The Effectiveness
Of Exercise Therapy
For Temporomandibular Disorders

A report submitted to the University of Adelaide
in partial fulfillment of the requirements for the degree of

DOCTOR OF CLINICAL DENTISTRY

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ABSTRACT

Background: Therapeutic exercises have been used by Physiotherapists to manage musculoskeletal disorders, specifically Temporomandibular Disorders (TMD) for some time but they are less commonly used in dental practice. The current evidence about home exercise programs to treat TMD is weak despite some generally recognised benefits such as low cost, reversibility and reinforcement of the patient's coping skill, essential for management of chronic conditions like TMDs.

Objective: To evaluate the effectiveness of home exercise programs used as part of dental management for TMDs.

Methods: A search of the Cochrane Central Register of Controlled Trials (Cochrane Library Issue 7, 2012), Medline, Web of Knowledge and Scopus databases (January 1966 to February 2012) and reference lists of articles. Only randomized and quasi-randomised controlled trials published in English that compare exercise therapy to treatments without exercise therapy for TMDs were included. Two authors independently assessed the suitability of trials for final inclusion and also contacted study authors for additional information as required.

Results: Eleven trials involving 688 people were included. Two trials compared exercise programs to no-treatment control subjects for Anterior Disc-Displacement with Reduction (ADDwR). A significant risk ratio of 0.44 (0.29-0.59) (44% improvement rate) for improvement in clicking after at least four weeks of exercise therapy was revealed. Three trials compared exercise programs for Anterior Disc-Displacement without Reduction (ADDwoR) with no-treatment control subjects. An overall improvement in the pain-free range of maximal mouth opening with exercise intervention was observed although the differences were not statistically significant in one of three trials. Six trials compared exercise programs for Myofascial Pain patients with no-treatment controls. A standardised mean difference in jaw pain score of 0.73 (95% CI -0.63 – 2.10) indicates no effect from exercise therapy for this TMD subgroup.

Conclusion: Exercise therapy appears to be effective for treatment of some TMD subcategories and unlikely to present any adverse outcomes.

DECLARATION

I, Sofie Chau Diem Bui certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution in my name and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Dr. Sofie Chau Diem Bui
Date: 17th July 2013

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The journey of learning will go on. The three years of postgraduate life is a momentous paving stone for all my future endeavours.

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This thesis is dedicated to my son, Nguyễn Bùi Quốc Khiêm who is the energy that stimulated me to undertake and completed the challenge of postgraduate study.

My humbling experience is only minute in comparison to the sacrifice by my husband, Mr. Nguyễn Hoàng-Thanh Tâm - My partner in Love, Life, and Dreams. If not for his endless love and support, most of all, believing in me, this thesis would not be possible. Thank you dear for being the fervor energy that made this journey possible. Thank you for seeing the best in me, as I have seen in you. You have been a much-desired company to walk this path with.

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Con cảm ơn Ba và Mẹ đã sinh con, nuôi con lớn đến ngày hôm nay và tạo cơ hội cho con được học hành. Đặc biệt Ba Mẹ đã hy sinh tất cả, cũng như đã bỏ qua những cái bất toàn của con và chấp nhận con. Công ơn của Ba Mẹ con chỉ bù đắp lại bằng mảnh bằng nhỏ này, hy vọng Ba Mẹ vui và mãn nguyện như Ba Mẹ sẽ rất vui với những năm còn lại của cuộc đời với con cháu.

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CHAPTER 1. LITERATURE REVIEW

INTRODUCTION

The orofacial region can be affected by a number of chronic pathological conditions, which may be debilitating and painful. A prevalent and painful condition in this region are collectively known as Temporomandibular Disorders (TMD) [1].

TMDs are defined as a heterogeneous group of symptoms of muscular and joint pathologies where a TMD patient may classically complain of three symptoms: Muscle and/or joint pain, joint sounds and restriction, deviation or deflective mouth opening paths [2]. A list of common symptoms and signs of TMDs is summarized in Table 1 [3]. Functional disturbances of the masticatory system have been known by many names including *Costen syndrome* [4], *temporomandibular joint dysfunction syndrome* identified by Shore (1959) as cited by Okeson (2003) or *functional temporomandibular joint disturbances* coined by Ash and Ramfjord (1995). While some names stress a major symptom such as pain (*pain-dysfunction syndrome, temporomandibular pain-dysfunction syndrome*), other names suggest causes for example *occlusomandibular disturbance* [5]. The broad and collective term "temporomandibular disorders" which was suggested by Bell [6] has become widely used and is the chosen term in this review.

Table 1. Common signs and symptoms of temporomandibular disorders [3]

- Pain or tenderness in the temporomandibular joint, muscles of mastication, facial areas, ear region, shoulder and neck
- A clicking, popping or grating sound when opening or closing the mouth or while chewing
- Catching or locking of the joint with deviations or deflections of the mandible on opening or closing the mouth
- Limitations in opening or closing the mouth
- Difficulty or discomfort while chewing
- Sensation of an uncomfortable bite

1.2 AETIOLOGY

The aetiologies of TMDs are complex and have been extensively studied and described in the literature. They have been described as studies that seek to "know why a particular patient began to have both the biology and the perception of his (or her) pain in the absence of frank trauma" [7]. This definition highlights the importance of the patient's perception of potential or real biological changes in a particular anatomical area. To understand the aetiologies of TMD, some authors [8, 9] classify aetiological factors into three descriptive categories, which contribute towards the TMD presentations. These categories are: predisposing; initiating or precipitating; and perpetuating factors. In simple terms, predisposing factors pertain to structural, metabolic, morphological and/or psychophysiological conditions that heighten one's susceptibility to develop TMD. Initiating or precipitating factors relate to any traumatic event or repetitive occurrence, for example stress or hyper-function resulting in an adverse loading on the masticatory system, all of which lead to onset of symptoms [9]. Perpetuating factors, on the other hand, include conditions that sustain the problems such as poor healing capacity, failure to control aetiologic factors or secondary gains from being sick. These factors may also be associated with any predisposing or initiating factors [9, 10].

The aetiologies of TMDs have been described as being dependent on the specialized training of the dental discipline involved and as a result approaches to patient treatment have varied according to the background of the provider [11].

Several aetiological theories originating from different dental and medical disciplines will be discussed in the following section. Historical aetiology theories that emerged from otolaryngology since Costen's time in the early 1930s will not be discussed here. Neither will minor "unorthodox" concepts (for example craniosacral therapy (osteopathy), applied kinesiology (chiropractic) or nutritional theory) arising from non-dental professions be included in this review, as they have lost support over time [7].

From an orthodontic historical viewpoint, the concept of TMD associated with orthodontic management was influenced by Thompson who believed that TMD is a result of structural disharmony, that is, the mandibular condyle was in a superior-posterior position and that there was a need to free-up a distalised (trapped) mandible by traditional orthodontic treatment. [9] Subsequent developments, such as functional jaw orthopedics aimed to

achieve the same outcome by mandibular advancement [12, 13]. but these latter concepts have not been widely accepted within the orthodontic field [12, 14]. Nowadays, it is generally accepted[15] that the relationships between occlusal problems, TMD and orthodontic treatment is minor and that TMD signs and symptoms can occur in patients undergoing orthodontic treatment but that the two may not be related. McNamara and colleagues went as far as suggesting that this may be a naturally occurring phenomenon [16].

From a prosthodontic perspective, an extensive multifactorial analysis done by Pullinger and coworkers [15] demonstrated only a few defined occlusal conditions that had significant risks for TMD problems. These included anterior open bite, unilateral maxillary lingual crossbite, overjet greater than six to seven millimeters, missing five or more posterior teeth and a slide from centric position to intercuspal position greater than two millimeters. The estimated contribution of these occlusal factors towards TMD development was reported between 10-20% [16]. Okeson [5] reviewed 57 epidemiological studies of the relationships between TMD and occlusion and found that 35 of 57 studies suggested variable relationships without consistent features that could be reported. In the past some invasive prosthodontic treatments based on an assumed association between "malocclusion" and TMD advocated treatment that included occlusal equilibration, bite opening condylar repositioning, TMD anterior repositioning appliances and major restorative dentistry [17].

Several allied health professionals in the field of musculoskeletal conditions hypothesized a causal relationship between altered craniocervical posture and TMD through biomechanical influences on the musculoskeletal activity in the masticatory and neck regions [18-20]. Other authors have postulated the co-morbidity relationships between altered head posture as an initial cause of neuromuscular disharmony and occlusal abnormalities which in turn may cause TMD [21]. Cervical spine symptoms often occur as common co-morbidities to the primary symptoms arising from the (temporomandibular joint) TMJ region, thus requiring concurrent management [21]. However, the evidence supporting a causal link to TMD has not been consistent [7].

Increasingly, TMD conditions are being studied and treated from a medical perspective, acknowledging the role of orthopedic principles and multidisciplinary management approaches, combined with an appreciation of the principles for managing chronic pain effect and the biopsychosocial impacts of TMD on the patients [3]. The current most popular theory regarding TMD aetiology encompasses aspects of biology, psychology and

the social effects on patients and guide management along the rehabilitation model rather than toward the hope of a "permanent cure" [3]. In fact, the body of research that supports the biopsychosocial approach can be traced back over forty years to the early work of Schwartz, Moulton, Laskin, Greene, Lupton and others whose ideas were advanced by Rugh and Solberg in the 1970s and 1980s, and by Turk and Rudy's groups in the past twenty-five years [7]. According to Greene [7], the term appropriately describes the experience of a patient with pain, especially chronic pain conditions, that exists as a *biological* problem which may or may not be demonstrable as a pathology but the associated *psychological* effects that occur before or as a behavioral consequence can affect the person's interactions with friends, families and others within their *social* networks. This broad level of appreciation apparently can explain TMD subtypes at a group level but is difficult to apply on an individual basis and as a result applying the concept in a clinical situation can be difficult.

Current research that seeks to understand the role of gender-related factors in a multitude of functional (non-organic) disorders such as fibromyalgia, interstitial cystitis, irritable bowel syndrome and pelvic pain highlight the fact that the current understanding of TMD aetiologies is no longer a unilateral, mechanically driven causal approach, but rather involves multiple body systems within a medical framework [3]. Studies on pain that include the pathophysiologic processes of pain, neuroanatomic regions of pain processing, molecular and cellular pathophysiology of muscle and joints and behavioral aspects of pain as well as neuroplasticity and chronic pain [3, 22] explain the broader approach on TMD management.

According to Dworkin [1], 95% of patients with TMD seek treatment to relieve pain. Psychological symptoms are less subtle and require careful assessment, subjectively and objectively. Often they become the primary focus of management as in other chronic pain conditions such as headache and back-pain [1].

1.3 PREVALENCE

According to the U.S National Institute of Dental and Craniofacial Research, of all musculoskeletal conditions resulting in pain and disability, TMD is second only in prevalence to chronic low back pain, affecting between 5 and 12% of the U.S population

(over 10 million Americans) at an estimated annual cost of $4 billion to the health care system. In a retrospective case control study of 1713 cases versus 532,485 control cases, Shimshak and DeFuria [23] reported a higher financial cost associated with TMD patients compared to non-TMD patients, $956 vs. $517 per patient. (Accessed 11/8/2012, http://www.nidcr.nih.gov/OralHealth/Topics/TMJ/).

Currently there are numerous reported epidemiologic studies (albeit small samples of limited population groups) that examined the prevalence of TMD conditions in various populations [24-31]. Okeson estimated an average of 41% of people with at least one TMD symptom and 56% with at least one clinical sign [5]. Fricton and Dubner [32] reported an even higher prevalence (up to 75%) demonstrating objective signs and less than half (33%) presenting with subjective complaints of symptoms. It is evident that the prevalence for objective signs of TMD is always higher than subjective complaints of symptoms. The difference between these two figures indicates that not all patients with TMD signs seek treatment. In addition, clinical assessment reveals that frequent, high-intensity pain that limits daily activities is not significantly associated with TMD signs [1].

Epidemiologic studies have also shown that TMD conditions can exist in any age group. For children and adolescents the prevalence varies widely between 16% (primary dentition) to 90% (mixed dentition) [10] and the prevalence increases with pubertal development independent of gender in the adolescent age cohort [33]. This large variation may be explained by the low sensitivity of diagnostic tests especially in younger age groups [10].

In a study analyzing diagnostic prevalence according to age group, the younger group (under 38 year-old) characteristically had more disc-related problems and conversely, the older age group (above 38 year-old) was more likely to be diagnosed with arthritic/degenerative conditions [2]. A study published by the Cochrane group (2011) reported 80.9% of children between 6-12 years had been diagnosed with TMD symptoms [34], whereas the prevalence in a geriatric population was reported as 38%. It has been observed that not all patients with TMD signs require treatment. Schiffman and co-workers [31] reported 6.7% of respondents required treatment and the remainder did not require further treatment.

Variation between genders has also been reported in the literature. In a prevalence study of 199 Northern Italian patients, Manfredini and colleagues [2] found a higher proportion of women (83%) than the men (17%) affected by TMD. The higher prevalence of women

observed in this study is a common recurring pattern with the highest prevalent commonly reported in women at "child-bearing age" [2].

The prevalence for any particular TMD diagnosis is lower than combined diagnoses and the following rates 4.5%, 12.1% and 19.1% have been reported for muscular, disc-related and joint-related TMD problems respectively by Manfredini and co-workers [2]. In contrast, about 64% of the patients were found to have more than one diagnosis. A breakdown of prevalence rates amongst TMD subtypes revealed muscle disorders to be more common (49.7%) when combined with other diagnoses[2].

Reported prevalence also differ between ethnic groups with Yap and co-workers [24] reporting a prevalence of 31% for the Asian populations and List and colleagues [25] reporting TMD problems in 76% in Swedish and American populations.

To interpret the observed differences between studies, it is important to understand how patient groups are classified as descriptive TMD diagnoses contribute to the large variations observed in the literature over the last few decades. Manfredini and colleagues' study classified their subjects according to the Research Diagnostic Criteria for TMD (RDC-TMD), a dual-axis system that classifies TMD subtypes according to physical diagnoses as well as psychological aspects. Axis I diagnoses are divided into the following three groups [35]:

- Muscle diagnoses
    - Myofascial pain
    - Myofascial pain with limited opening
- Disc displacements
    - Disc displacement with reduction
    - Disc displacement without reduction, with limited opening
    - Disc displacement without reduction, without limited opening
- Arthralgia, arthritis, arthrosis
    - Arthralgia
    - Osteoarthritis of the TMJ
    - Osteoarthrosis of the TMJ

In their study, muscle disorder with limited opening (Group 1b) was found in 7.5% [2] of the patients which falls within the previously reported range of 2-30%[36]. If the condition

presents with concurrent moderate or severe depression, these patients are more likely to be distressed by headaches, a common finding in the TMD population and other non-specific pain conditions including heart, chest, lower back pain [37].

Disc-displacement (Group II diagnoses) occurred more commonly with the reduction subtype (Group IIa) reported to occur in about 27.6% for the left temporomandibular joint (TMJ) and 28.6% for the right joint [2]. Studies of the Swedish and Israeli populations reported prevalence rates within this range, however lower rates have been reported for the American and Asian populations. On the other hand, disc displacement without reduction, with or without limited opening (Groups IIb and IIc) were diagnosed in 1.5-8% of the population [2].

These diagnostic groups were described in detail by Manzione [38, 39] whose illustrations are reproduced in Figures 1-5.

If the elastic fibers of the posterior attachment (p) are functionally impaired, the disc (m), owing to a loss of elasticity and recoil within the posterior attachment, may become anteriorly displaced. The anteriorly displaced disc sits in the angle formed by the anterior border of the condyle and the articular eminence. When this occurs, the disc pushes the lateral pterygoid muscle and the lateral pterygoid fat pad out of this angle (Figure 1).

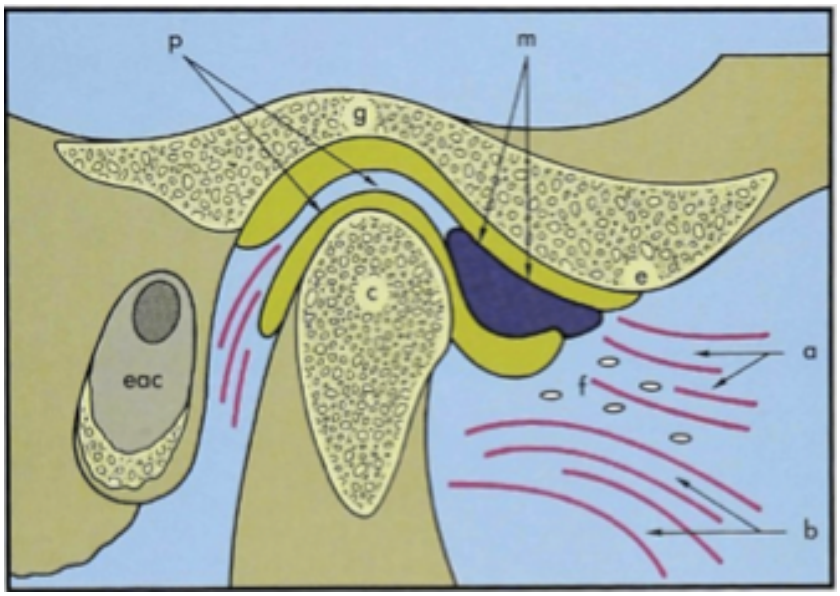


Figure 1. Closed mouth view. Anterior displaced disc.

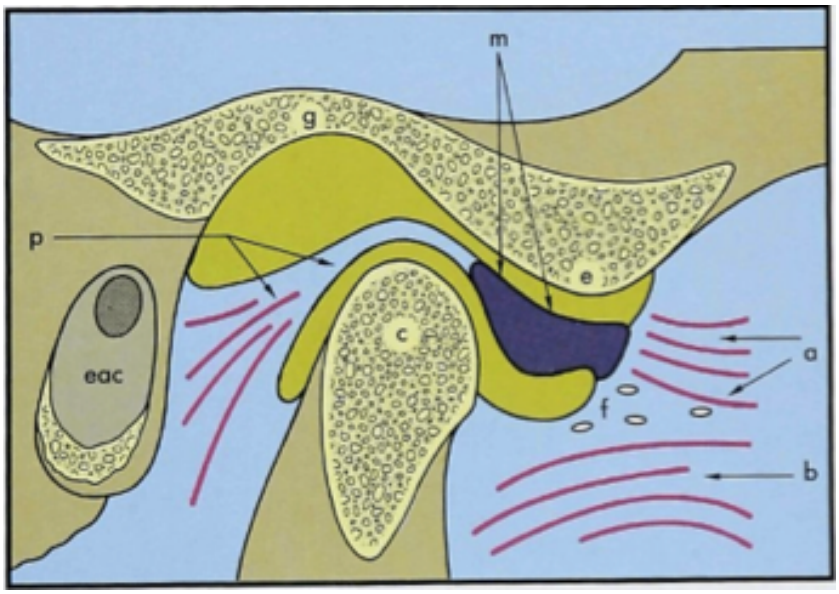


Figure 2. Open mouth view. Anterior displaced disc causing limited condylar translation.

The anteriorly displaced disc may mechanically limit the condylar translation (Figure 2). Clinically, the process will result in deviation of the mandible to the side of disc displacement. This occurs because the normal condyle will translate normally, and translation on the side of the displacement may be absent or only partial. The anteriorly displaced disc sits in the angle formed by the anterior aspect of the condyle and the articular eminence. The disc displaces the structures that normally are located within this angle (lateral pterygoid muscle and fat pad).

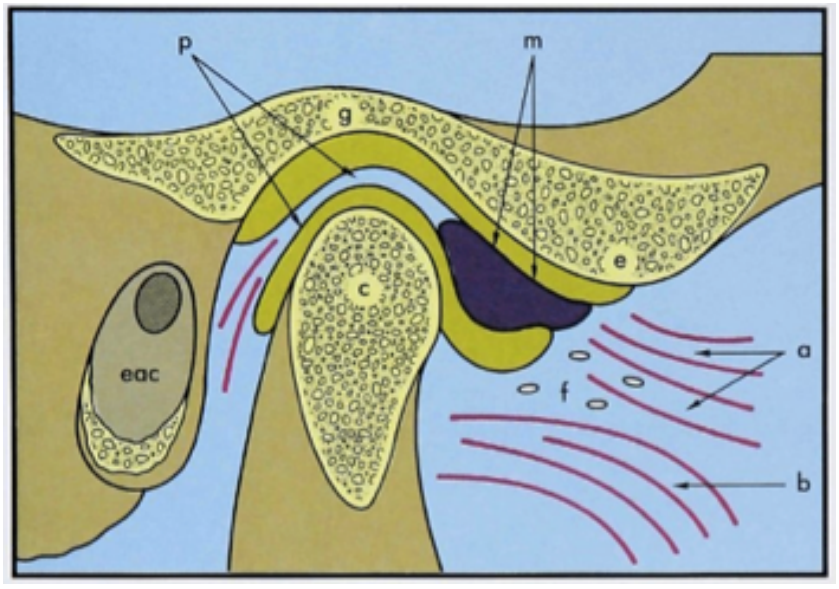


Figure 3a. Anterior disc displacement with reduction RDC-TMD Type IIa.

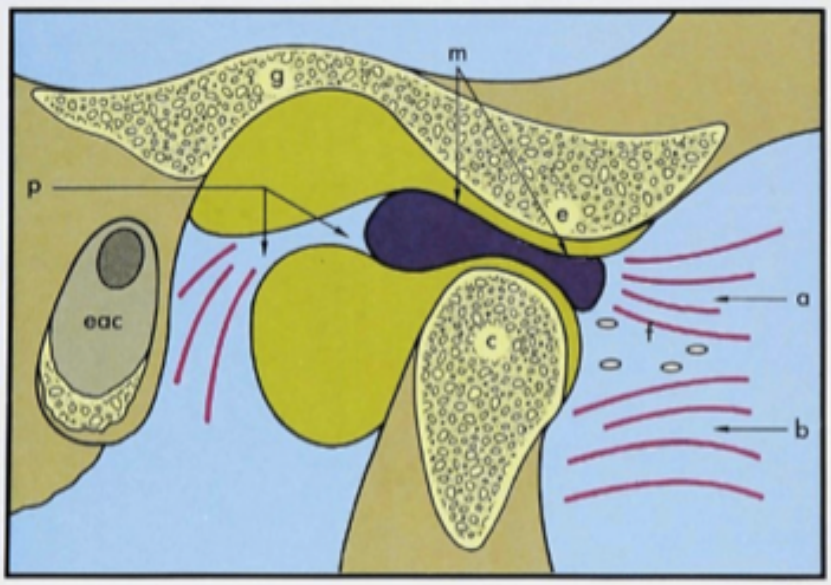


Figure 3b. Articular disc reduced on condylar surface.

