten die spier- of gewrichtspijn rapporteerden (middels SRV), en de classificatie in arthrogene en myogene pijnpatienten, gebaseerd op de uitkomst van de dynamische en de statische pijntesten ($p=0.0003$). De uitkomsten van 4 andere orthopedische testen: passive maximale mondopening ($p=0.0001$), palpatie van het kaakgewricht en de kauwspieren ($p=0.0002$), gewrichtsspel van het kaakgewricht ($p=0.0001$), en gewrichts-compressie ($p=0.0138$) vertoonden significante verschillen tussen de gewrichts-pijn- en de spierpijnpatienten. De resultaten van dit onderzoek ondersteunen de toepasbaarheid van de dynamische en de statische pijnprovokatietesten. Daar echter de statische provokatietest geacht wordt uitsluitend pijn op te wekken in het spier-peesapparaat wordt de interpretatie van de uitkomst van deze test bemoeilijkt wanneer het kaakgewricht compressiegevoelig is. Een aanvullende compressietest van het kaakgewricht is dan nodig voor de juiste interpretatie van de herkomst van de pijn.

In hoofdstuk 6 zijn de uitkomsten van de parameters aktieve maximale mondopening, eindgevoelafstand, en CM stijfheid in drie CMD patienten subgroepen vergeleken met de waarden gemeten bij de gezonde proefpersonen van hoofdstuk 4. De CMD patienten subgroepen bestonden uit myogene pijnpatienten, en arthrogene pijnpatienten met een 'closed lock' (b.v., CL; een discusverplaatsing zonder reductie) en arthrogene pijnpatienten zonder een closed lock. Zowel de myogene CMD patienten als de arthrogene CMD patienten met een closed lock demonstreerden grote verschillen met de contole groep op alle onderzochte parameters ($p<0.05$ - $p<0.001$). Echter geen van de onderzochte parameters vertoonden verschillen tussen de arthrogene CMD groep zonder closed lock en de controle groep. De aan iedere patient gegeven subjektieve eindgevoelclassificatie 'meer-elastisch', 'elastisch' of 'minder-elastisch' werd gerelateerd aan de uitkomsten van de eindgevoel afstand en de CM stijfheid. De classificatie 'meer-elastisch' correspondeerde met grotere eindgevoelafstanden en lagere CM stijfheid waarden, terwijl de classificatie 'minder-elatisch' correspondeerde met kleinere eindgevoel afstanden en grotere CM stijfheidswaarden ($p<0.05$ - $p<0.01$).

This thesis is based on the following publications:

* Factors influencing joint mobility in general and in particular respect of the craniomandibular articulation: a literature review.
  Hesse JR, Hansson TL. *J Craniomandib Disord Facial Oral Pain* 1988; 2:19-28

* Mandibular border positions and their relationships with peripheral joint mobility.
  McCarroll RS, Hesse JR, Naeije M, Yoon CK, Hansson TL. *J Oral Rehabil* 1987; 14:125-131

* Craniomandibular stiffness toward maximum mouth opening in healthy subjects: a clinical and experimental investigation.
  Hesse JR, Naeije M, Hansson TL. *J Craniomandib Disord Facial Oral Pain* 1990; 4:257-265

* Subjective pain report and the outcome of several orthopaedic tests in CMD patients with recent pain complaints.
  Hesse JR, Van Loon LAJ, Naeije M. *J Oral Rehabil* (accepted for publication)

* Craniomandibular stiffness in myogenous and arthrogenous CMD patients and control subjects: a clinical and experimental investigation.
  Hesse JR, Naeije M, Hansson TL. *J Oral Rehabil* (accepted for publication)

NAWOORD

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