An anteriorly displaced disc (Figure 3a) may move (reduce) onto the condylar surface during translation (Figure 3b). In this situation, the disc is displaced anteriorly when the condyle sits in the glenoid fossa (g) (closed mouth position) (Figure 3a). If the posterior attachment is only partially injured, it may contain enough elasticity to allow the disc to slip or reduce onto the condylar surface during translation. Once this occurs, the disc is in a normal relationship to the condyle (Figure 3b). Clinically, this event often corresponds to the palpable or audible opening click. During opening, the midline of the mandible may initially deviate to the side of the displacement owing to the limited condylar translation. Once the opening click occurs, the condyle is no longer mechanically limited by the displaced disc; therefore, translation becomes normal and the midline deviation is corrected. When the condyle moves from the opening to the closed position, at some point during closure position the disc falls anteriorly to the surface of the condyle. This corresponds in many patients to a closing or reciprocal click. This sequence of events is repeated during each opening and closing cycle.

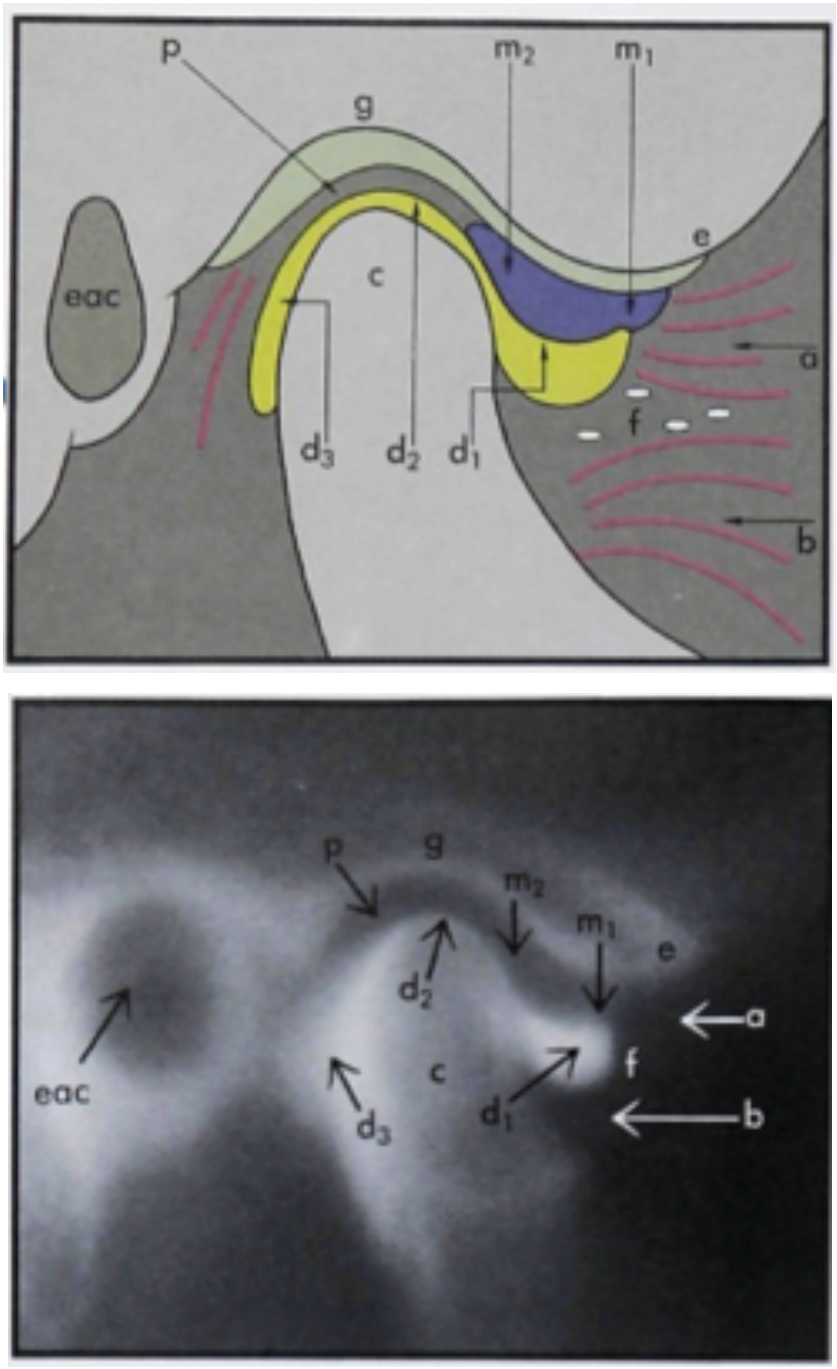


Figure 4. Top and bottom pictures. Anterior disc displacement without reduction (RDC-TMD Type IIb or c) - closed mouth.

Figure 4 demonstrates the features of an anterior displaced disc in the closed position. Note the abnormally elongated horizontally positioned anterior recess that is concave in its upper margin (d1). These findings contrast to the normal and indicate an anteriorly displaced disc.

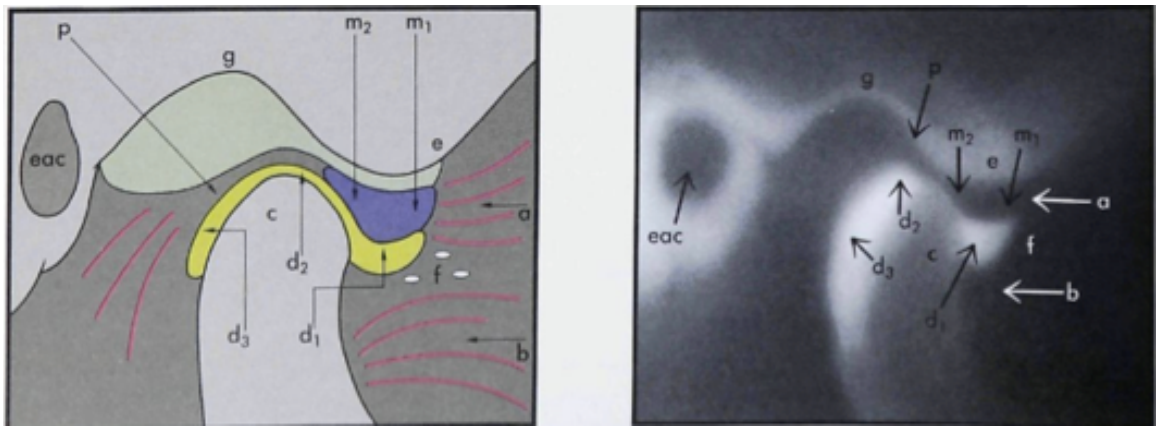


Figure 5. Anterior disc displacement without reduction (RDC-TMD Type IIb or c).

An open mouth view (Figure 5) indicates that only a limited amount of condylar translation has occurred, the anterior recess remains abnormally elongated, horizontally positioned, and concave in its upper region. The persistence of these abnormal findings involving the anterior recess as well as the absence of a normal concavity at the upper margin of the posterior recess (d2) indicates that the disc has remained anteriorly displaced. The displaced disc is mechanically limiting condylar translation.

Group III diagnoses were much more prevalent (81.4%) in Manfredini's study where arthralgia was found in about one third of cases and osteoarthritis/osteoarthrosis was found in one-fifth of study population [2]. The literature, according to the authors, reported a much lower rate (50%) for this subtype.

The variation observed between the reported frequencies of signs and symptoms may also be explained by the different study populations (e.g. random vs. non-random, patient vs. non-patient, different ages, age ranges, sample size, study methods).

Yap and colleagues [37] examined a Chinese cohort using a computer-aided diagnostic system (NUS TMD v1.1) and reported that the majority of TMD patients experience low disability (78.5%) with only 4.6% affected with high levels of disability and moderate limitation. Using a Jaw Disability Checklist, the three most frequent jaw disabilities reported were: eating hard foods, yawning and chewing [37].

Kohler and colleagues followed 100 individuals aged 3, 5, 10 and 15 year-old over a period of 20 years in a cross-sectional stratified epidemiological investigation [26]. TMD-related symptoms were rare in the 3-5 year-old group, whereas in the 10 and 15 year-old

groups, a rate of 5-9% was reported for severe symptoms and up to 50% showed one or more signs but only 1-2% required treatment. Over the observed period, the prevalence remained consistently associated with para-functional habits and general health factors.

Shiau and Chang [40] reported that 42.9% of 2033 Taiwanese students had TMD symptoms but a low treatment need. Concurrent contributory factors such as balancing contacts, dental restorations, molar guidance in eccentric movements were often found in the TMD group and are associated with higher scores for general anxiety, emotion and anger levels.

Conti and colleagues [27] reported a prevalence of the condition using a different severity classification, namely severe (0.65%), moderate (5.81%) and mild (34.83%) and found a significant association between severity and female gender, tension and para-functional habits. These reported prevalence rates are consistent with other cross-sectional studies [28, 29].

Manfredini and colleagues [2] reported that the cluster diagnosis of TMD (group II combined with others) was more commonly found in the younger age group (25-38 years of age) while group III diagnoses combined with others was associated with the older age group (over 52 years of age).

To appropriately interpret the prevalence data reported by Manfredini and colleagues the limitations of the study need to be understood. First, the single-center nature, and second, less importantly, the non-calibrated status of the main examiners but with known involvement in RDC/TMD projects for several years. This study also did not gather information on Axis II, psychological aspects of TMD, which we know plays a large role in designing each individual treatment plan.

1.4 ANATOMY OF THE MASTICATORY SYSTEM

Being one of the most complex joints in the body, the temporomandibular articulation is considered a ginglymoarthrodial joint which allows rotational and translational movements of the mandible against the cranium[5]. The presence of an articular disc permits complex movements of the condylar head against the glenoid fossa, and therefore also classifies the temporomandibular joint by function a compound joint[5].

1.4.1 Articular Disc

The articular disc is made up of fibrous connective tissue and is mostly denervated and avascular except at its periphery. Dimensionally, the disc is slightly larger on the medial aspect and from a sagittal plane, can be divided into three sections: Anterior, posterior and intermediate zones. Under functional demands, the disc is said to have the ability to accommodate for functional movements but this does not mean reversible morphological changes. On a biomechanical level, the disc morphology plays an important role in explaining its transition in relation to the condylar head during movements.

Disc attachments are via the superior and inferior retrodiscal laminae posteriorly and anterior collagenous attachments to the joint capsule, the temporal bone and the articular surface of the condyle and the tendinous fibers of the lateral pterygoid muscle (superior head). With the presence of the disc, the joint space is divided into a superior and an inferior space filled with synovial fluid, which serves as a lubricant during function as well as providing nutritional supply to the articular tissues.

The articular cartilage that covers the condylar head consists of four histologically different zones: Articular, proliferative, fibrocartilagenous and calcified layers which together are believed to better withstand the functional forces (compressive and lateral) and are also better able to repair and remodel in response to the effects of aging than hyaline cartilage (Figure 6).

Figure 6. Temporomandibular joint with disc. Sagittal cross section shows normal relationship of condyle to meniscus. Thickened anterior (arrowhead) and posterior (arrow) ridges. Adapted from Katzberg et al. 1980 [41]

1.4.2 Temporomandibular Joint Innervation

The TMJ is innervated by the auriculotemporal branch of the mandibular nerve (Trigeminal Nerve V), deep temporal and the masseteric nerves (Figure 7).

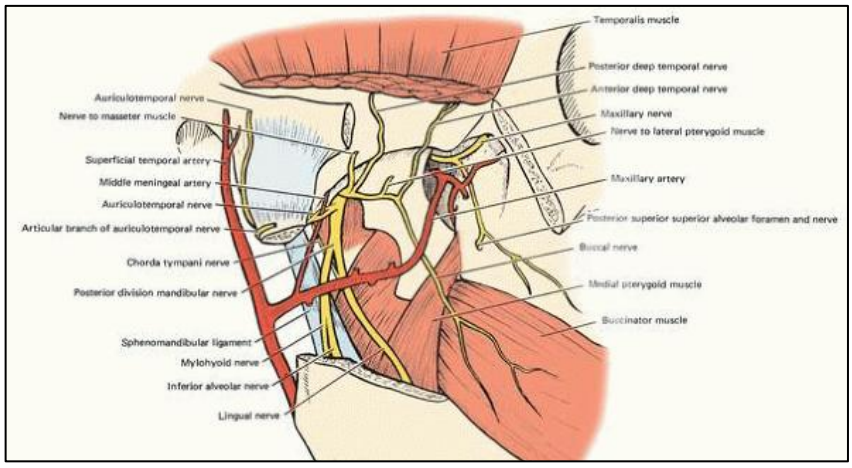


Figure 7. Trigeminal nerve supply for the TMJ. Source www.dentallecnotes.blogspot.com.au, accessed 1/10/2012.

1.4.3 Temporomandibular Joint Vascular Supply

The TMJ vascular supply comes from the surrounding vessels: the superficial temporal artery (from posteriorly), middle meningeal artery (from the anterior), and internal maxillary artery (from the inferior aspect). Other contributory vessels include the deep auricular, anterior tympanic and ascending pharyngeal arteries. Marrow spaces allow vascular supply from the inferior alveolar artery and other feeder vessels (Figure 8).

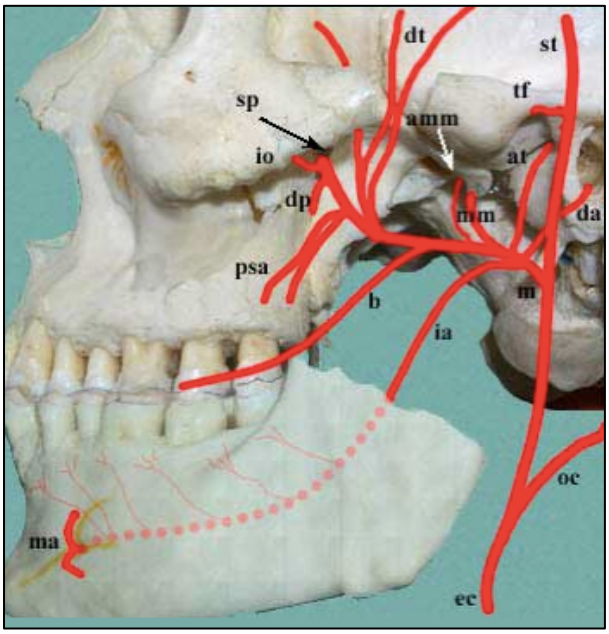


Figure 8. TMJ Vascular supply.
Source www. home.comcast.net,
accessed 1/10/12

1.4.4 Mandibular Ligaments

The TMJ is surrounded by three functional ligaments, namely: the collateral, capsular and temporomandibular ligaments and two accessory ligaments, sphenomandibular and stylomandibular ligaments. The main role of ligaments is to passively restrain and restrict extreme border joint movements (Figure 9).

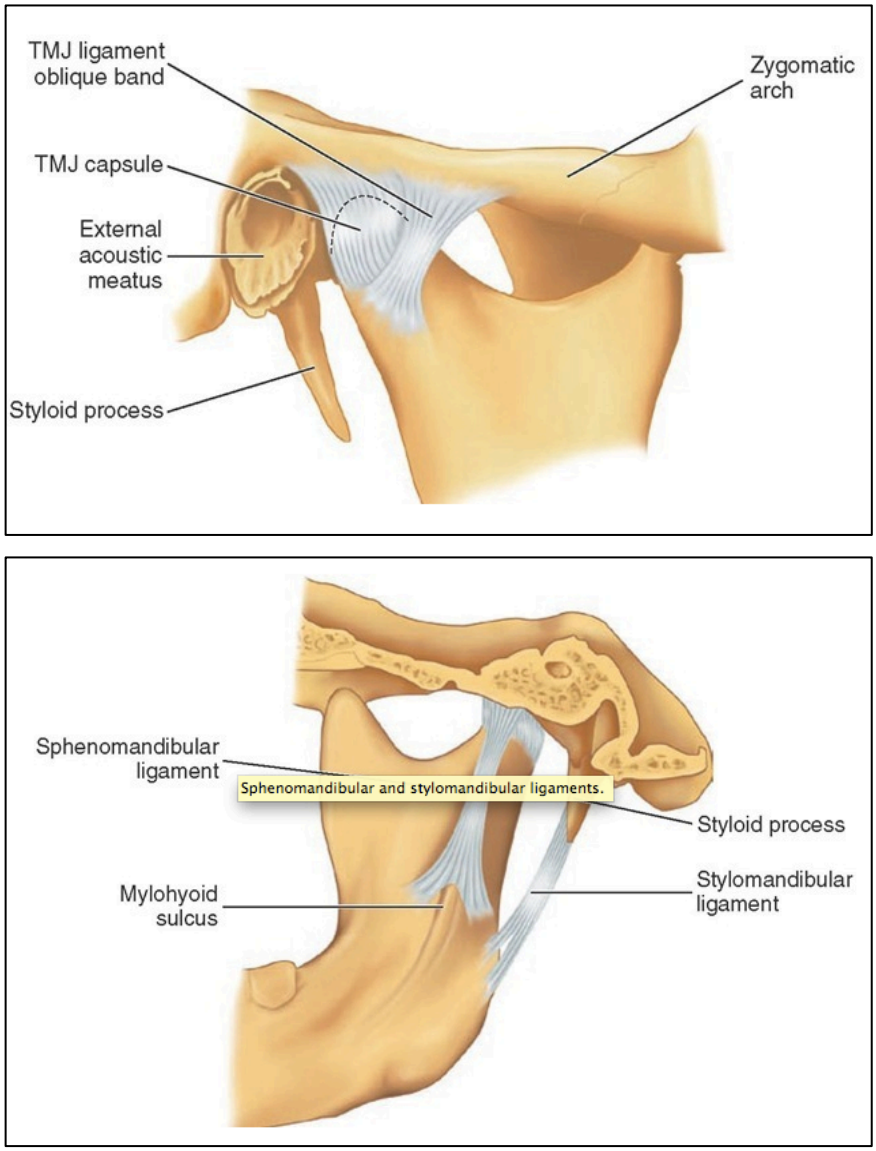


Figure 9. Mandibular ligaments.
Adapted from http://what-when-how.com/dental-anatomy-physiology-and-occlusion/the-temporomandibular-joints-teeth-and-muscles-and-their-functions-dental-anatomy-physiology-and-occlusion-part-1. Accessed 1/10/12.

1.4.5 Muscles of Mastication

A set of muscles (masseter, temporalis, medial and lateral pterygoid) surrounds each joint and affects its movements:

The diagrams (Figures 10 – 13) demonstrate the muscles of mastication.

The lateral pterygoids (Figures 10a, 10b, 10c) are predominantly (80%) slow muscle fibers (type I), which indicate their resistance to fatigue and support for condylar movements.

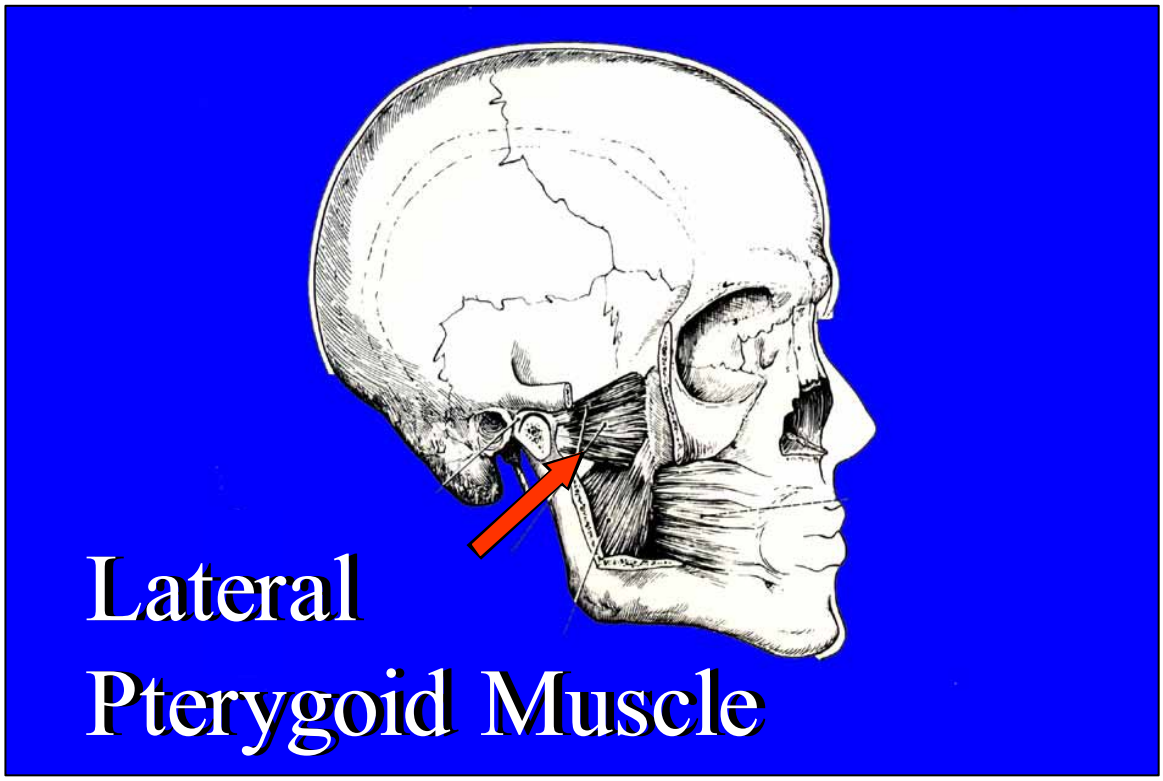


Figure 10a. Lateral pterygoid. Lateral view.

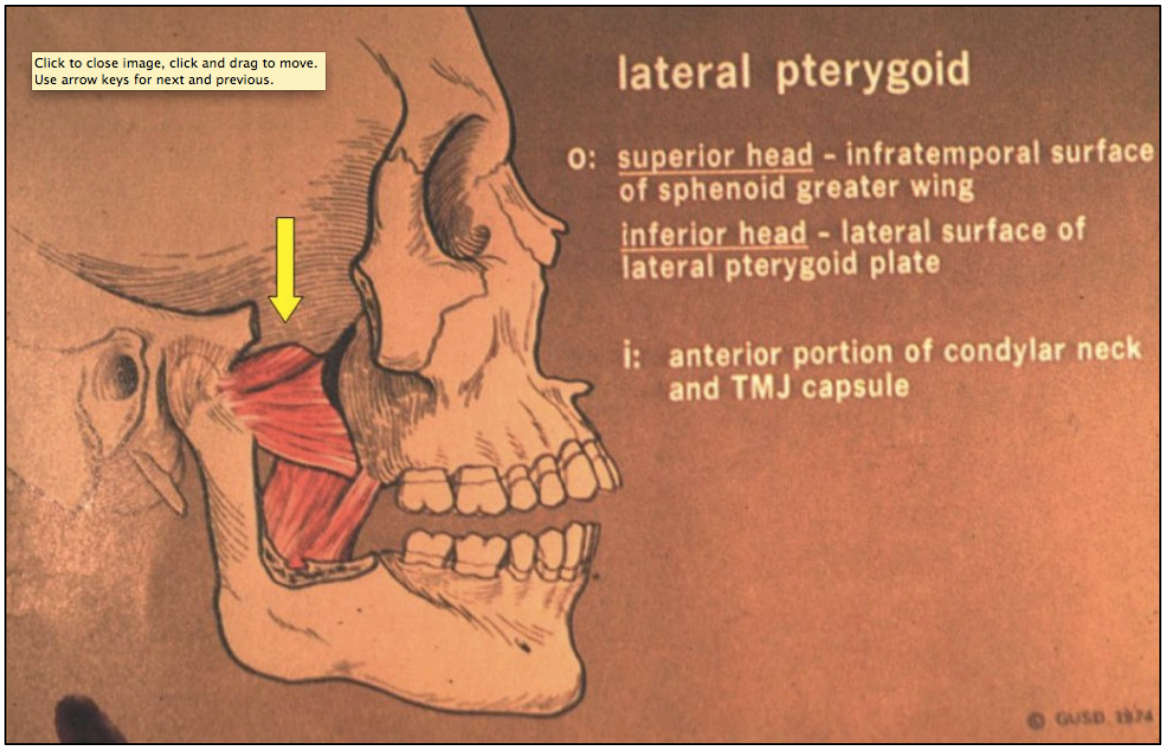


Figure 10b. Origins and insertion of lateral pterygoid muscle

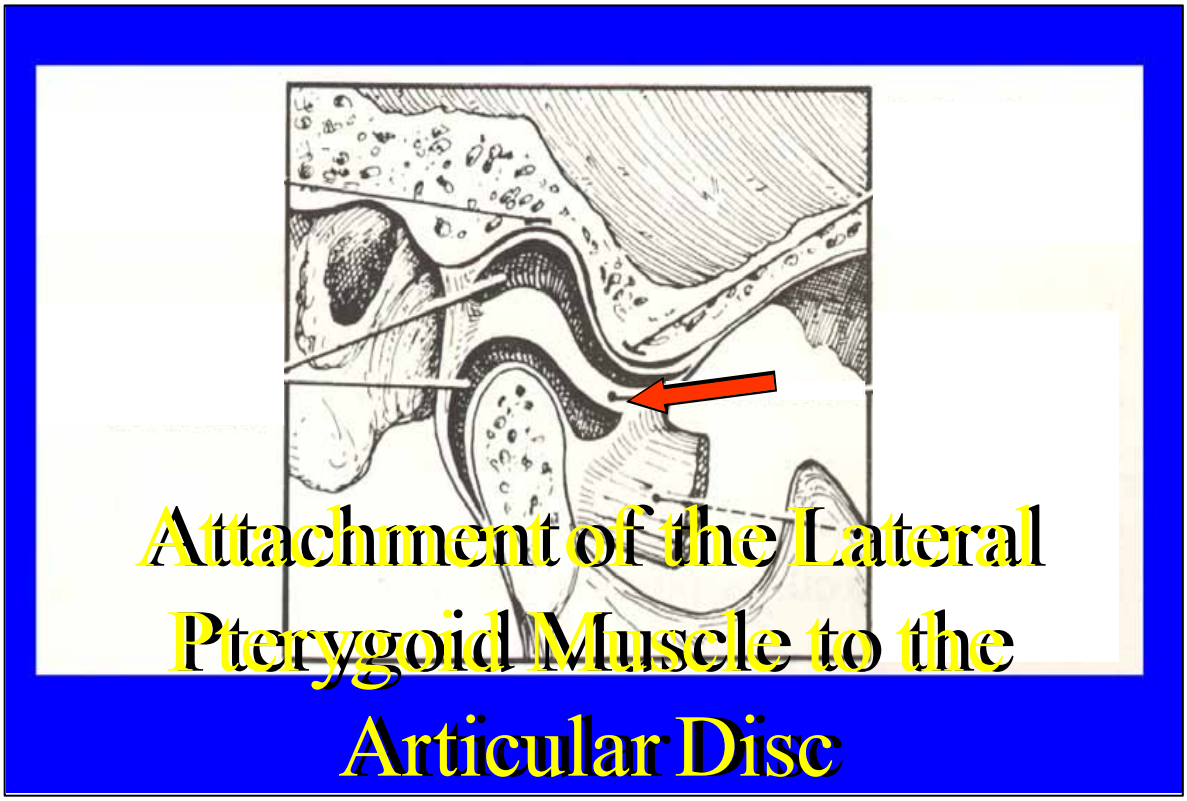


Figure 10c. Attachment of lateral pterygoid to disc. Sagittal view.

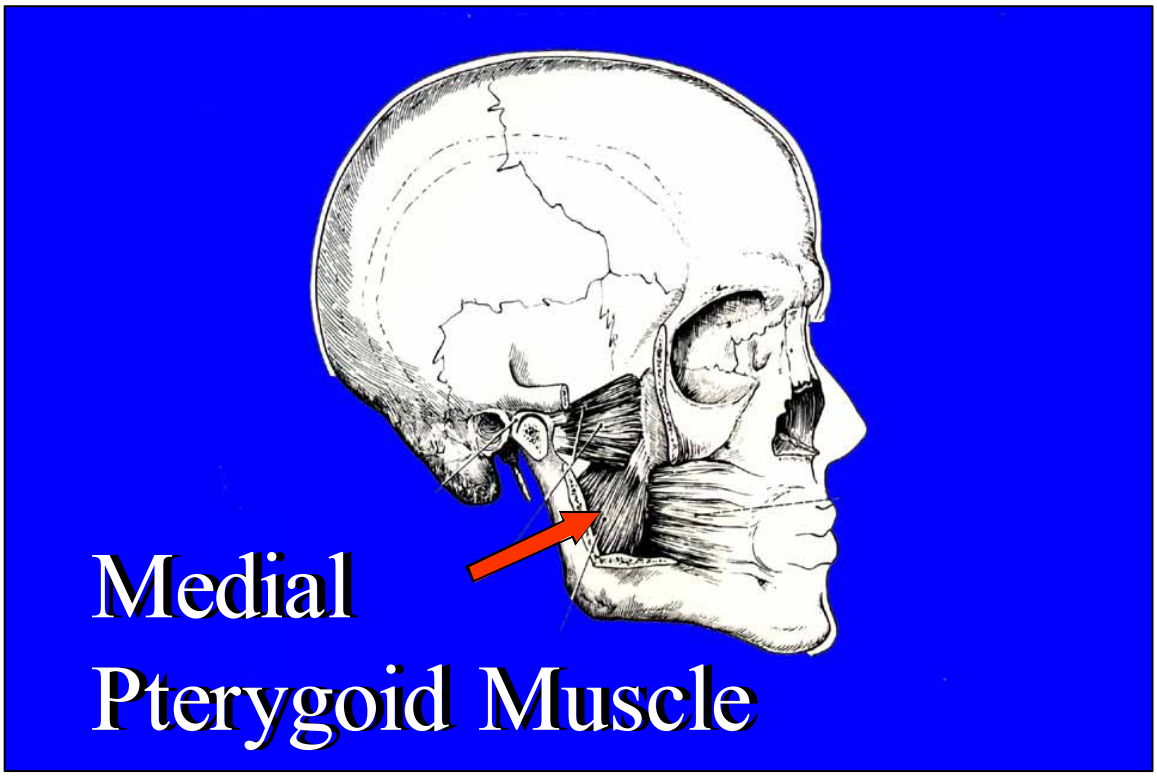


Figure 11a. Medial pterygoid. Lateral view.

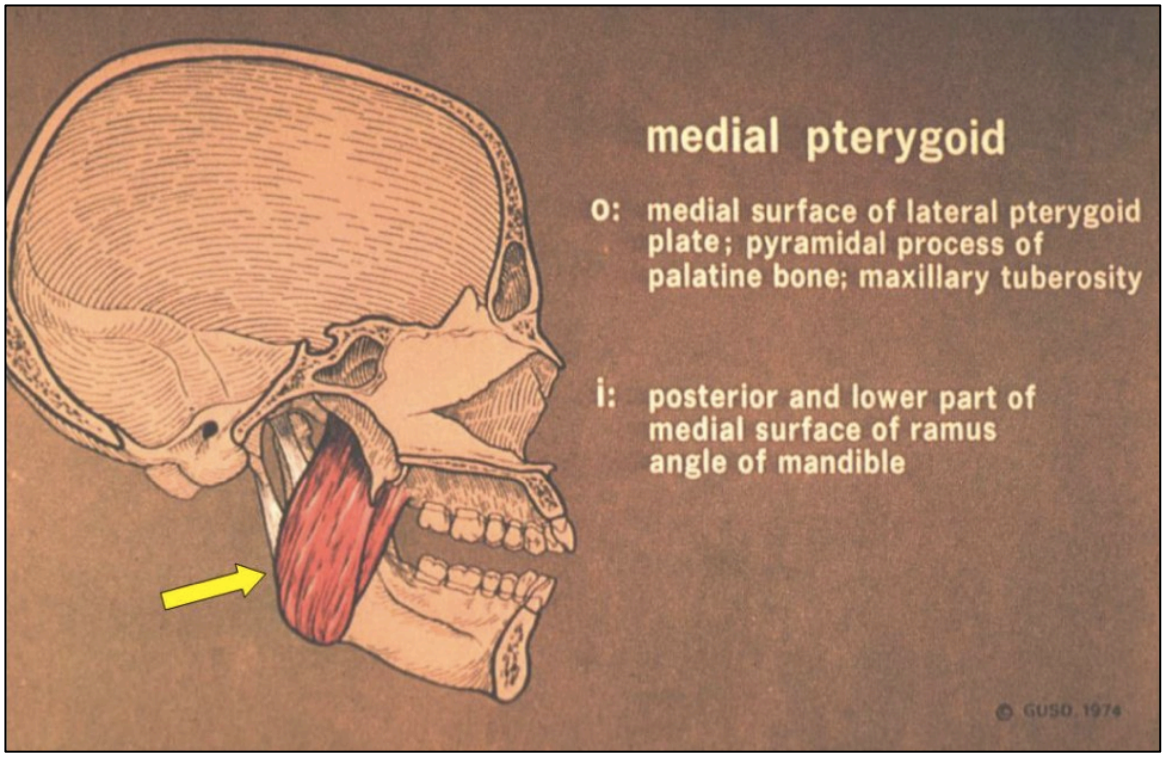


Figure 11b. Origin and insertion of medial pterygoid muscle

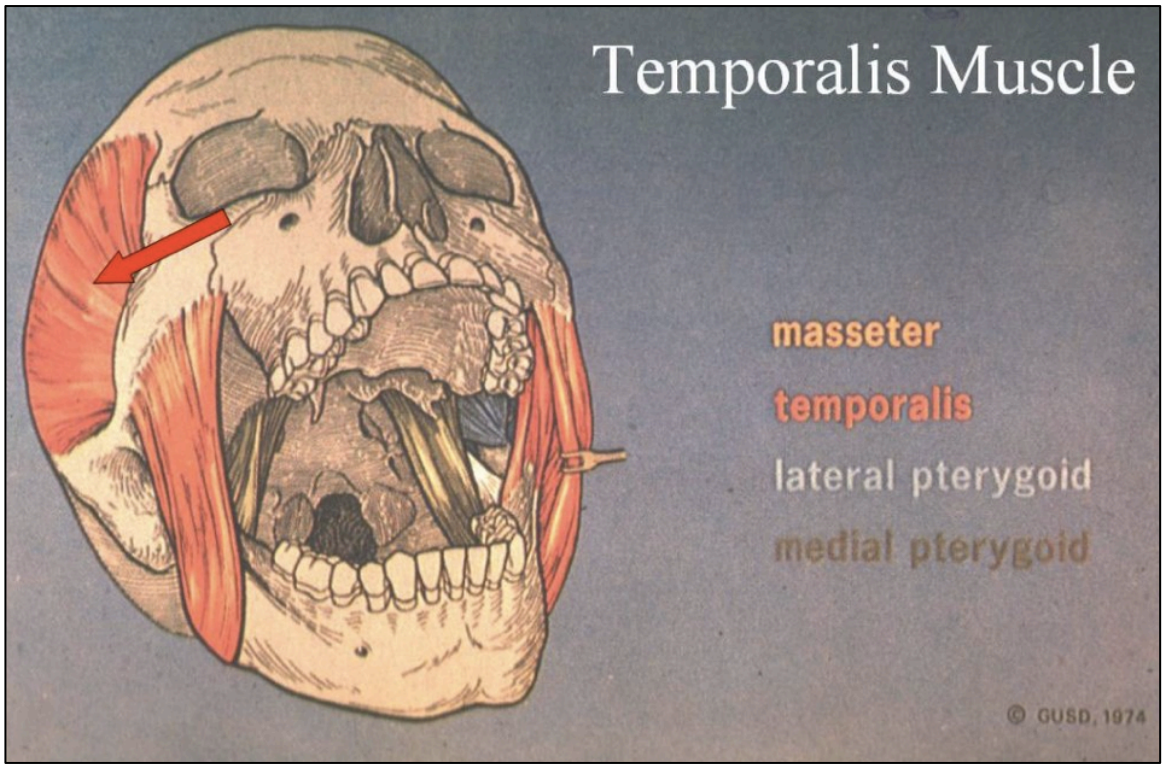


Figure 12. Temporalis muscle

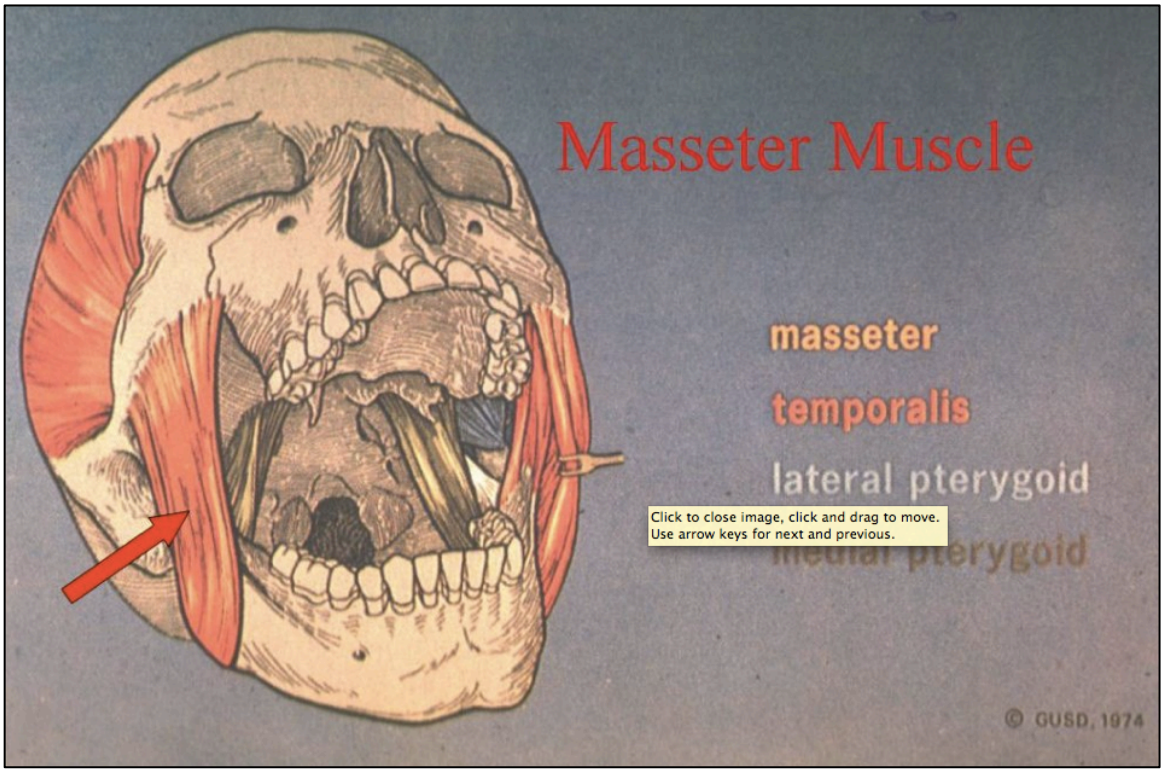


Figure 13. Masseter muscle
Adapted from http://sojinstitute.co.uk/PDFs/Occlusion/8Temporomandibular_Joint%20Problems.pdf Accessed 22nd April, 2012.

It is recognized that muscles below and above the hyoid bone, muscles of the cervical spine responsible for neck extension, and other anterior neck muscles such as the sternocleidomastoid muscles are also activated and involved in mandibular movements as part of the fine tuned dynamic between the neck and the head, therefore the effects of structures other than those in the immediate relations to the masticatory system should also be considered part of the TMJ complex.

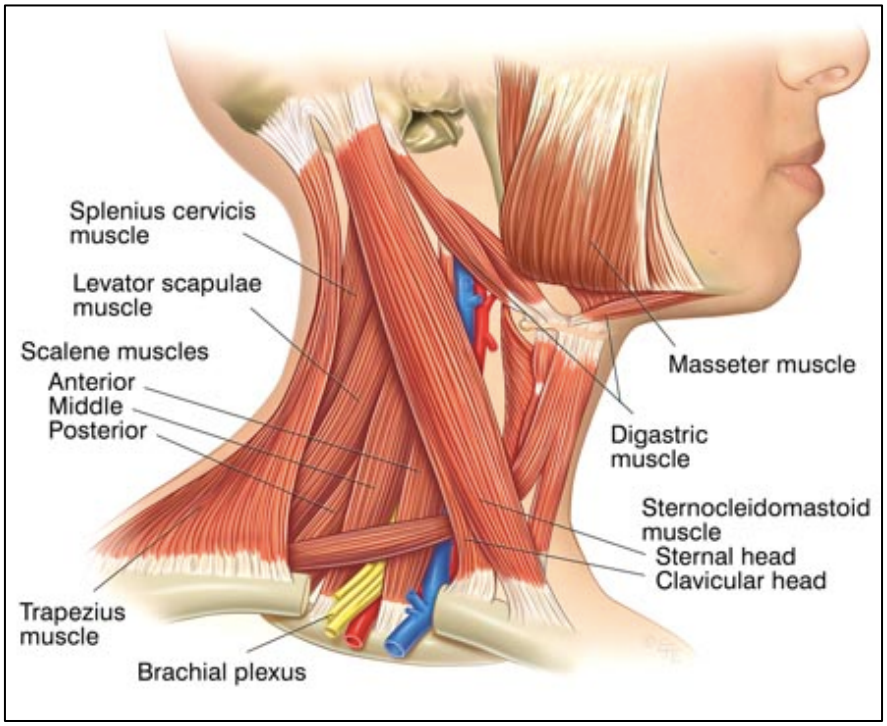


Figure 14. Neck muscles proximity to the TMJ complex.
Source: www.edoctoronline.com, accessed 1/10/12.

1.5 GENETICS

As every individual possess a different level of susceptibility to TMDs and variable outcomes to treatment on the basis of their familial risks, environmental and behavioral factors and genetic vulnerability, depicted by the diagram below [42] (Figure 15).

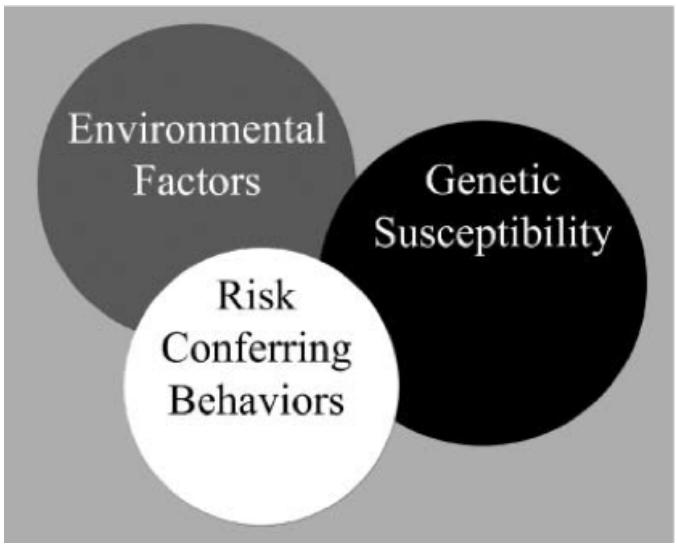


Figure 15. Interaction between environmental, behavioral and genetic influences.

In general, genetic influences may contribute to TMD presentations through the following mechanisms:

1. Gender and ethnicity
2. Perception of pain
3. Pro-inflammatory cytokines
4. Breakdown of extracellular matrix
5. Variation in genes expressed in TMJ tissues
6. Syndromes [43]

1.5.1 Genetics, Gender and Ethnicity

More females are affected by TMD than males, and so it is not surprising to see a plethora of research seeking to understand the link between gender and TMD [43-46]. Riberio-Dasilva and co-workers [46] studied the link between the estrogen receptor-α (ERα) (which is implicated to be associated with the pathophysiology of TMD) and gene polymorphisms Xba I and Pvu II single nucleotides on intron 1, chromosome 6 (Figure 16).

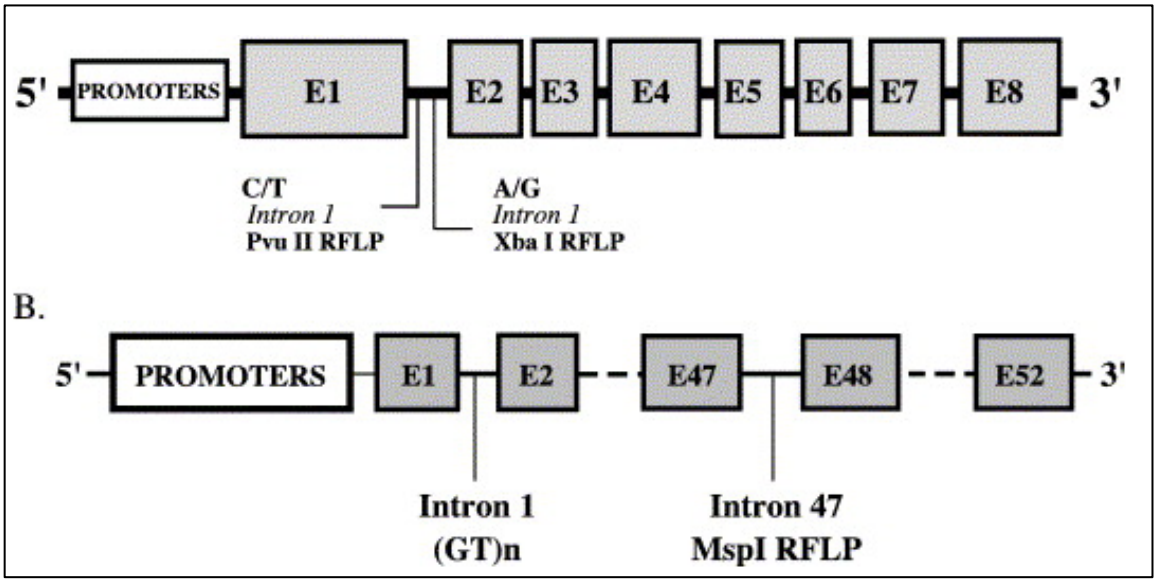


Figure 16. The structure of the ER and COL1A2 genes and the locations of the studied polymorphisms in the two genes.
Adapted from Lei et al [47].

These polymorphisms are now understood to affect mRNA production and thus transcription up-regulation, resulting in overexpression of ERα. The authors reported

genotype-linked increased risks odds ratio (OR) of 3.203 times for subjects with TMD symptoms and pain and of 2.51 for subjects with TMD without pain compared to controls subjects (no TMD diagnoses). In testing this theory, the authors speculated that sex differences where females have a higher tendency for inflammatory conditions such as osteoarthritis, rheumatoid arthritis and greater sensitivity to experimental pain response compared to men indicate that there is a possibility of difference in pain processing between women and men. These polymorphic sites are the most studied nucleotides on the estrogen receptor-α where they had been linked to higher prevalence of arthritis and skeletal changes in females with osteoarthritic temporomandibular joints. The theory supporting the involvement of gonadal hormones is further supported by TMD prevalence in young adults and teenagers before pubertal changes. Steroid hormones are said to act on peripheral and central receptors (alpha and beta) and also produce effects on the inflammatory process and central pain transmission. They affect monocytes and macrophages and regulate the production of cytokines such as interleukin-1, interleukin-6, tumor necrosis factor- α. The presence of these cytokines in the joint synovium during inflammation and their roles in promoting cartilage reabsorption, inhibiting proteoglycans and promoting inflammation in the TMJ have been suggested in the literature [46]. The authors speculated that estrogen might have a functional role after trauma or significant change where the risk is then increased. However, a more recent study reported by Kim and colleagues [44] did not find any statistical differences between TMD and control subjects in the distribution of ERα haplotypes nor any association with specific TMD symptoms. The authors suggested that future research studies on TMD and ERα should be more comprehensive and include other genetic factors that might explain the higher female risk factors in TMD population. Evidence to support the role of ethnicity as a factor in variation in pain perception to hot/cold stimuli comes from a study of experimentally induced pain study which found differences were to related to the delta opioid receptor subtype 1 (OPRD1) [48].

1.5.2 Genetics and Pain Perception

Studies on human susceptibility to pain, pain perception and chronic pain development target several areas of human genetics. The catechol-O-methyltransferase (COMT) genotypes are one of these [49, 50]. COMT is a key enzyme that metabolizes catecholomine, involved in regulation of pain perception, cognitive function and mood. The genetic

variations coded at valine-methionine (val/met) amino acid 108/158 in the soluble or membrane bound COMT proteins affects the rate of reduction of COMT activity (Figure 17) . Thus higher COMT activity equates to more rapid metabolism of catecholamines (val/val genotype) and slower metabolism occurs with met/met genotype, resulting in prolonged presence of catecholamines thus exposing the central dopaminergic and noradrenergic transmission in higher brain centres to experience greater pain sensory and affective information content (Figure 17). Women are known to have 20-30% lower COMT activity than men, consistent with greater prevalence and severity of TMD [42]. Reports suggest that carriers of low-pain haplotype on the gene coding COMT appear to have less risk of developing myogenous TMD by as much as 2.3 times [43]. Other "pain genes" which express functional proteins MCR1, OPRM1, HTR2A, IL-1A, IL-1RN, ATP1A2, IL-10, MBL2, ADRB2 have been identified through animal studies and conditions such as fibromyalgia, irritable bowel syndrome, low back pain, idiopathic migraine, pelvic pain syndrome and vulvar vestibulitis which have been suggested as possible cause for individual variation in pain perception in TMD population [45].

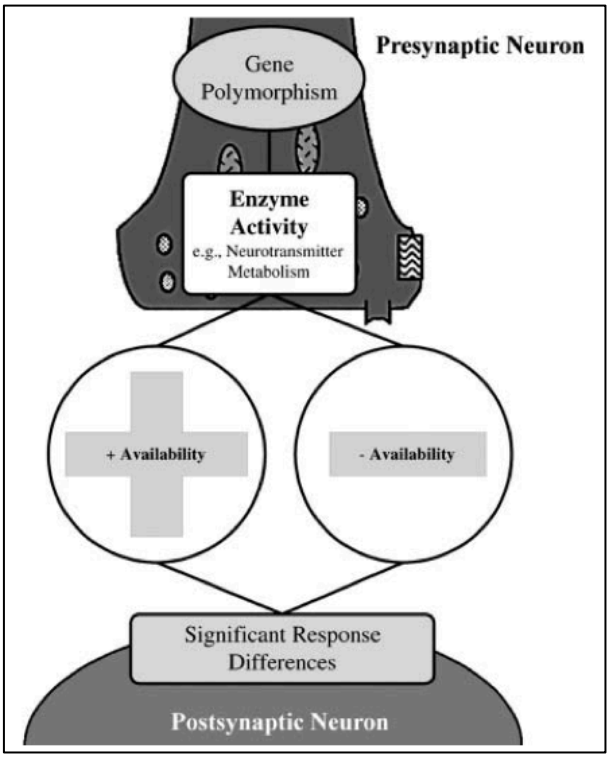


Figure 17. Genetic variations. Consequential changes to downstream neurotransmitter availability and effects. Adapted from Stohler 2004.

1.5.3 Genetics and Pro-inflammatory Cytokines

Early studies on immune-related markers investigated the possible role of human-leukocyte antigens (HLA) (major histocompatibility complex) in inflammation but these studies were inconclusive. Recent research focus has been on immune-inflammatory genes such as those of IL-6, IL-1B, TNF-α in rats and their roles in synovial changes and other studies on enzymes that affect the extracellular matrix collagen and proteoglycans (MMP2, MMP9, aggrecanase) which are potential biomarkers for articular degeneration[45].

1.5.4 Genetic Variants

Relationships between genetic variants and disease can be investigated using family aggregation studies. A study of TMD signs and symptoms in monozygotic and dizygotic twins reared together and reared apart revealed negligible genetic and environmental effects on TMD signs and symptoms. Any variations within twin pairs was found to be the result of the unique environmental influence acting on the individuals [51]. On the other hand, through studies on wild-type mouse embryos and rats, specific genes expressed in the TMJ such as the Indian hedgehog, AQP3 (Aquaporin 3), SPP2 (secreated phosphoprotein 2), NOV (nephroblastoma overexpressed gene), DKK3 (dickkopf homolog 3 (Xenopus laevis) and EGLN3 [(egl nine homolg3 (Caenorhabditis elegans)] have been identified and suggested to have some influence on the progression and remodeling capacity of the condylar head and cartilage [52, 53].

Researchers on genetics and TMD have also sought to understand the link between syndrome presentations and TMD phenotypes [45] (Tables 2 and 3). Accordingly, there are seven syndromes that include TMDs displayed in the Online Mendelian Inheritance in Man (OMIM) database and only four of these have had genes mapped. Anterior disc displacement is a common finding in hypermobile joint syndrome such as Ehlers-Danlos (OMIM 147900) [54], whereas in Hallemann-Streiff syndrome (OMIM 234100) the common feature is a partial inability to open the mouth (mandibular joint range restriction) due to hypo-development and cervical soft tissue restriction.

A table of OMIM TMD syndromes is shown below:

Table 2. TMD syndromes (OMIM)

Source: Oakey and Viera, 2008 [45]

Syndrome	Main clinical characteristics	Gene (locus)
Auriculocondylar syndrome (%602483)	Bilateral external ear malformations and hypoplastic mandible	–
Ehlers-Danlos syndrome type III (#130020)	Benign joint hypermobility without skeletal deformity	*COL3A1* (collagen type III alpha 1; 6p21.3) and *TNXB* (tenascin XB; 2q31)
Ehlers-Danlos syndrome type VIII (%130080)	Skin lesions in association with periodontal disease leading to early loss of teeth	–
Fibrodysplasia Ossificans Progressiva (#135100)	Intermittently progressive ectopic ossification and malformed big toes	*ACVR1* (activin A receptor type I; 2q23–q24)
Ophthalmomandibulomelic Dysplasia (%164900)	Eye, mandible, and limb anomalies	–
Schwartz-Jampel syndrome type I (#255800)	Short stature, myotonic myophaty, dystrophy of epiphyseal cartilages, joint contractures, eye anomalies	*HSPG2* (heparin sulfate proteoglycan 2; 1p36.1)
Tight Skin Contracture syndrome, Lethal (#275210)	Restrictive dermopathy	*LMNA* and *ZMPSTE24* (lamin A/C and zinc metallopeptidase STE24 homolog of *Saccharaomyces cerevisiae*, respectively; 1p34)

Table 3. Candidate genes of current and past researches published in the literature

Adapted from Oakey and Viera, 2008 [45]

Table 1. **Summary of candidate genes for TMD**

Gene	Locus	Protein function*
OPRD1	1p35.3	Opioid receptor
ATP1A2	1q23.3	Responsible for establishing and maintaining the electrochemical gradients of Na and K ions across the plasma membrane
PTGS2	1q25.2–q25.3	Involved in prostaglandin biosynthesis
IL10	1q32.1	Involved in immunoregulation and inflammation
IL1B	2q13	Mediator of the inflammatory response, and is involved in a variety of cellular activities, including cell proliferation, differentiation, and apoptosis
IL1A	2q13	Involved in various immune responses, inflammatory processes, and hematopoiesis
IL1RN	2q13	Inhibits the activity of IL1A
IHH	2q35	Defines a variety of patterning events during development by intercellular signaling
CCL20	2q36.3	Regulates mitogenic signaling
SPP2	2q37.1	May coordinate an aspect of bone turnover
CXCL3	4q13.3	Chemokine ligand that has chemotactic activity for neutrophils
CXCL2	4q13.3	Suppresses hematopoietic progenitor cell proliferation
IL8	4q13.3	Mediator of inflammatory response
ADRB2	5q33.1	Beta-2-adrenergic receptor
OPRM1	6q25.2	Opioid receptor
IL6	7p15.3	Plays an essential role in the final differentiation of B-cells
NOV	8q24.12	Likely plays a role in cell growth regulation
AQP3	9p13.3	Water channel protein
MBL2	10q21.1	Activates the classical complement pathway and recognizes mannose and *N*-acetylglucosamine on bacterial pathogens
DKK3	11p15.3	Inhibitor of the Wnt signaling pathway
HTR2A	13q14.2	Serotonin receptor
EGLN3	14q13.1	Catalyzes the post-translational formation of 4-hydroxyproline in hypoxia-inducible factor alpha proteins
CYP19A1	15q21.1	Catalyzes many reactions involved in drug metabolism and synthesis of cholesterol, steroids, and other lipids
BCL2A1	15q25.1	Reduces the release of pro-apoptotic cytochrome *c* from mitochondria and block caspase activation
MC1R	16q24.3	Receptor protein for melanocyte-stimulating hormone
SLC6A4	17q11.2	Integral membrane protein that transports serotonin from synaptic spaces into pre-synaptic neurons
CCL7	17q12	Attracts macrophages during inflammation and metastasis
CSF3	17q21.1	Controls the production, differentiation, and function of granulocytes
BCL2	18q21.33	Blocks apoptotic death of some cells such as lymphocytes
CACNA1A	19p13.13	Mediates the entry of calcium ions into excitable cells of the neuronal tissue
INSR	19p13.2	Insulin receptor
BAX	19q33.3	Apoptotic activator
CYP2D6	22q13.1	Catalyzes many reactions involved in drug metabolism and synthesis of cholesterol, steroids, and other lipids
MMPs	–	Collectively they are capable of degrading all kinds of extracellular matrix proteins
ADAMTs	–	Collectively they contribute to inflammation and cancer

*Information obtained from the UCSC Genome Bioinformatics (http://genome.ucsc.edu) and National Center for Biotechnology Information (http://www.ncbi.nlm.nih.gov).

1.6 TMD CLASSIFICATIONS

As variable as the theories behind TMD aetiologies are, many authors have attempted to classify the condition based on the prevailing knowledge and belief of the time. To have a thorough understanding of the contributions that past clinicians and researchers have made, it requires an awareness of the evolution of TMD taxonomy [55].

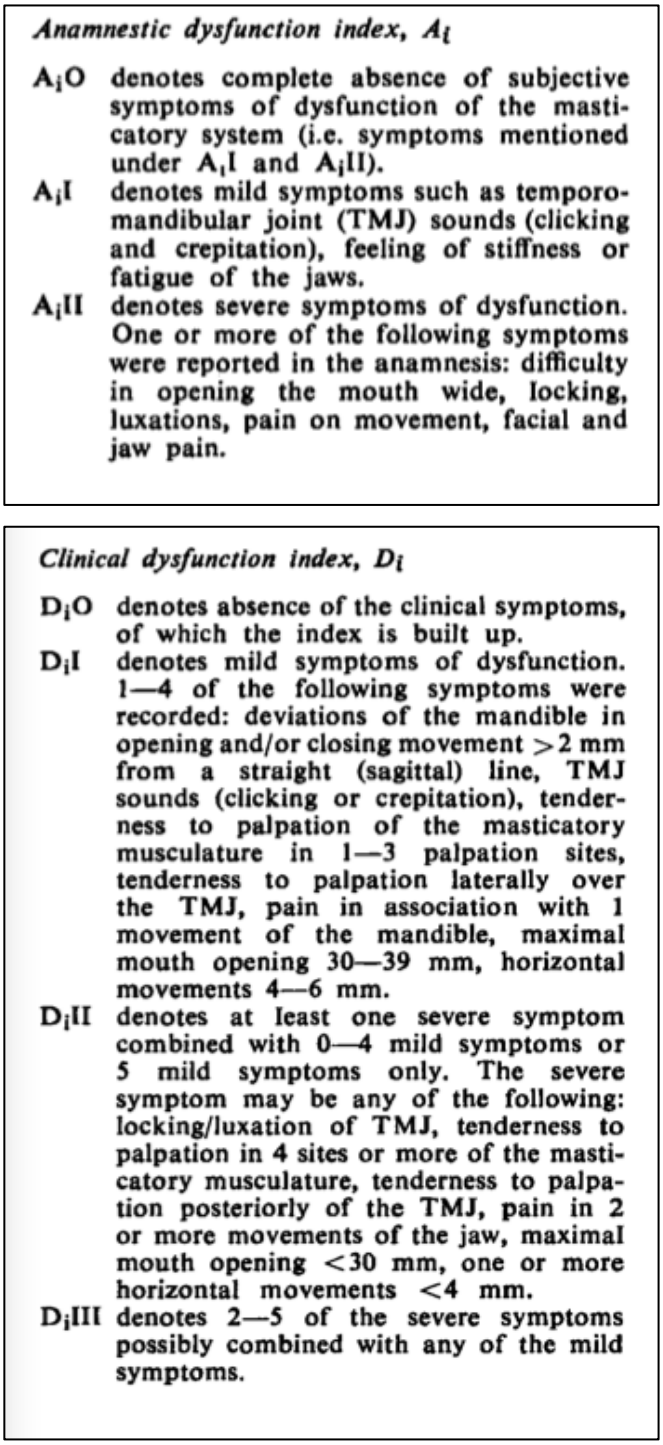
Weinmann and Sicher proposed the first classification scheme in 1951 which categorised TMJ problems into (i) vitamin deficiencies (ii) endocrine disorders and (iii) arthritis [56]. At

about the same time Schwartz (1956) suggested the term "temporomandibular joint-pain-dysfunction syndrome" based on his appreciation of the involvement of intracapsular and muscular factors in the aetiology of the condition [57]. A review by Poveda Roda and colleagues [58] provides an overview of the classification systems over the years.

One of the earlier classifications was proposed by Farrar in 1972. This incorporated eight dimensions of musculoskeletal dysfunction: Masticatory muscle hyperactivity, capsulitis and synovitis, rupture or distension of the capsular ligaments, anterior disc displacement, muscle incoordination, and reduction of the mandibular movement range secondary to degenerative joint disease. Compared with earlier classifications this system provides additional information but does not address painful muscle disorders. In 1980, another classification was proposed by Block which brought myofascial pain dysfunction in line with other musculoskeletal conditions based on medical models from neurology and orthopedics.

Work by Bell in 1960 instigated a review by the American Dental Association and subsequently a national conference during which the terminology and classification for "temporomandibular disorders", suggested by Bell, were approved [56]. W.E Bell developed a classification system based on orthopedic-mechanical model of masticatory pain, restriction of mandibular movements, joint interference during mandibular movements, and acute malocclusion with underlying pathological processes myositis, muscle spasm, myofacial pain, late-onset muscle irritation and protective co-contraction or protective stiffness.

The Helkimo Index was constructed in 1974 in which amnestic and clinical scores are used at a population level and not designed to predict treatment outcome [59, 60]. It assesses the prevalence and severity of TMJ symptoms in mandibular pain and occlusal instability and is specific in identifying non-TMD subjects within a population. However, it has been noted that the Index does not separate articular from muscular conditions, and it is not sensitive enough to detect small changes in severity. Additionally it places unequal weighting on different signs and thus difficult to calibrate and score [60]. Criteria from this index are reproduced in Figure 18.



Anamnestic dysfunction index, A_i

A_iO denotes complete absence of subjective symptoms of dysfunction of the masticatory system (i.e. symptoms mentioned under A_iI and A_iII).

A_iI denotes mild symptoms such as temporomandibular joint (TMJ) sounds (clicking and crepitation), feeling of stiffness or fatigue of the jaws.

A_iII denotes severe symptoms of dysfunction. One or more of the following symptoms were reported in the anamnesis: difficulty in opening the mouth wide, locking, luxations, pain on movement, facial and jaw pain.

Clinical dysfunction index, D_i

D_iO denotes absence of the clinical symptoms, of which the index is built up.

D_iI denotes mild symptoms of dysfunction. 1—4 of the following symptoms were recorded: deviations of the mandible in opening and/or closing movement >2 mm from a straight (sagittal) line, TMJ sounds (clicking or crepitation), tenderness to palpation of the masticatory musculature in 1—3 palpation sites, tenderness to palpation laterally over the TMJ, pain in association with 1 movement of the mandible, maximal mouth opening 30—39 mm, horizontal movements 4—6 mm.

D_iII denotes at least one severe symptom combined with 0—4 mild symptoms or 5 mild symptoms only. The severe symptom may be any of the following: locking/luxation of TMJ, tenderness to palpation in 4 sites or more of the masticatory musculature, tenderness to palpation posteriorly of the TMJ, pain in 2 or more movements of the jaw, maximal mouth opening <30 mm, one or more horizontal movements <4 mm.

D_iIII denotes 2—5 of the severe symptoms possibly combined with any of the mild symptoms.

Figure 18. Helkimo Index

Fricton and Schiffman developed the craniomandibular index (CMI) (Table 4), which uses clearly defined criteria and simple clinical methods [60]. The CMI is a good measure of global severity of a craniomandibular problem, whereas the subscales of dysfunction and palpation indices are more specific to the diagnoses. The authors demonstrated a construct and criterion validity of the index for clinical research but advised strict methodological compliance with the application especially in a multi-raters setting. The tables below are examples of criteria for assessment and scoring of the CMI.

Table 4. Craniomandibular Index

Adapted from Fricton and Schiffman, 1987 [60]

Scales	Method	Range
Dysfunction index (DI)	DI = (MM + TM)/26	0-1
Mandibular movement (MM)	No. of positive responses	0-16
TMJ noise (TN)	No. of positive responses	0-4
TMJ capsule palpation (TM)	No. of positive responses	0-6
Palpation index (PI)	PI = (EM + NM + IM)/36	0-1
Extraoral jaw muscle palpation (EM)	No. of positive responses	0-18
Intraoral jaw muscle palpation (IM)	No. of positive responses	0-6
Neck muscle palpation (NM)	No. of positive responses	0-12
Craniomandibular index (CMI)	CMI = (DI + PI)/2	0-1

Temporomandibular index TMI- Operational definitions for CMI were redesigned recently to conform precisely to those RDC-TMD and resulted in a clinical evaluation protocol, the TMI that is expected to be similar in producing diagnostic outcomes as the Research Diagnostic Criteria for Temporomandibular disorders. The evolution of TMD taxonomy is depicted in the diagram below (Figure 19):

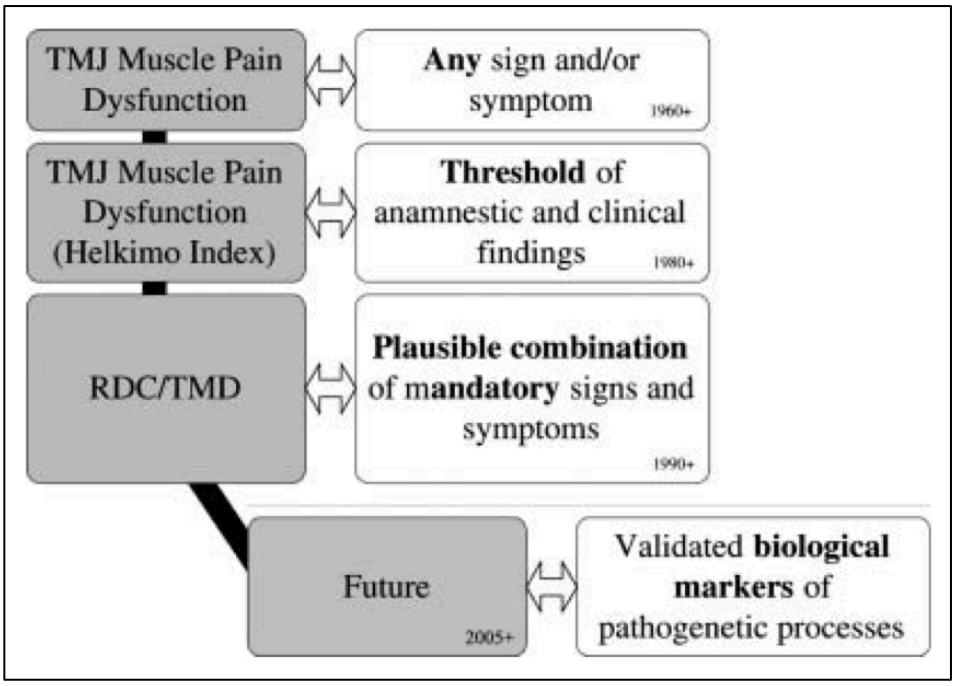


Figure 19. Evolution of TMD taxonomies.

Adapted from Stohler, 2004.

In 1986 the International Association for the Study of Pain (IASP) published a classification describes temporomandibular pain and dysfunction syndrome and osteoarthritis of the TMJ under craniofacial pain of musculoskeletal origin but failed to highlight pain arising from masticatory muscles [56].

The American Academy of Craniomandibular Disorders (AACD) in 1988 proposed integration of TMD and headache in the International Headache Society (IHS) classification (section 11.7) and an updated version of this classification is included in Table 5.

Table 5. ICHD-II

Adapted from Schiffman et al, 2012 [61]

Table 2. ICHD-II (11.7) Diagnostic criteria for *Headache or facial pain attributed to temporomandibular joint (TMJ) disorder* (2004).

Diagnostic criteria

A. Recurrent pain in one or more regions of the head and/or face fulfilling criteria C and D.
B. MRI and/or scintigraphy demonstrate TMJ disorder.
C. Evidence that pain can be attributed to the TMJ disorder, based on at least one of the following:
   1. Pain is precipitated by jaw movements and/or chewing of hard or tough food.
   2. Reduced range of or irregular jaw opening.
   3. Noise from one or both joint capsule(s) of one or both TMJs.
   4. Tenderness of the joint capsule(s) of one or both TMJs.
D. Headache resolves within three months, and does not recur, after successful treatment of the TMJ disorder.

ICHD-II: International Classification of Headache Diseases, 2nd edition.

A recent published report from Schiffman and colleagues [61] demonstrated that diagnostic accuracy and higher sensitivity and specificity were achieved using a revised version of the IHS-ICHD-II criteria (Table 6), proposed by Olesen and colleagues in 2009.

Table 6. Olesen diagnostic criteria for secondary headaches

Adapted from Schiffman et al., 2012 [61]

General diagnostic criteria for secondary headaches proposed by Olesen and colleagues (2009)

Diagnostic criteria

A. Headache of any type fulfilling criteria C and D.
B. Another disorder scientifically documented to be able to cause headache has been diagnosed.
C. Evidence of causation shown by at least two of the following:
   1. Headache has occurred in temporal relation to the onset of the presumed causative disorder.
   2. Headache has occurred or has significantly worsened in temporal relation to worsening of the presumed causative disorder.
   3. Headache has improved in temporal relation to improvement of the presumed causative disorder.
   4. Headache has characteristics typical of the causative disorder.
   5. Other evidence exists of causation.
D. The headache is not better accounted for by another headache diagnosis.

Another group of authors, Talley and colleagues, in 1990 [62] published a position paper offering a new classification system of five TMD categories, and two non-TMD categories. Traditional and nontraditional disorders were included with brief explanations but without diagnostic criteria. In 1992, Truelove and colleagues [63] proposed the Clinical Diagnostic Criteria for Temporomandibular Disorders which defined clinical conditions into structural etiologies: Muscular, articular degeneration, intra-articular disc and joint capsule. This classification was regarded as a landmark development as it allowed for multiple diagnoses within the same subject and also had operational criteria for each diagnostic group to enable consistency between researchers. From this point, a new classification system was devised to incorporate both physical and psychological aspects in a dual-axis system. The Research Diagnostic Criteria for Temporomandibular Disorders (RDC-TMD) project was led by Samuel Dworkin and Linda LeResche. They aimed to establish standardize criteria for clinical research and epidemiological work [58]. The RDC-TMD classification comprises a set of diagnostic criteria to identify structural aetiologies as well as measures of pain parameters such as: Pain intensity and degree of disability using chronic pain grading scale; Depression, measured according to the Symptom Checklist-90 Revised scale (SCL-90R) and limitations as a result of the dysfunction. They drew on previous extensive research by Turk and Rudy [64], Von Korff and colleagues [65], Sherbourne, Derogatis and colleagues on constructs of chronic pain dysfunction from the Multidimensional Pain Inventory (MPI), graded pain scale and Medical Outcomes Survey and the SCL-90 respectively [35]. This classification system is believed to be reliable and valid due to the comprehensive nature of the included criteria and reproducible instruments used to measure these parameters [58]. Critics of this classification system argue that it is not easy to utilize in a clinical environment for four "speculative" reasons: excessive assessment, lack of consensus between clinician groups, lack of a "coherent overarching taxonomy" based on ontological principles and difficulty with outcome prediction [66].

Interestingly, the current International Classification of Diseases Version: 2010 (ICD-10) classifies temporomandibular joint disorders under section K07.6, subsection to section XI "Diseases of digestive system", synonymous with other names: Costen's complex or syndrome, derangement of temporomandibular joint, snapping jaw, temporomandibular joint-pain-dysfunction syndrome. Endorsed by the World Health Organisation, the ICD is used as a diagnostic tool for epidemiology, health management and clinical purposes. According to information published on the WHO website (www.who.int/classifications/icd/en), ICD is a consistent system that enables the records, storage and retrieval of information,

useful for clinical research as well as management and resource allocation. Although it does not adequately address the complex physical and psychological effects of TMD.

1.7 DIFFERENTIAL DIAGNOSES

Pain arising from the orofacial region can be of many origins, but commonly there are two groups of conditions which the dentist is required to recognize: Pain arising from the temporomandibular joint complex (TMD) and pain arising from other origins (orofacial pain disorders) (Figure 20).

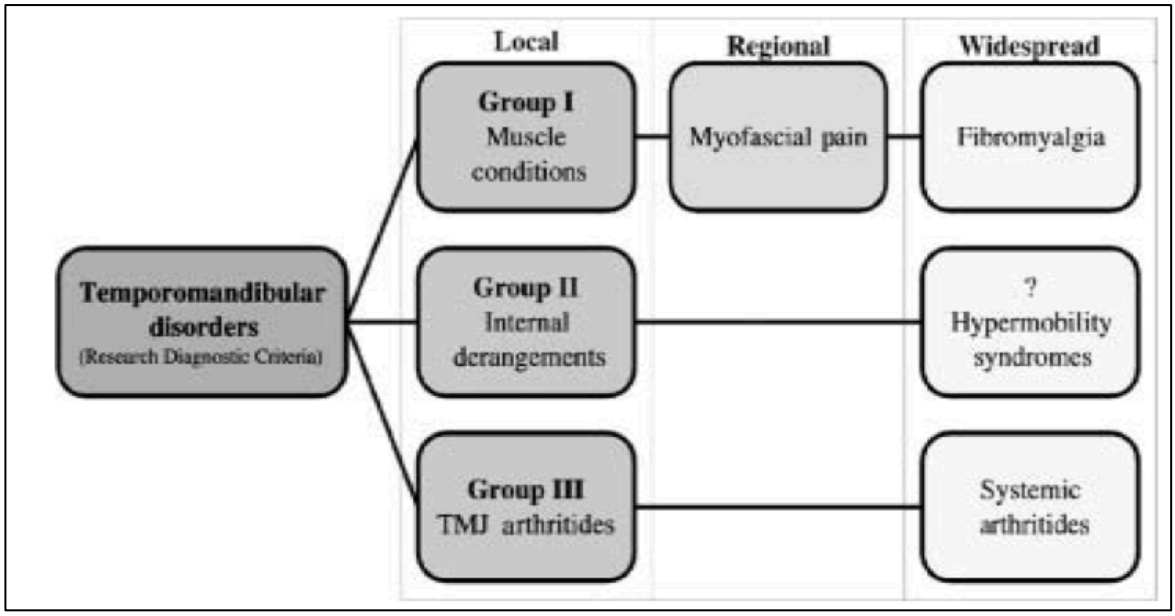


Figure 20. Differential diagnoses base on local, regional and widespread causal origins. Adapted from Stohler, 2004 [42].

This section will review common orofacial pain disorders, which would present similarly to pain arising from TMD with or without somatization, anxiety and depression.

To begin with comparable pain diagnoses, a review of typical features of TMD pain distribution as often reported in the literature is presented. Primarily, pain originates from the masticatory structures, elicited by jaw movements and increased with frequency of function. Symptoms are often reported in the pre-auricular areas, face or temples, during mouth opening or chewing with or without functional limitations such as speaking or singing. Joint sounds (clicking, popping, grating, crepitus) may be accompanied with pain

and precede an episode of joint locking. Other sources of pain should be suspected if the primary pain complaint does not have an association with jaw function.

A distinction between masticatory muscle disorders on the basis of pain description must be made in clinical differential diagnosis. Pain arising from muscles can range from a slight tenderness to extreme discomfort. The myalgia is a dull ache quality and often associated with a feeling of muscle fatigue and tightness. Pain location is often reported as broad or diffuse and can be bilateral. Pain intensity correlates with functional movements. Myofascial pain is characterised by the presence of a localised, firm, hypersensitive area which has been described as a "trigger point". This area can be felt as a deep pain and may subsequently cause central sensitisation or referred pain in remote tissues such as teeth and the gingival tissues. Pain may also arise from the cervical muscles but with a primary presentation site in the orofacial region. As a result of pain, the patient may experience alteration of normal jaw movement, which occurs as a protective co-contraction mechanism in the antagonistic muscles in response to pain in the primary muscle group (agonist). It is also important not to misunderstand muscle pain as muscle spasm and to be aware that a centrally mediate process of muscle pain can be the reason. Common orofacial pain disorders are categorized into two groups: neuropathic pain and headache.

1.7.1 Neuropathic Pain Conditions

By definition, neuropathic pain is described as pain arising from abnormalities in the neural structures, not the somatic tissue at the heterotopic locations of pain, and can be episodic or continuous in duration. Trigeminal neuralgia is the most common episodic neuropathic pain. It is characterized as lancinating, electric shock-like pain arising from an innocuous stimulus. In descending order of most to least frequently affected are the maxillary branch of the trigeminal nerve, the mandibular branch and the ophthalmic branch being least common. Continuous neuropathic pain such as atypical odontalgia, can fluctuate but tends to remain for extended periods and management is difficult. The characteristic features are a dull burning pain sensation that may be ongoing, and may be accompanied by other neurologic signs such as anesthesia, paraesthesia, hypoesthesia or hyperesthesia. Causes of episodic and continuous neuropathic pain conditions are thought to include demyelination of the nerve root or central sensitization processes following de-afferentation of a trauma site.

Other sources of atypical pain the in the region include [67]:

- Burning mouth syndrome which may have a local and systemic initiating factors associated with the onset of symptoms. These include contact allergy, denture irritation, oral habits, infection, reflux esophagitis, menopause, vitamin and mineral deficiency, diabetes, oral infection and chemotherapy.

- Intracranial causes of facial pain coming from meninges, cranial nerves and blood vessels such as thalamic dysesthesia where facial pain and dysesthesia distribute unilaterally on the face and may involve the trunk and limb of the same side. Intracranial neoplasms are another consideration for atypical pain the orofacial region and are reported in up to 60% of cases.

1.7.1.1 Headaches / Migraine disorders/Tension type headache

The trigeminal nerve is the final conduit between the different regions in the orofacial area, thus it is possible that migraine, tension or sinus headache and TMD symptoms present as multiple symptoms in any one patient or each can be triggering or perpetuating factors for others. Pathologically, TMD sufferers can present headache as a secondary symptom or on the contrary, headache patients may present with pain referred to the TMJ [67]. As less than 5% of the reported studies of TMD management include control groups, it is hard to derive a definitive recommendation for treating headache and TMD due to the lack of evidence to support or refute any particular therapies [67]

The International Headache Society classified more than 150 varieties of headaches and TMD diagnosis is obviously a consideration (section 11.7, ICHD, 1998) when differentially diagnosing headaches (Table 7).

Table 7. ICHD Classification

Adapted from Kraus, 2007 [68].

Box 4. Classification and diagnostic criteria for headache disorders, cranial neuralgias, and facial pain

1. Migraine headache
2. Tension-type headache
3. Cluster headache and chronic paroxysmal hemicrania
4. Miscellaneous headache, unassociated with structural lesion
5. Headache associated with head trauma
6. Headache associated with vascular disorders
7. Headache associated with nonvascular intracranial disorders
8. Headache associated with substances or withdrawal
9. Headache associated with noncephalic infection
10. Headache associated with metabolic disorder
11. Headache or facial pain associated with disorder of cranium, neck, eyes, ears, nose, sinuses, teeth, mouth, or other facial or cranial structures
    - 11.1 Cranial bones including the mandible
    - 11.2 Neck
    - 11.3 Eyes
    - 11.4 Ears
    - 11.5 Nose and sinuses
    - 11.6 Teeth and related oral structures
    - 11.7 Temporomandibular joint
    - 11.8 Masticatory muscles
12. Cranial neuralgias, nerve trunk pain, and deafferentation pain
13. Headache not classified

Adapted from International Headache Society, Classification Committee. Classification and diagnostic criteria for headache disorders, cranial neuralgias and facial pain. Cephalalgia 1998;8(Suppl 7):9–96.

Migraine is reported to affect 12% of the population and presents with pain of moderate to severe intensity, in the temple region or behind the ear as well as in the maxillary dental arch and can thus be misdiagnosed as pain of dental origin.

Piekartz and Ludtke [69] studied the prevalence of TMD symptoms in 43 patients who presented with cervicogenic headaches/tension-type headache over 3 months. Of these patients 44.1% had co-existing TMD symptoms (joint sound and masseter and temporalis muscular tenderness on palpation) and headache significantly improved with treatments, which included additional TMJ manipulation. Regardless of the lack of evidence to prove a causal relationship between the TMJ and some types of headaches, the authors suggested treatment of the TMJ should be considered for cervicogenic headaches for both short and long term outcomes.

Pathologies of the TMJ and the craniocervical region are distinct conditions that may share psychiatric aetiologies[70]. In a study, Mongini and colleagues[70] reported improvement in

50% of headache patients (who also had concomitant TMJ clicking) with physical treatments of the TMJ. The author hypothesised a cascade effect where TMD treatment could improve the headache condition and secondarily reduce musculoskeletal stresses on the TMJ[70] (Figure 21). They suggested that psychiatric comorbiditiy (depression and/or anxiety) should be carefully screened for any craniofacial pain including TMD (Figure 21).

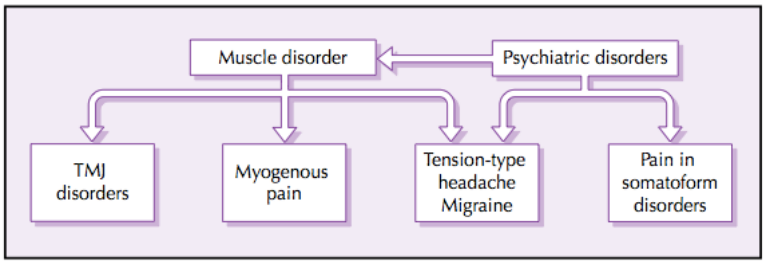


Figure 2. Facial pain disorder as a somatoform disorder is a psychiatric disorder. Furthermore, psychiatric disorders may negatively influence the headache history either directly or by increasing muscle disorder. The latter is a potential etiologic factor of temporomandibular joint (TMJ) disorders, myogenous pain, tension-type headache, and, to some extent, migraine.

Figure 21. TMD and other facial pain disorders. Adapted from Mongini 2007 [70]

1.8 BODY POSTURE AND TMD

A clinician who treats TMD patients must be cognizant of the musculoskeletal nature of the disorder [9] as the problem itself is no different from other joint problems in the body. An appreciation of orthopaedic principles is fundamental to proper understanding and management of TMD.

The stomatognathic system and the rest of the body are interactive in maintaining their respective positions [19]. The resting positions of the mandible vary according to body posture. The mandible rotates anteriorly on assuming an upright sitting position whereas a posterior rotation of the mandible is expected in the supine position [71, 72].

Gangloff and Perrin tested the influence of trigeminal afferents on postural stabilization by performing unilateral mandibular nerve truncular anaesthesia and measured the resultant disturbance of the body posture [73]. Their results revealed a shift of body weight towards the contralateral side and resulted in inferior limb contraction homolaterally. In other words, trigeminal sensory signals are important for balance control, an alteration of which can result in dis-equilibrium distally as well as proximally through effects of on the tonicity of sternocleidomatoid and trapezius muscles [73]. Symmetrical mandibular position would allow better symmetry in bodily muscular control, in particular the sternocleidomastoid and masseter muscles, both of which control the head posture [74].

Dental occlusion has been reported with to have an influence on body posture and the spinal curvature (for example, scoliosis and lordosis) although the evidence to support this link is weak. Accordingly, class II malocclusion has been positively correlated with a more anterior displacement of body posture and class III malocclusion with more posterior displacement [75].

Lippold and colleagues [76] demonstrated a correlation between craniofacial parameters and back shape profiles such that those with long and distal craniofacial patterns appeared to have higher thoracic-lumbar-pelvic angles (Figure 22). Furthermore, patients with idiopathic scoliosis were found to have a higher frequency of malocclusion, which include Angle class II malocclusions, lateral crossbites, lower midline deviations and facial asymmetries [77, 78].

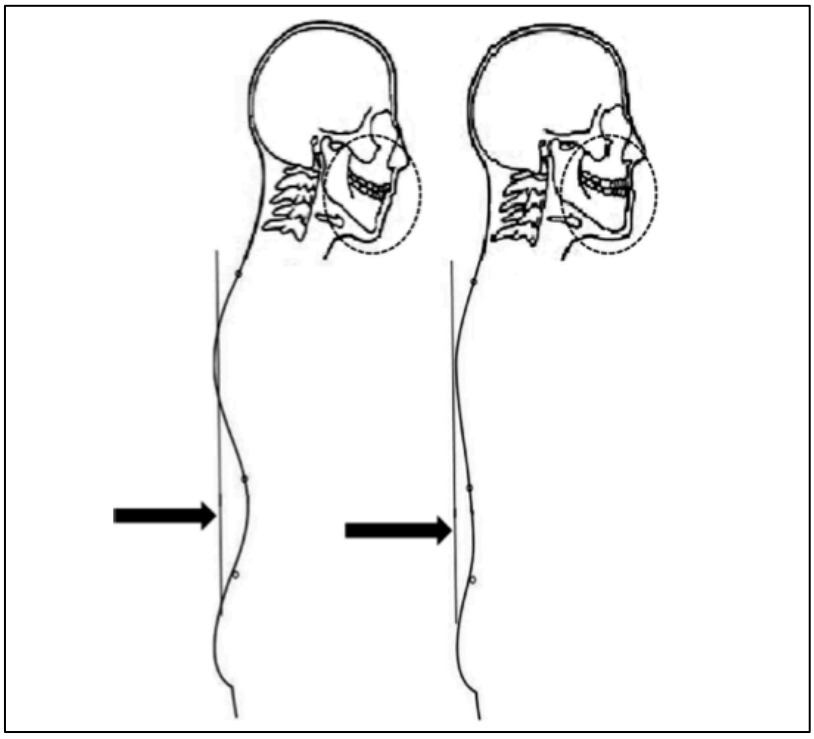


Figure 22. Spinal curvatures.
Correlation between craniofacial parameters and back shape profiles: patients with distal and vertical craniofacial patterns present higher than normal upper thoracic, lumbar-lordotic, and pelvic angles; patients with mesial and horizontal craniofacial pattern present smaller than normal upper thoracic, lumbar-lordotic, and pelvic angles. Figure modified from Lippold et al. (1971).

Logically, the next level of argument and evidence has been investigated to provide support for the hypothesis that TMD and body posture interact. The proposal is that anterior head posture, (via alteration of the field of vision), causes compensatory musculature contraction and subsequent shortening of cervical extensors such as suboccipitalis, semispinalis, splenii and upper trapezius and sternocleidomastoid muscles. The anterior head position shifts the centre of gravity forward and modifies the mandibular position [79, 80]. Olmos and colleagues demonstrated an increase in retrodiscal space between 1.67-1.92mm ($p<0.0001$) after five months of treatment for fifty-one TMD subjects with corresponding significant postural improvement [80]. The resting length of upper cervical flexor and extensor muscles become dramatically affected with changes in the mandibular position, demonstrating the observed compensatory changes known as musculoskeletal imbalance [81].

Patients with musculoskeletal imbalance present with TMD symptoms and comorbidities such as soft tissue tenderness in the upper cervical regions. Consequential or compensatory changes may be seen as hyperextension of the upper cervical spine, reduced lower cervical spine curvature, shoulder protraction and elevation, and an increase in thoracic spine kyphosis. These descriptions in total are features of forward head posture composition that can be observed and assessed in patients with TMD symptoms [81]. Lee and colleagues performed a case control study to demonstrate the relationships between TMD and head position. They found a significant relationship between the angle formed between the ear-spinous process of the 7th cervical spine and-horizontal plane with the angle being smaller in TMD patients, indicating a more forward posture compared to the gender and age-matched control group [82]. Weakness of the sternocleidomastoid muscles, suprahyoid muscles and anterior neck flexors have been implicated as perpetuating the forward head posture (reduced head angle, increased shoulder angle) and unbalanced stretching of the temporomandibular joint and has been shown to be significantly related to TMD signs based on MRI, radiographic and clinical criteria [20].

Critically, the evidence to prove a biomechanical link between the stomatognathic system, TMD and body posture is inconclusive due to the lack of high quality studies [19]. As pain is a major symptom that influences whether a patient will seek intervention, there have been research into the relationships between TMD and body posture from a nociception perspective. La Touche and colleagues [83] demonstrated this biomechanical and nociceptive

relationships in a small study of 29 subjects with myofascial temporomandibular disorders. The authors argued that converging afferent inputs from the suboccipital region, the upper cervical spine and the temporomandibular area as well as neuronal plasticity together might have explained concomitant pain and dysfunction in these systems. The authors further cited references from Goldstein and co-workers [21, 84], that altered neck position can alter the amount of mandibular opening in healthy subjects, in particular, the forward head posture allowed a greater amount of mandibular opening than neutral or retracted positions and improved control and strength of deep neck flexors which can lead to improved TMD signs and symptoms [85, 86].

Ferrario and colleagues [87], however, failed to demonstrate a relationship between posture and the stomatognathic system and more recent studies reported by Visscher and co-workers [88] and Olivio and co-workers [89] have also failed to establish a significant relationships between TMD and body posture. At this point in time, more controlled studies of high quality are required to provide a better understanding of the issue. This in turn would allow better explanation of the roles exercise therapy has in TMD management.

At the neural connection level, Cuccia and co-workers [19] can only explain the relationship between the stomatognathic system (and TMD) with body postural control with hypotheses based on the neural connections between the ocular, vestibular, and the trigeminal neurons. They stated that a change in the trigeminal stimulation can cause imbalance in these latter systems (vestibular and oculomotor) [73].

Nociceptive inputs from the TMJ, muscles of mastication and posterior cervical muscles in poor posture positions are said to possibly cause central sensitization by bombardment of afferents onto the spinal trigeminal nucleus, increasing the excitability of brainstem nociceptors (central sensitization) as well as causing temporal summation and activation of glial cells (microglia and astrocytes) [90, 91]. Additionally, the jaw system that encompasses from deeper to more superficial body organs including muscles and bone accumulate pre-tension when stimulated via the interstitial and ruffini endings, thereby influencing the posture of the body [19]. It is believed that the jaw muscle system possesses smooth-muscle like cells that conduct tension and behave as if they were a single muscle, their existence explains why disorders of the masticatory system such as swallowing, chewing can be transmitted to other spinal musculatures. It seems that studies in the past have demonstrated possible physical relationships between more distal pain origins for

example, the effect from knee and anterior cruciate ligament injuries on central spinal muscular contraction and spinal positions. Likewise, this explanation is also applicable for peripheral muscles such as the masticatory muscles and the neck muscles (SCM; upper and lower trapezius).

Clinically, the relationship between symptoms of the stomatognathic system and cervical spine disorders were reported to be present in between 72 to 82% of patients particularly with joint sounds on active movements, pain on joint palpation and joint play tests [92].

At a functional level, the relationship between TMD and the cervical musculature has been suggested from EMG studies involving experimental induction and/or alleviation of pain in humans and animal studies. Pallegama et al [93] demonstrated a positive correlation between resting EMG activity in the sternocleidomastoid and trapezius muscles in TMD patients whose pain was of myofascial origin compared to normal controls or patients with TMDs of disc origins. The authors' explanation involved a co-activation theory of functional relationships between the masticatory system, TMD and the cervical muscles via the trigemio-cervical reflex.

1.9 DIAGNOSTICS

In 2010, the American Association for Dental Research issued the following position statement to guide the dental profession on TMD diagnosis and management based on evidence from clinical trials, experimental and epidemiologic studies:

> *"It is recommended that the differential diagnosis of TMDs or related orofacial pain conditions should be based primarily on information obtained from the patient's history, clinical examination, and when indicated TMJ radiology or other imaging procedures. The choice of adjunctive diagnostic procedures should be based upon published, peer-reviewed data showing diagnostic efficacy and safety. However, the consensus of recent scientific literature about currently available technological diagnostic devices for TMDs is that, except for various imaging modalities, none of them shows the sensitivity and specificity required to separate normal subjects from TMD patients or to distinguish among TMD subgroups. Currently, standard medical diagnostic or laboratory tests that are used for*

evaluating similar orthopedic, rheumatological and neurological disorders may also be utilized when indicated with TMD patients. In addition, various standardized and validated psychometric tests may be used to assess the psychosocial dimensions of each patient's TMD problem".

Evidently, this controversial topic became the subject of debate with both positive and negative comments published within the opinion columns of the respective journals. The statement mentioned "*adjunctive diagnostic procedures"* referred to technical devices used in the field of neuromuscular dentistry (NMD) to measure EMG activities, jaw tracking device, occlusal analysis and joint sound as unreliable and not indicative of the need for treatments.

Therefore, this section will review the main diagnostic instruments which are supported and recommended by the greater majority of the dental and medical professions, namely tomography, computerised tomography, magnetic resonance imaging for imaging intra-articular disc, arthroscopy, arthrotomography and fluoroscopy.

1.9.1 Imaging Technology

TMD diagnoses should be made clinically by subjective questioning and only rely on the aid of imaging methods such as panoramic tomography, magnetic resonance (MRI) or computerized/arthrographic tomography when indicated.

1.9.1.1 Panoramic Tomography

Winocur and co-workers [94] reported that panoramic radiography was of no diagnostic value on 94.4% of 372 TMD cases, and when the group was divided into separate diagnoses, only 20% of degenerative TMJ cases were positively correlated with the clinical diagnosis. Despite its low cost and low radiation exposure, the panoramic tomography is known to have less accuracy in imaging for the condylar areas and as such can produce false negative interpretations. This has led to it being rejected for routine TMD diagnosis [94].

1.9.1.2 MRI

Manfredini and co-workers [95] reported "fairly good kappa statistics" for the relationship between MRI and clinical examination data using RDC-TMD criteria for disc-displacement with reduction (k=0.69); disc-displacement without reduction (k=0.57) and normal (k=0.61). The literature has reported a wider range of correlations (59-90%) due to methodological differences between studies and the diagnostic criteria utilized [95]. In a study to compare accuracy between MRI and TMD data, some authors have reported poor agreement between MRI and clinical TMD diagnoses using the RDC-TMD criteria (K = 0.13 – 0.33) for ADDwR, Normal and ADDwoR and a positive predictive value of only 44% [96]. Emshoff and colleagues have published a number of studies questioning the value of MRI diagnostic technology for TMD and Yatani and co-workers [97, 98] have also indirectly supported this critical stance by stating that clinical examination alone can produce considerable accuracy.

MRI is believed to have a higher rate of false positive findings in contrast to a clinical examination that is more likely to result in higher false negative rate. One study indicated that up to 33% of cases positively identified by MRI were clinically asymptomatic [99]. In an in-vivo study which examined the correlations between MRI and tomography of twenty-four temporomandibular joints, MRI was found to be as accurate as arthrotomography in confirming disc displacement and more accurate in disclosing gross arthrosis than tomography. The best use for arthrography was in disclosing perforations. The best of all correlations to surgical findings, however, was with data from a clinical examination [99]. The question whether MRI tends to over-diagnose the presence of internally deranged TMJ was answered in a study by Watt-Smith and colleagues [100] where arthrographic and clinical diagnoses of 50 joints were made. Comparatively MRI was shown to have over-diagnosed disc-displacement without reduction. A frequently cited study by Katzberg and co-workers [41] published in the radiology literature in 1980 was well regarded for a long time as it added another dimension of radiology to the diagnostic tool kit of many oral surgeons and dentists. However, Helms [101] commented that the need for expensive tools has possibly been made redundant over the years largely as a result of our improved understanding of the condition coupled with a better sensitivity with diagnostic criteria.

Even though magnetic resonance imaging and tomography can provide more accuracy information on the structural changes of the condyle, prohibitive cost and high radiation exposure often make frequent usage unattractive. A conclusion that can be drawn from these studies is that no one method can be used to diagnose TMD and in particular, ADDwoR.

The tendency for MRI to overdiagnose also raises questions about the diagnostic criteria used in interpreting MRI images. Manfredini and co-workers highlighted the role and limitations of anamnestic examination and MRI in a report in relation to audible sounds. A clicking sign could lead to over-diagnosing ADDwR or ADDwoR. Clicking alone can certainly be present in some normal joints as well as in derangement cases, and most importantly, clicking does not always have to be present in ADDwR, as 22 of 42 MRI-diagnosed ADDwR cases were silent on clinical exams [95].

Clicking, crepitus and limitation of opening show the least positive predictive value in ADDwoR diagnosis. A crepitus sound may be instantly attributed to osteoarthritis but it may also be a presentation of long term disc displacement and concurrent muscle disorder (therefore poor control of joint movement) [95]. This is also explained by the lower rate of clinical finding of osteoarthritic degenerative joint disorder (11%) [94].

Table 8 provides a summary of relative the accuracy and general conclusions from studies of imaging/diagnostic modalities selected for a review published in the Journal of Oral Rehabilitation [102]

Table 8. Summary of systematic reviews on TMD diagnosis

Adapted from Manfredini et al. 2011 [102]

Table 1. Summary of findings from systematic reviews on TMD diagnosis (PubMed search, 9 November 2009)

First author and year	Diagnostic modality reviewed	No. of studies reviewed	Type of review	Main conclusions
Manfredini, 2009 (89)	Ultrasonography	20	Systematic	US accuracy: 54–100% for disc displacement, 72–95% for joint effusion, 56–93% for osteoarthrosis US is operator-dependent Parameters for normality should be set
Perinetti, 2009 (69)	Posturography	21	Qualitative systematic	Little usefulness of posturography (large variability of recordings) The different posturographic methods showed low diagnostic accuracy
Koh, 2009 (87)	Magnetic resonance (degenerative and inflammatory disorders)	23	Qualitative systematic	OR: pain-ID 1.54–2.04; pain-DDwoR 4.82; crepitus-DDwoR 3.71 No clear evidence for a relationship between clinical and MR findings
Hussain, 2008 (88)	Imaging techniques (erosions and osteophytes)	9	Systematic	Axially corrected sagittal tomography is the imaging modality of choice for TMJ erosions and osteophytes CT seems to add nothing to axially corrected sagittal tomography
Suvinen, 2007 (68)	EMG	142	Systematic	Many shortcomings of EMG literature Biological variation, capacity for adaptation, fluctuations in TMD symptoms are limits to the clinical application of EMG The clinical use of EMG as a diagnostic method for TMD is not recommended
Limchachaina, 2006 (86)	Magnetic resonance (degenerative and inflammatory disorders)	22	Qualitative systematic	Insufficient evidence for diagnostic efficacy expressed as sensitivity, specificity and predictive values
Turp, 2005 (90)	Clinical (palpation of digastrics muscle)	2	Systematic	The posterior belly of the digastrics muscle is not palpable (anatomical reasons) Risk for false positives with clinical palpation and consequently unnecessary diagnostic and therapeutic measures
Turp, 2001 (91)	Clinical (palpation of lateral pterygoid area)	5	Systematic	Unacceptable degree of intra- and inter-examiner variability with regard to the palpation of the lateral pterygoid area
Baba, 2001 (65)	Electronic devices	62	Systematic	None of the proposed electronic devices (EMG and jaw motion recordings, joint vibration analysis, jaw muscle tenderness) has stand alone diagnostic value for TMD Unacceptable sensitivity and specificity values

US, ultrasonography; AADR, anterior disc displacement with reduction; MO, mouth opening; OR, odds ratio; ID, internal derangements; DDwoR, disc displacement without reduction; TMJ, temporomandibular joint; TMD, temporomandibular disorders.

1.9.1.3 Computed Tomography

Manzione and co-workers [39] reported 96% accuracy in detecting degenerative arthritis and 94% accuracy in detecting meniscal derangements and recommended that computed tomography (CT) should be used to investigate suspected primary internal derangement or

arthritis. The main advantage of CT investigations are that they are non-invasive, able to have both joints assessed under one examination and can be set to optimize bone details where abnormalities of osseous structures can be assessed. However, they are not able to provide dynamic details of the disc in function and therefore any dysfunction during movements cannot be assessed as it would be in arthrography.

The following tomographic images demonstrate normal and disc-deranged TMD conditions (Fig 23- 30).

Tomography images [41]

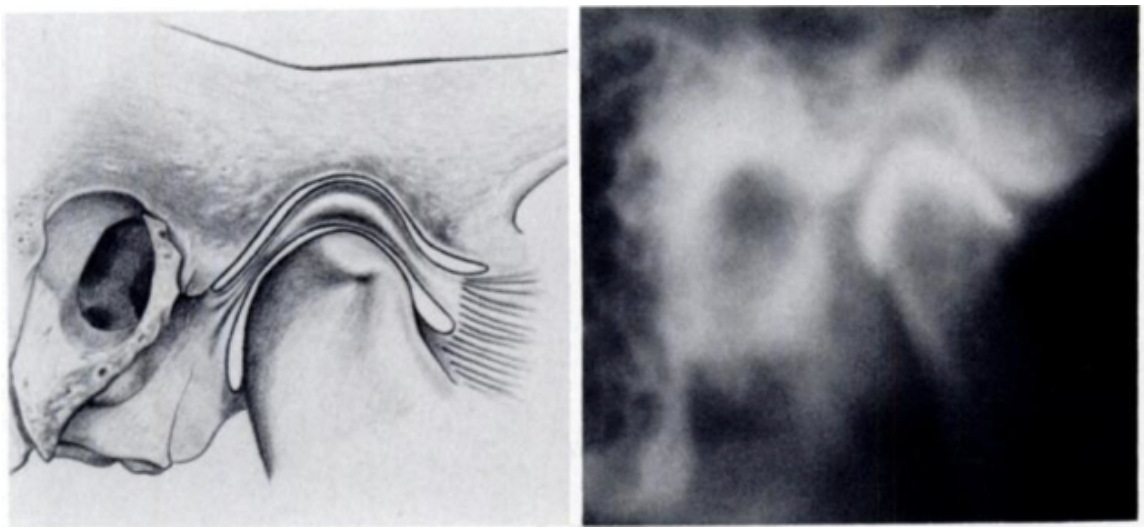


Figure 23a. Normal joint.
Closed mouth position. Anterior recess of lower joint space in small teardrop configuration delineates lower margin of anterior ridge of disc. Central thin zone of disc articulates between anterior convex aspect of condyle and inferior convex slope of eminence.

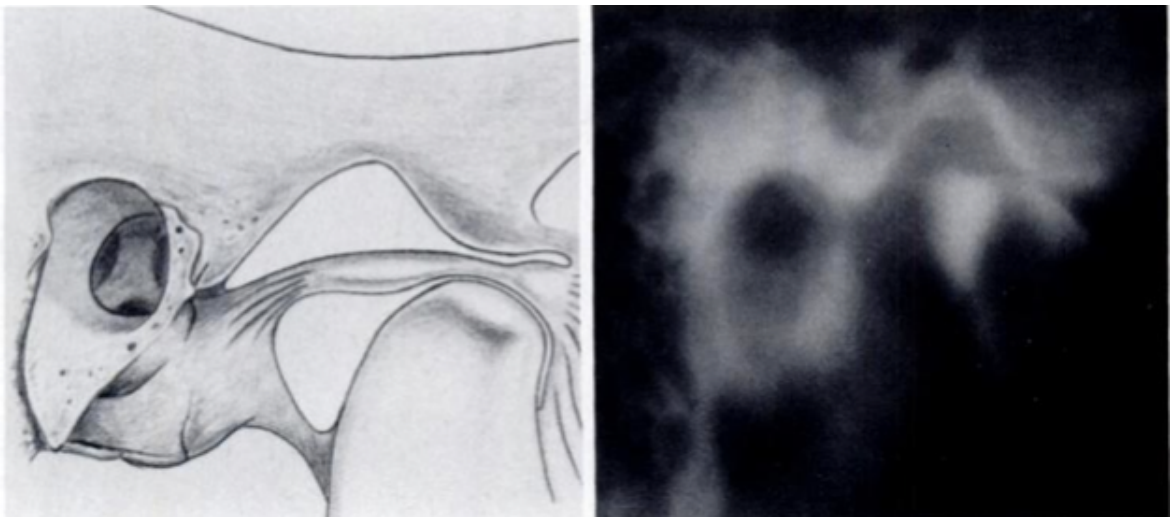


Figure 23b. Normal joint.
Mouth in opened position. Joint space opened posteriorly.

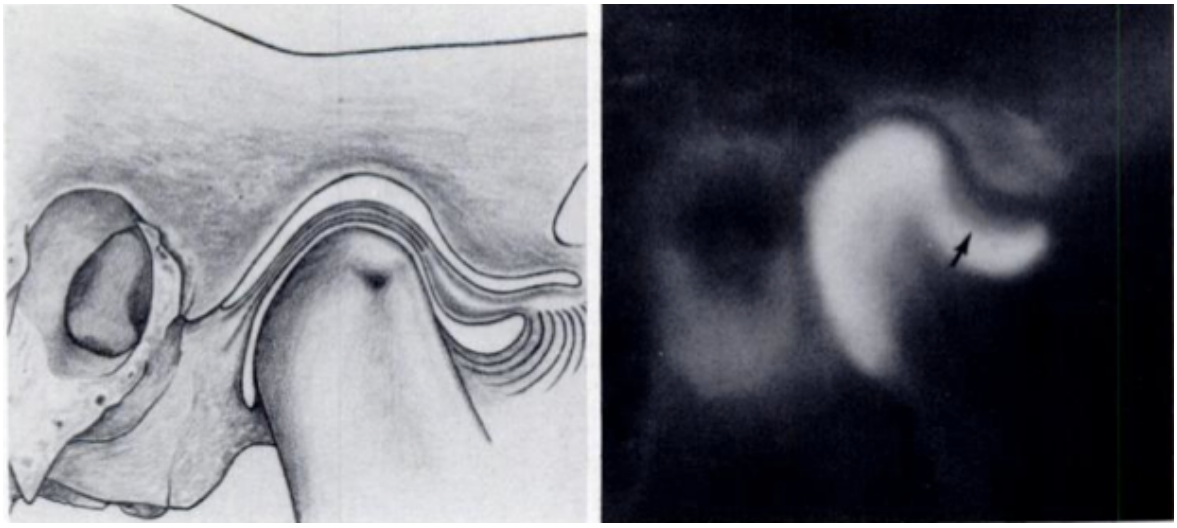


Figure 24. Anterior disc displacement without reduction.
Closed mouth. Posterior ridge of disc anterior to condyle causes impression on large anterior recess.

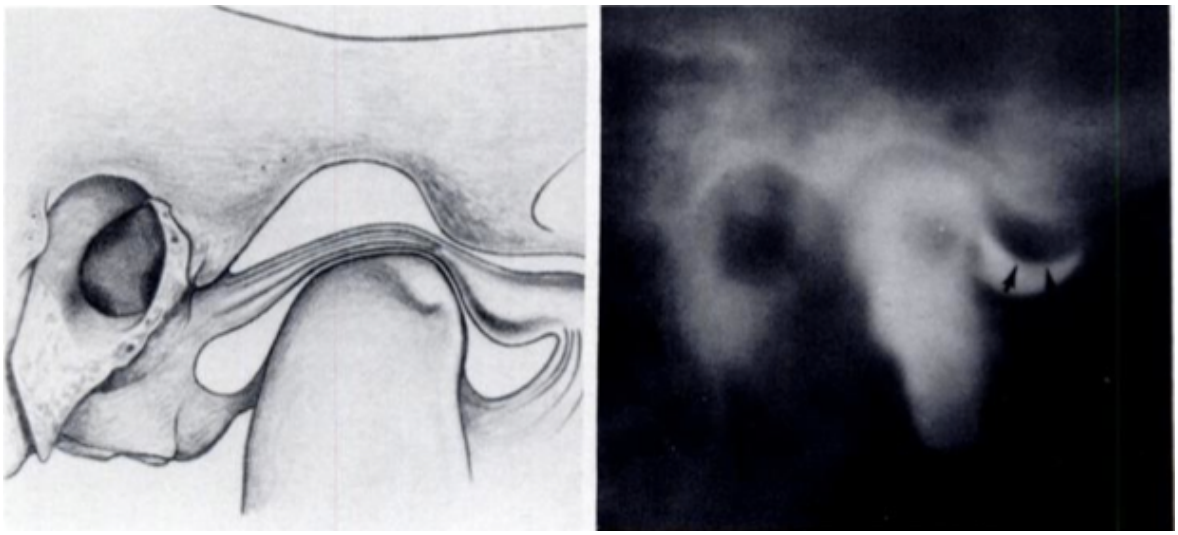


Figure 25. Anterior disc displacement without reduction.
Mouth in maximal opened position. Decreased condylar translation with impression on anterior recess by anteriorly displaced disc (arrow).

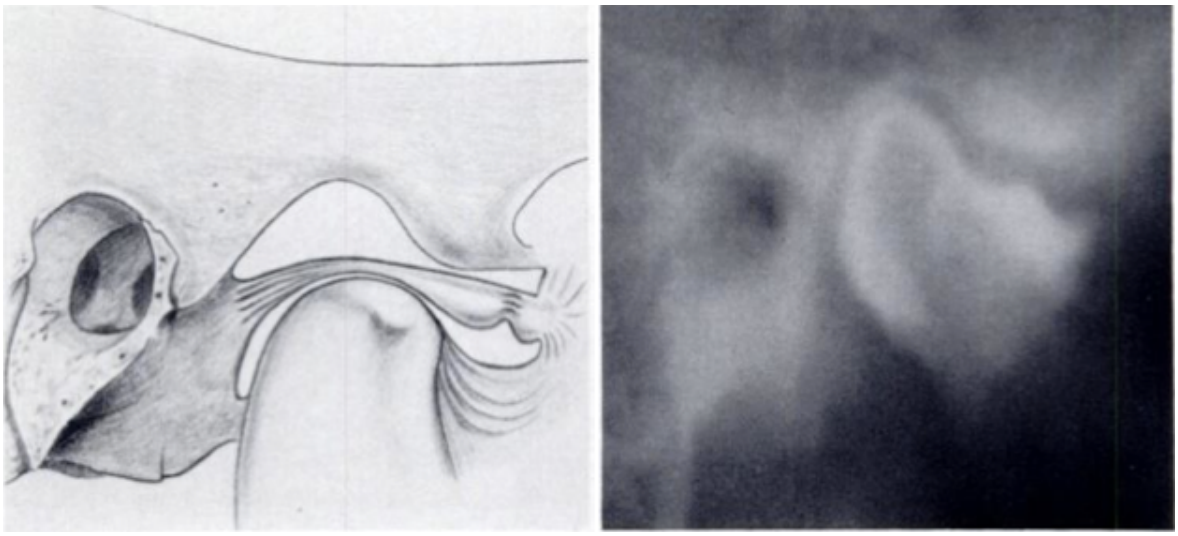


Figure 26. Anterior disc displacement without reduction.
As above, but with a double impression of the disc with central thin zone folded upwards.

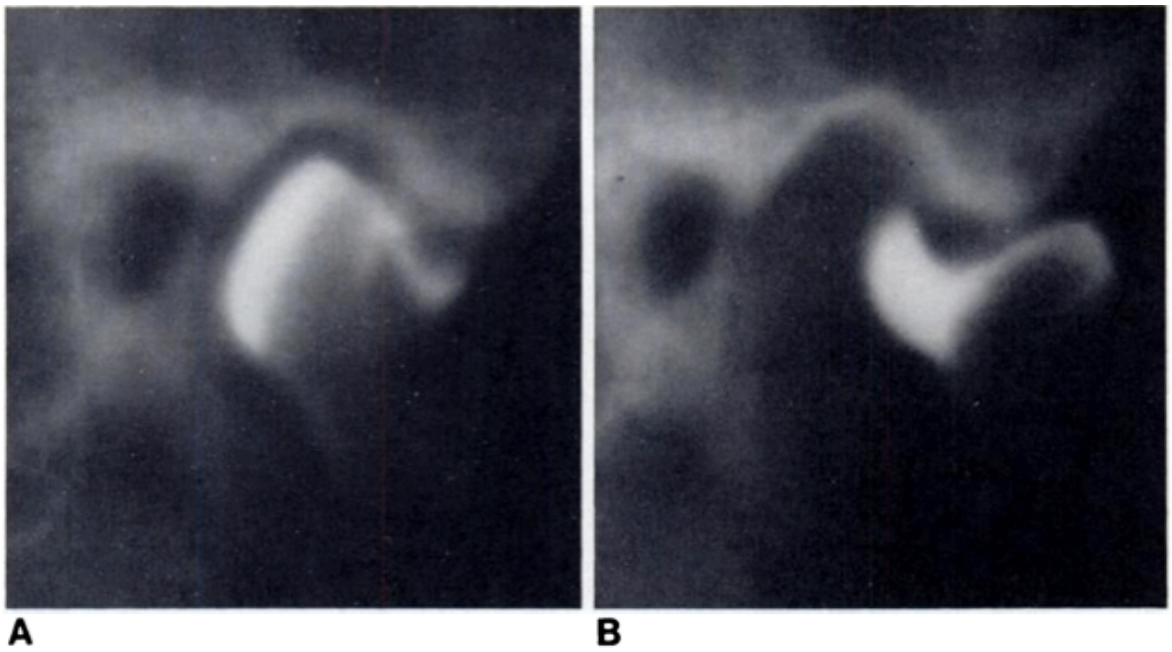


Figure 27. Anterior Disc displacement with reduction.
Arthrotomogram just before click begins in opening mouth.
A. Impression on anterior recess by posterior ridge of anteriorly displaced meniscus.
B. Full condylar excursion after click (reduction of displacement) with normal arthrotomographic features.

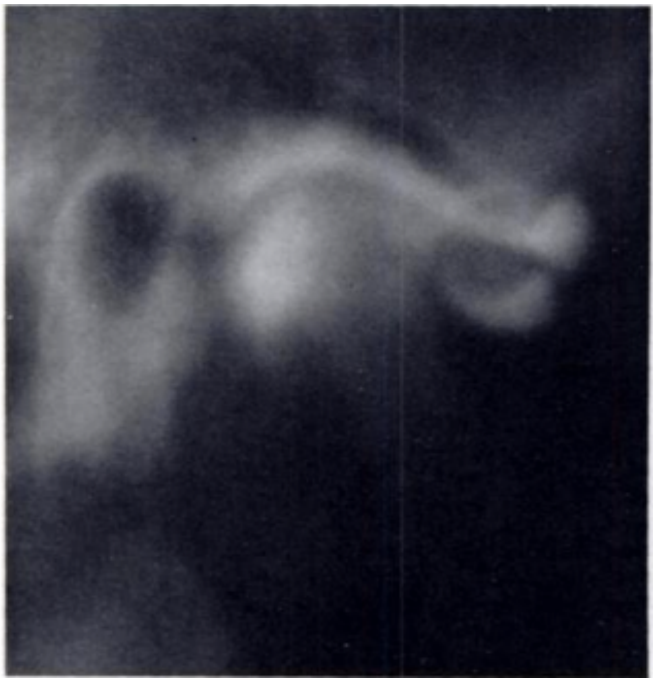


Figure 28. Other condition. Perforation and disc displacement without reduction.

Figure 29. Adhesions. Only small and irregular upper joint space could be opacified. Adhesions are from prior mandibular fracture.

1.10 MANAGEMENT

It has been suggested that primary treatment methods which address psychosocial concomitants may take precedence over biomedical treatments of actual physical signs and symptoms [1]. The Research Diagnostic Criteria for TMD (RDC-TMD) tool has been developed to classify TMD subtypes for both physical impairments, associated psychological distress and psychosocial dysfunctions (chronic pain, depression and somatization) [37] and to standardize between multicenter and cross-cultural populations for researches on TMDs. Many scales have been used to measure psychological aspects of TMDs, some of which measure pain (Multidimensional pain Inventory – MPI, developed by Turk and colleagues), while others generally measure the impact of chronic pain (Symptom Check List-90-Revised (SCL-90-R), Graded Pain Scale) [65] and somatization (Minnesota Multiphasic Personality Inventory scale – MMPI)[1].

Dworkin [1] cited a range of treatment success rates between 80-100% for TMDs using diverse physical modalities, occlusal adjustment, counseling, biofeedback and surgery. Contrasting with this are studies that have noted poor ability to predict TMD treatment outcomes [103] and the observed increase of primary care visits for undiagnosed physical symptoms which may increase the patient's risk of iatrogenic sequelae of multiple diagnostic and treatment procedures [1]. Furthermore, it is estimated that 30-50% of patient presentations will not yield a specific diagnosis and the overall health care costs are significantly higher than matched controls [1]. On examining the longitudinal changes, the net effect of approximately 60% of TMD patients reported at least some joint pain on a 3-year follow up [1]. Long term prognosis for TMD patients has been shown to relate to pre-treatment non-specific symptoms (somatization) and not physical clinical signs such as range of movements or joint sounds [1].

1.10.1 Guideline Statements

Management for TMD has been a subject of vigorous debate and extensive research over the last hundred years. As practitioners in the "evidence-based era", providing treatment for TMD symptoms must be based on good scientific evidence to ensure that selected treatment modalities are effective for the problems concerned and to minimise potential harmful effects on the patient.

In 2010, the Neuroscience group of the American Association for Dental Research issued a policy statement as the latest position paper on diagnosis and treatment of TMDs. Published as a guideline; the authors of the paper had compiled the statement on these premises:

- The body of evidence in the literature supports TMD management using a medically-oriented model
- Biopsychosocial approach within a behavioural framework might be used to supplement conservative care for TMD pain conditions
- A small proportion of patients who do not respond to treatment might develop pain chronically hence the current research effort to "unravel" the complex nature of the problem.

The release of this guideline was welcomed by some parts of the international dental profession (eg. Japanese Prosthodontic Society [104]) but was initially received negatively by other craniomandibular pain groups (eg. School of the Pacific[1]). The AADR guideline is not the only publication available but it represents a consensus view on conservative TMD management. Other published guidelines for dental practitioners include the ACDA guidelines 2009 (Revision, July 2009) which were written for Ontario dentists and have also been used by the practising dental profession and other bodies; The American Academy of Orofacial Pain published guidelines in 1990 and 1993 and the American College of Prosthodontists's 1995 guideline for prosthodontics[2] treatments have also been published

1.10.2 Historical Recall [55]

Since the fifth century B.C when Hippocrates described a method of reducing mandibular dislocation, the TMJ problems experienced by the human subjects have undergone numerous changes in taxonomy and corresponding treatment philosophy that include surgical, occlusal adjustment and treatment for mechanical displacement.

In the last seventy years, a paradigm shift has seen TMD being considered with combined aetiological factors involving the TMJ, masticatory system and the psychophysiologic dimension. As a result, a range of terminologies have evolved, such as "myofascial pain-dysfunction syndrome" to distinguish TMD of muscle origin from intracapsular conditions. A belief emerged in the early 1980s that includes both anatomical and psychological aspect that shaped the biopsychosocial model. It is easily misunderstood by and large with the current use of the term temporomandibular disorders to focus management on the joint itself above other potential causes [55]. In addition, over the years, clinicians and researchers have noted that TMD patients are strong placebo responders and it has been frequently demonstrated that it is often not "what" is done, but "how" that is important in TMD management [11].

Regardless of how fragmented this area appears and without a consensus on diagnosing and managing TMD subtypes, it is generally accepted that management for TMD has moved beyond the mechanistic dental model originating many years ago and that this has

[1] Journal of the American Dental Association, volume 141 (12), 2010
[2] Journal of Prosthodontics, volume 4 (1), 1995;58-64

been replaced with a biopsychosocial medical model that addresses the concurrent psychophysiologic presentations.

Also, TMDs are generally believed to improve with time [42]. One report that cited a wide range of success rates (between 75-95%) for TMD patients using different treatment modalities [42] critically attributed improvements to biological and psychological adaptation and sometimes merely due to the statistical phenomenon of "regression to the mean" where pain, if used as an outcome, will be reduced towards the mean regardless of treatments or no treatments [105].

A recent systematic review by List and Axelsson synthesized evidence of effectiveness of different treatment modalities from published systematic reviews [106]. The authors reported that there is some evidence to support a comprehensive, holistic and multidisciplinary approach using occlusal appliances, pharmacological intervention and jaw exercise therapy. Other non-dental modalities include acupuncture, behavioural therapy and postural training by other health professionals. However, the authors highlighted that due to high level of variation in the primary studies and the variable quality of the evidence, recommendation for a specific treatment regime is not possible.

Turp et al [107, 108] explored the question in relation to simple/single vs. multimodal therapy in TMD management. They defined simple therapy as care provided by the clinician without the need for technical dental interventions. This included brief information, self-care instructions, home remedies including thermal packs, and over the counter drugs. Multimodal therapy refers to at least two treatment modalities. According to the authors, there are different indications for single and multimodal therapy depending on the presence of psychological affects, different tissue pathologies, individual patient characteristics and/or comorbidities such as depression and anxiety. In such cases a multidisciplinary approach is recommended. On the contrary, if TMD symptoms represent local joint pathologies and are limited to physical functional deficits, simple therapy can provide sufficient improvement up to six months [107].

1.10.3 Dental Management

The AADR recommended that dental management for TMD should be based on conservative, reversible and evidence-based therapeutic modalities to prevent undue

irreversible changes, risks or harm to the patient as no specific therapies have been proven uniformly effective or significantly more effective than conservative means [109].

1.10.4 Splint Therapy

It has been said that splints are the most widely adopted choice of treatment for TMD and purportedly many other applications including bruxism, electroconvulsive therapy, motor disorders such as Parkinson's disease and oral tardive dyskinesia, snoring and obstructive sleep apnea, chronic sinusitis with resultant sensitive teeth and headache [110]. Understanding the true efficacy of splints in managing temporomandibular disorders is important given the frequency with which they are prescribed and the cost to the health system. Dao and co-workers[110] cited that splint therapy accounted for 2.91% of all dental related cost (equivalent to $990 million US dollars per year) in the US health system in the year 1990. However, the mechanisms of splint effectiveness in TMD management remains unclear and is listed in Table 9.

Table 9. Mechanisms of splint efficacy

Mechanisms Proposed for Oral Splint Efficacy
Myofascial pain
a. Change vertical dimension
b. Repositioning TMJ
c. Decrease in the level of muscle activity
d. Reducing bruxism
e. Removal of occlusal interferences
f. Enhancing patient's cognitive awareness
Disc displacement disorders
1. Recapturing disc
2. Unloading joints
Arthritis/arthralgia
1 Unloading joints
Sleep Bruxism
Removal of occlusal interferences
Change muscle activity
Modification of habits

The evidence relating to each of these proposed mechanisms was reviewed in detail by Dao et al.

The relative effectiveness of splint therapy for common TMD conditions has been studied by a number of investigators:

1.10.4.1 Disc displacement TMD conditions

For the ADDwR subtype, proponents for "repositioning" splints believed in therapeutic measures that re-align the condyle-disc relationship while the "functionalists" have emphasised that functional healing and acceptance of a less than ideal condyle-disc relationship is appropriate and that the TMJ complex will remodel to the new functional position without any permanent deterioration. The repositioning theory presumes that the final therapeutic goal requires fixed rehabilitation but this principle has been subjected to modification in favour of a more "selective" use only when pain accompanies the clicking ADDwR cases [111, 112]. In addition many authors have demonstrated that long-term stabilization of the disc position is not always possible [113, 114]. Manco and Messing [114] performed a study comparing lateral computed tomography images of the disc position after treatment with splint. In this study 41.8% of subjects did not show recapturing of the disc-condyle complex despite their clinical improvements. A study reported only two years earlier by Manzione and co-workers also revealed a similar rate of non-responders with 46% of subjects remaining with painful ADDwR [39]. Likewise, de Leeuw [115] followed 99 patients who had been diagnosed with internal joint derangement for thirty years. The patients' clinical state during this time changed minimally and did not compromise their functional performance.

In this debate an intermediate group has emerged who believed that repositioning splints are to be used discriminately and fixed occlusal rehabilitation to maintain new positions should only be applied to patients whose risk: benefit evaluation clearly favours the the proposed intervention [111, 116].

Furthermore, a successful clinical outcome cannot be relied on to be associated with a reduction of audible joint sounds. Okeson demonstrated that 66% of patients of patients who did not find the need to seek additional treatment for jaw pain and dysfunction had persisting joint sounds [111, 117].

In ADDwoR, Sato and co-workers [118] demonstrated 41.9% success rate after one year in a "natural course" group who did not have any treatment. Subjects in this group showed a significant increase in mouth opening and pain reduction and their joint sound remained unchanged. In this study, 55% and 77% success rates for the stabilization splint and surgical groups were reported respectively. For the ADDwoR subtype, Schmitter and co-workers reported results from a randomized controlled trial of 74 patients with MRI-confirmed ADDwoR in at least one joint. In these patients a stabilization splint was more effective for improving range of movement (opening) than distraction splint [119].

Santacatterina and co-workers [112] synthesizing information from six studies comparing the effectiveness of repositioning and flat plane intra-oral appliances. These authors reported a 75% success rate for click reduction with repositioning splints compared with 17% using a flat occlusal bite plane. Similarly, the therapeutic repositioning splint improved pain in 80% of the studied populations compared with 33% in the comparison group.

Surface electromyographic activity (sEMG) of masticatory and cervical muscles has been investigated as an outcome of splint interventions for ADDwR TMD [120, 121]. Tecco and co-workers reported that after 10 weeks of wearing an anterior repositioning splint sEMG activities at rest significantly improved in the masseter, sternocleidomastoid and lower trapezius muscles. For maximal voluntary contraction electrical signals, an increase was seen only in the masticatory muscles. The improvement appears to be dependent on the level of protrusive anterior ramp as previous studies have shown using a "relaxation" splint which resulted in reduction of electrical signals on maximum voluntary contraction [120, 122, 123]. However, the correlations between improved muscular sEMG activity and clinical improvement of TMD conditions are yet to be elucidated which means that sEMG studies can only be interpreted within the context of other information obtained during a clinical assessment.

Past studies have attempted to clarify the mechanism of action and efficacy of intraoral splints for managing disc-displaced TMD. However, the relative roles of placebo, the natural course, and how patients appreciate of the positive changes, remains the subject of debate [110]. This does not indicate that splints are not effective for TMD management, as demonstrated by the high success rates and an appealing option due to their minimal invasiveness [110, 117, 124].

Side effects such as occlusal alteration from wearing stabilisation splints as part of treatment for TMD are related to the length of time used (for example, full time vs. part time use) which could result in less undesirable effects with part time use. Based on a case report of three complications from using an upper flat stabilisation splint for orthodontics, myofascial TMD, and post-orthognathic/orthodontic treatment, Magdaleno stated that the risk for side effects is low and rarely requires irreversible corrective treatments. To avoid possible side effects, the author recommended that splints should not be used all day and routine review by a dentist to ensure occlusal stability is required [124]. Predicting factors for risk of occlusal alteration are not established and some authors recommend that patients should be informed of the risk of irreversible occlusal changes if a discrepancy less than three millimeter between intercuspal and centric occlusion positions occur (Witt and Palla, 2003, cited by Magdaleno 2010). Actual changes to the position of the mandible possibly due to muscular activity, different distribution of occlusal load or modifications in the vertical dimension are possible explanations for the observed occlusal alteration [124].

1.10.4.2 Myofascial TMD

For the myofascial TMD subtype, Turp and co-workers [125] examined the effectiveness of occlusal splint therapy by systematically reviewing the literature. Their qualitative analysis of the included studies found that splint therapy for myofascial TMD is more effective than no treatment and can produce short-term relief of symptoms. However, splint therapy outcomes were not significantly different results with soft splints or non-occluding palatal appliances (placebo) and evidence is still lacking when compared to other "alternative" treatments such as acupuncture, physiotherapy and occlusal adjustment.

These results are similar to a Cochrane review reported by Al-Ani and co-workers who compared night time wear of stabilization splints (described as Tanner, Fox, Michigan or centric relation appliances) to other active treatments and no treatment controls [126]. They reported evidence, albeit weak, for the use of a stabilization splints compared to no or minimal treatment controls in terms of pain reduction at rest and on palpation (Figure 30).

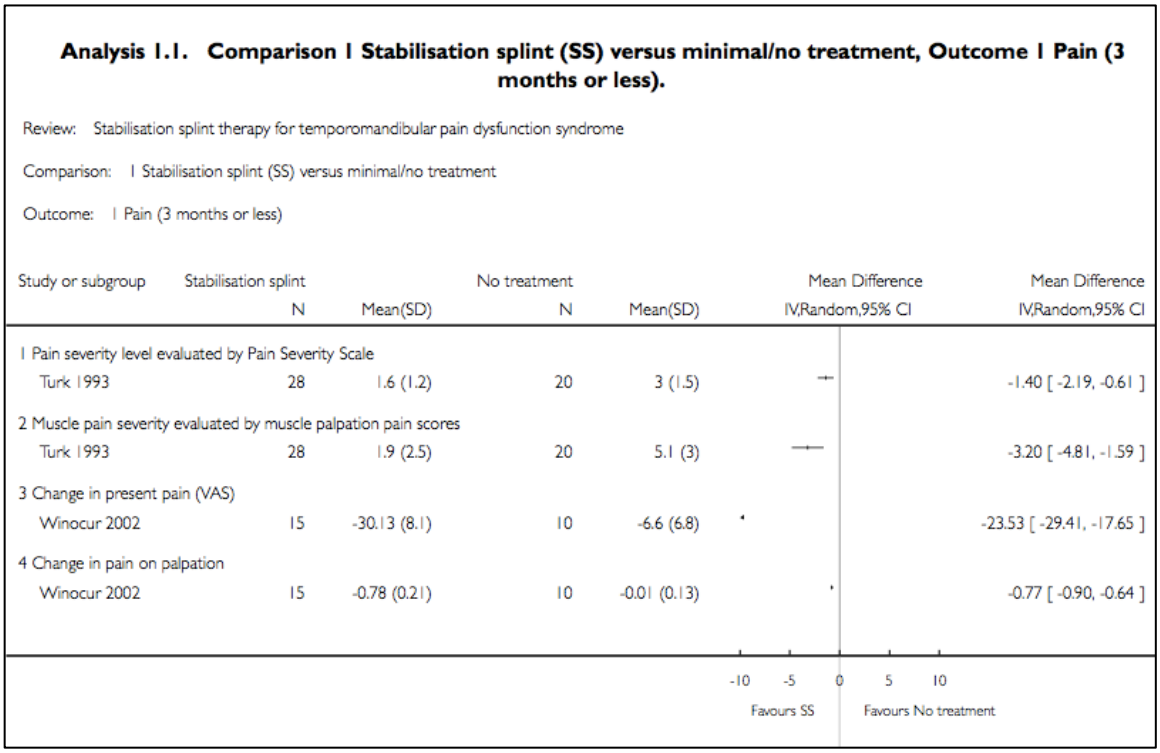


Figure 30. Forest plot of effects of stabilization splint vs. no treatment. (from Al-Ani et al. 2004)

Another systematic review by Fricton and co-workers reported that stabilisation splints can reduce pain in severe TMD as can other means such as physiotherapy, behavioural medicine and acupuncture although heterogeneity in the diagnoses meant that there was not enough evidence to establish whether splints worked better for subtypes of muscle, joint or headache TMD. The authors concluded that anterior positioning splints could reduce clicking and locking more than stabilization splints as a short-term improvement. It was also concluded that for long term benefit, behavioural therapy may be better than splint therapy especially for patients with severe conditions and psychosocial problems, and stabilization splints are better than pharmacological treatment for headache pain. In the authors's view the latter two comparisons however, required [127].

1.10.4.3 Splint design

As to splint designs other than the stabilization (Figures 31 and 32) and anterior repositioning splints dicussed above, Nilsson and co-workers reported that resilience splints, at least for short term follow-up, did not show statistical significant improvement compared with non-occluding controls [128-130]. This result is similar to the results on soft splints reported by Fricton and co-workers who found some evidence of them being more

effective than placebo controls for pain reduction [127]. The same authors also examined anterior bite plane design and found that the evidence of effectiveness of this type of design on headache was inconclusive. In addition, for partial coverage appliances there is always a concern that they may result in occlusal changes. Fricton et al. advised against the use of this design in the absence of definitive evidence of their therapeutic advantage [127].

Furthermore, the use of small partial coverage appliances (for example, the Nociceptive Trigeminal Inhibition-tension suppression system- NTI-tss splint) greater risk of aspiration during night time use and a medical emergency associated with this treatment has been reported in the literature [131].

Most often a maxillary appliance is the treatment of choice, however, a randomized clinical trial performed by Siegert and Gundlach [132] reported statistical significant improvement with mandibular splints compared with "relaxing" or anterior occluding maxillary splints.

Some researchers advocate alternative splint designs, including canine guidance and non-working side contacts (on the basis of reduction of tension in the temporal and masseter muscles and protection for the ipsilateral TMJ), and mutually protected occlusion. Conti and co-workers demonstrated in a randomized controlled study a significant improvement in reported joint pain, comfort and reduction of joint noise frequency with either type of splints (canine guidance or bilaterally balanced) and that both were better than non-occluding controls for ADDwR cases. Because there was no statistical difference established between centric stabilization and. canine guidance splints, the authors argued against the specific need of having canine lateral guidance ramps [133]

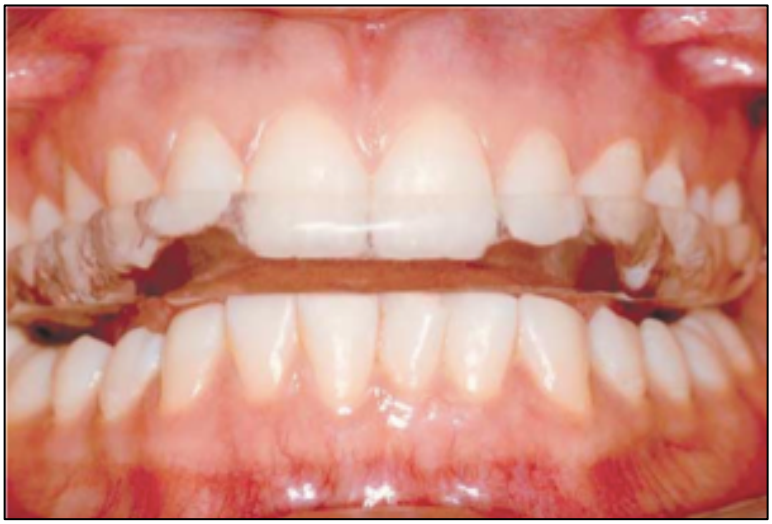


Figure 31. Occlusal splint.
Frontal view of bilateral balanced stabilization splint with picture showing posterior teeth in contacts on protrusion. Ideally should see even contacts in both anterior and posterior segments from mandibular buccal cusp tips contacting flat occlusal surface of the upper maxillary splint in all movement directions (from Conti 2006)

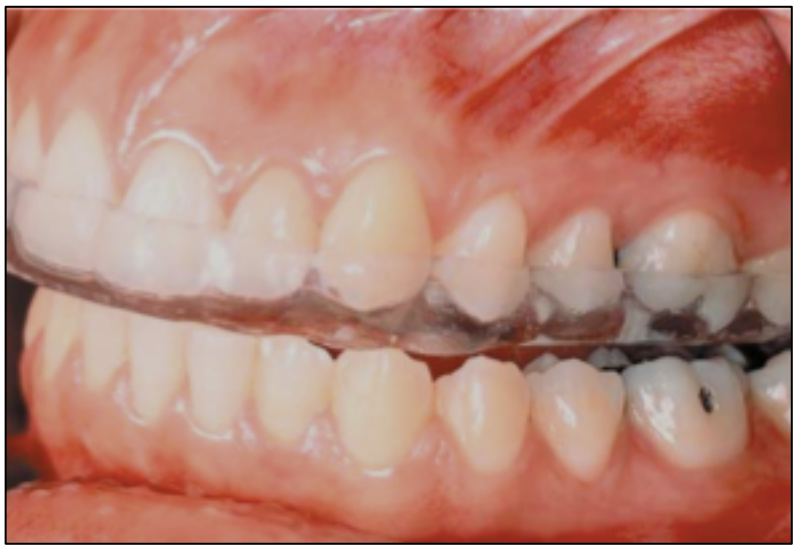


Figure 32. Canine guidance stabilization splint.
Disclusion of posterior teeth by contacts on the canines in lateral movements and contacts between anterior teeth in protrusion. (from Conti et al. 2006)

In general it is difficult to interpret much of the research on the use of splints when there are significant heterogeneity between the studies due to problems such as:

- Defining the study and control populations
- Randomization and blinding methodologies a
- Selection of treatments and control conditions[134].

As a result of these shortcomings, it is difficult to make definitive recommendations for the use of splints as a single efficacious mean for pain relief from TMD when moderate results can be obtained by other pain treatments [135].

1.10.5 Occlusal Adjustment

Early authors [136, 137] who studied TMDs proposed that abnormal occlusal contacts resulted in TMD problems. However, there has been a considerable loss of interest in this concept since many human and animal experiments have proven that the association between malocclusion and TMD is not a proof of causality. The conclusion "there are no clinical trials demonstrating that this treatment (occlusal adjustment) is superior to noninvasive therapies" made by a panel of scientists on the 1996 National Institute of Health (NIH) Technology Assessment Conference on TMD represents the current consensus on treatment for TMD [137].

Tsukiyama and co-workers reviewed the literature from eleven experiments (413 subjects). Six studies reported the effects of occlusal adjustment on primary TMD, the remainder examined the relationships with other diagnoses where TMD was secondary such as headache, neck pain and bruxism. From this, the authors concluded that irreversible occlusal adjustments are not recommended as a treatment of choice for TMD unless obviously indicated in acute iatrogenic malocclusion situations [137]. Experimentally induced occlusal interferences that interrupted normal intercuspal position (ICP) are likely to cause localised symptoms in the periodontal and pulpal tissue of the affected teeth and increase muscle tension with possible joint clicking and disruption of the smooth jaw movements. Therefore, as interferences in lateral movements are unlikely to cause major instability, irreversible treatment such as routine occlusal adjustment is not justified [138]. Tsukiyama and co-workers did not find reliable evidence to demonstrate causal relationship between occlusal interference and nocturnal bruxism. They did not find any

significant differences between occlusal adjustment compared with mock adjustment for treatment of TMD [137]. Similarly, in 2003, Koh and Robinson [139] reviewed the effectiveness of occlusal adjustment and found an absence of evidence to support this procedure for the management of TMD pain or the prevention of TMDs in malocclusion cases. By 2006, Fricton and co-workers reached a similar conclusion and recommended that reversible treatment such as self-care, splints, physiotherapy and cognitive behavioural therapy could be used to initially manage signs and symptoms of TMD [127].

1.10.6 Cognitive Behavioural Therapy (CBT)

This is a conservative approach for TMD management where the patient is empowered to take control of his or her own health status. It aims to encourage patients to think and act more rationally and be less affected by irrational "thoughts, memories, mental images and bodily sensations" [140]. Morishige and co-workers demonstrated a significant clinical improvement in patients with TMD (both myofascial and intracapsular derangements) after 2 weeks and 3 months. However, the reported improvement was based only on patient's reports of their perceived progress and the study is clearly lacking in details of separate analysis of different treatment outcomes. Collective evidence to support CBT as an effective means of conservative therapy for chronic orofacial pain conditions such as TMD was demonstrated by Aggarwal and co-workers [13]. The authors concluded that either by itself or in combination with biofeedback or other conservative treatments, self-care, CBT improves outcomes for patients with TMD especially in the functional rating. There is currently no available consensus data as to how many sessions of CBT would be of benefit and how it should be best delivered. The study designs for the published clinical trials included in the review by Aggarwal are heterogenous which make it impossible to estimate for the effectiveness of CBT.

1.10.7 Biobehavioural Approach

Dworkin [141] suggested that TMD, just as other chronic back and neck pain, should be approached with a biobehavioural model of multidisciplinary treatments. TMD sufferers may present with anxiety, depression and fatigue [142] and Carlson and colleagues[143] have suggested that the evidence points towards emotional and physical activators contributing to the chronicity of the condition. A certain level of autonomic activation is essential for body

defense against stressors; however, chronic and prolonged stimulation of the sympathetic nervous system can be viewed as an important endogenous stressor in itself [143].

An experimental study in rats showed that induced hypocapneic activity of the peripheral receptors contributed to ectopic discharge believed to contribute to paresthesia and pain associated with chronic nerve injury. [144]. For example, in anxiety situations, a drop in alveolar carbon dioxide as part of an autonomic response may cause ectopic impulses to be discharged from the dense receptive fields within the trigeminal region [145]. The notion of central sensitization cannot be ignored and should be considered as part of management for pain patients regardless of its exact role. in causing or consequence to pain experience.

Compared with pain-free control subjects, myofascial pain patients, have significantly lower thermal pain and ischemic pain thresholds and thermal pain tolerance values [146]. Maixner and co-workers concluded from their study on experimental pain induction in TMD patients that this group are more sensitive to noxious stimuli than pain-free control. This evidence supports our current model of the condition being a psychophysiological disorder in which emotional, physiological and neuroendocrine responses are modulated by higher brain functions upon receiving peripheral stimulation [146]. Upon exposure to psychosocial and pain stressors, these patients demonstrate altered breathing patterns, fatigue, depression and sleep disturbance and when monitored for basal physiological status, myofascial pain patients demonstrated lower end tidal carbon dioxide levels and lower diastolic blood pressures than normal subjects[147].

Since biobehavioural elements associated with TMD may or may not be causal for the condition itself, these can be target end points for management strategies, and several research efforts on biobehavioural programs have focused on information about the disorder such as skill training for self-control strategies to modify pain perception for example, postural relaxation, therapeutic breathing exercises, proprioceptive re-education training and cognitive restructuring techniques to alter dysfunctional belief systems [143].

Dworkin and co-workers [148] demonstrated in a randomized controlled trial that a bio-behavioural approach is better for producing long term outcomes for TMD patients compared to intra-occlusal splint, albeit both are equivalent in the short term (scores of pain level and life interference). Carlson and co-workers [143] published a randomized controlled study comparing standard dental treatment for myofascial pain. The control

group received education on aetiologies, pain, diet advice, rest, relaxation and an occlusal splint. The study group received education on physical self-control (PSR) methods that target seven areas: Monitoring and reducing muscle parafunction in the head and neck region; proprioceptive awareness training to improve symmetric head and neck posture; instructions for improving sleep onset; position-oriented relaxation training; physical activities; nutrition/fluid management and training in diaphragmatic breathing. Dependent pain scores were measured with the Multidimensional Pain Inventory (MPI) and Pain score (VAS). Opening was measured using Okeson's method (inter-incisal opening). Muscle palpation was scored between zero to three (0=no pain, 1 = tender, 2= painful, 3= pain with withdrawal). Measures of psychological status included somatization, depression, anxiety, and obsessive-compulsive scales of the Revised Symptom Checklist – 90 (SCL-90-R). Other measurements include distress (using component of the MPI) and the Likert scale 0-10 for fatigue measurement. Sleep quality was measured using Pittsburg Sleep Quality Index. The authors demonstrated a significant improvement in reports of pain severity and perception of life interference as well as control after 26 weeks of treatment with physical self regulation training compared to control subjects who were issued with flat plane intra-oral appliance and basic self-care instructions. Furthermore, a significant decrease of affective outcomes including distress, somatization, obsessive-compulsive symptoms, pressure tenderness, awareness of tooth contact. Carlsson et al explained that physical self-regulation is effective because of physiological effects on sensory experience and observable functioning in a manner detectable beyond the normal dental treatment programs [143]. The authors alluded to non-treatment related effects of which may have resulted in differences between studies. These include: relationship between provider and patient; placebo effects, spontaneous remission, natural fluctuations or progression of a condition. At a cost-effectiveness evaluation level, the authors performed a cost-benefit analysis where a splint may cost $430 on average compared with clinical fees if PSR was used (2 sessions, 2x extended consultation charges of est. $130/session).

Regardless of the comparison, both methods resulted in reduction of 50% of pain in the early period and by 26 weeks and the PSR method achieved over 60% reduction.

Fatigue as an outcome was not seen to have changed in this study[143], and it is thought that there may be two components: State physiology and trait psychology, which may require sensitive measurement tools. Fatigue is not a measurable symptom and future research

needs to address both aspects of perceived and physiologic fatigue. This study was based on military personnel, and their findings indicated quite a low level of psychological effects. It was thus proposed that background social setting may have had some influence on the manifested symptoms; such as depressed clinical psychological symptoms in military personnel compared with higher psychologic symptoms in low socio-economic cases.

1.10.8 Physiotherapy

Physiotherapy management in collaboration with dental treatment is a common approach for treatment of TMD. It involves joint mobilization, exercise prescription, electrotherapy, education, biofeedback and relaxation and postural correction [149]. The goals in management of TMD conditions are to control pain and discomfort, reduce high muscle tone, improve kinetic parameters and improve joint function. Physiotherapy recognizes the broad bio-psychosocial model of health (and illness), the positive role of activity in health and healing as well as placing emphasis on function rather than impairment, is paramount in physiotherapy management of TMD. Physical therapy interventions often include therapeutic exercises for the masticatory or cervical spine muscles to improve strength and mobility in the region. Manual therapy techniques are commonly used to reduce pain and restore mobility. Physical therapy interventions also focus on associated impairments of the craniocervical system such as poor posture, cervical muscle spasm, cervical pain, or referred pain from the cervical spine and may or may not use oral exercise devices to assist with the exercises [150].

A systematic review by Medlicott and colleagues [149] was carried out to quantify the effect size of physiotherapy management for TMD based on Cohen's estimates of 0.20 (small), 0.50 (medium) and 0.80 (large). Of the 30 selected articles, 14 were investigations related to exercise therapy and/or manual therapy. Despite the limitations of the review, the evidence supported exercise programs prescribed by physiotherapists for acute disc-related TMD diagnosis (RDC-TMD axis Ia) and for acute and chronic myofacsial TMD (axis Ib). Postural training and mid-laser therapy were shown to be more effective than electrotherapy modalities in the short term and relaxation, biofeedback, EMG training, proprioceptive re-education were more effective than placebo treatments and occlusal splint therapy in decreasing pain and increase mouth opening in muscular TMD.

Specific to anteriorly displaced disc condition, Chortis and co-workers reported that currently the evidence to support exercise therapy (particularly related to the method and type of programme) is insufficient [151]

Physiotherapy management can be used for symptomatic relief of acute signs and symptoms as well as providing holistic management in chronic pain situations. The advantages of physiotherapy treatment are reversibility, low cost and positive coping skill, which are important for management of chronic conditions such as TMD.

1.10.8.1 Physiotherapy-exercise treatment

Exercise therapy is defined as "a regimen or plan of physical activities designed and prescribed for specific therapeutic goals. Its purpose is to restore normal musculoskeletal function or to reduce pain caused by disease or injuries" (NIH defined MeSH term, 2012). The physiotherapy exercise regime aims at ameliorate pain, improve coping ability for the patient, restore normal function, reduce inflammation, decrease high muscle activity, improve muscle coordination, and promote repair and regeneration of tissue [152].

Essentially, for muscle-related TMD symptoms, the following exercises have been reported in the literature [152]: relaxation exercise, diaphragmatic breathing, massage, heat, stretches and coordination exercises as well as proprioceptive training and posture correction. The suggested dosage is 5 minutes of diaphragmatic breathing every 2 hours and maintaining coordinated breathing as often as possible throughout the day. Mobilization exercises are useful in disc displacement with or without reduction where the patient is instructed to move the mandible laterally to recapture the disc. Stretching exercises are for jaw myofascial pain with limited mouth opening at a frequency of 2 sets hourly and holding 1 minute each stretch, 6 repetitions per set. Coordination exercises are performed three times per day, with or without postural adaptation exercises.

For intracapsular conditions, exercises aim at joint mobility of the joint and soft tissue. For muscular conditions, exercises improve muscle relaxation and coordination, and have a broad effect on the orofacial musculature. For arthritic conditions, exercises improve joint fluid lubrication and mobilisation of the joint and prevent stiffness.

1.10.8.2 Massage therapy

Temporomandibular disorders may be caused by multiple factors and result in imbalance of the masticatory muscles[153]. Massage therapy has been advocated as treatment alternative for myofascial pain as it is believed to be a potent mechanical stimulus for effective pain control[153]. In a report by Ariji and co-workers [153], it was found that massage therapy could reduce the thickness of the masseter using ultrasonic massage modality. According to the authors, this is possible due to therapeutic target on the venous blood flow; blood clotting process and edema and lymphatic drainage.

1.10.9 Self-care

Self-care programs have been shown to result in positive long-term improvement. These programs focus on counseling, patient education, habit reversal techniques, proper use[144] of the jaw function, thermal, massage and stretching exercises[152]. It is widely accepted that behavioral therapy should be approached first to address psychosocial factors and parafunctional activity and increased self-management is closely linked to successful rehabilitation [152].

1.10.10 Pharmacotherapy

Drug therapies may be prescribed for TMD patients which include: Non-steroidal anti-inflammatory drugs (NSAIDs); corticosteroids, opioids, muscle relaxants; anxiolytics, hypnotics, and antidepressants [154]. Turp and co-workers [107] reported in a systematic review that the non-selective COX inhibitor naproxen may lead to slightly better oral health-related quality of life than the selective COX-2 inhibitor celecoxib for TMJ arthralgia. However, according to Fricton and colleagues (2004)[3] the safety of selective COX-2 inhibitors may be greater than the non-selective NSAIDs for long term use with lesser risk of gastrointestinal effects. A combination of NSAIDs and benzodiazepines or cyclobenzaprine is recommended for myalgia with limited opening condition. For chronic TMD pain, tricyclic antidepressants such as amitriptyline and nortriptyline significantly ameliorate insomnia, anxiety and pain and can be used chronically whereas selective serotonin reuptake inhibitors (SSRIs) should be used

[3] Pain Clinical Updates, Volume XII, No. 2, 2004.

with caution in TMD patients because they may increase masticatory parafunctional muscle tension and aggravate muscle pain [155].

1.10.11 Surgical Approach

Failure to improve symptoms after attempts at non-surgical measures such as physical therapy, occlusal and splint therapy, pharmacotherapy or diet alterations can result in patients and clinicians seeking surgical solutions. Short-term success rates between 70 to 85% for surgical treatment of internal derangement have been reported [111]. In general, the less invasive surgeries are as efficacious as those that are more invasive and require post-operative management including analgesics, physical therapy, splint therapy when indicated with continued psychological treatment as appropriate[156]. Many surgical procedures have been reported, some of which are described below:

Arthroscopy: Performed under general anaesthesia, a fibre optic rigid cord with diameter between 1.7 to 2.7mm is inserted into the TMJ. Visualization and diagnostic procedures as well as irrigation and biopsies can be performed. The superior joint space is lavaged with lactated Ringer's solution, intracapsular adhesion can be lysed and triamcinolone injected as required. Manipulation of the mandible for excursive free range of movements, and sodium hyaluronate injection in the upper joint space at end of procedure are also possible.

Arthrocentesis: A procedure performed under local anaesthesia whereby the upper joint space is washed out (lavage) and hydraulic pressure and manipulation are employed to release adhesions and improve joint motion.

Lysis and lavage: Still a microscopic arthroscopic technique which aims to release fibrous adhesions and lavage with isotonic saline solution, under local anaesthesia or IV sedation normally in the outpatient setting. The point of entry is usually the inferior-lateral approach for trocar puncture with an outflow needle placed through the skin 5mm anterior and slightly below the trocar.
Arthroscopic anterolateral capsular release (AALCR) is the use of electrocautery to release any adhesions of the capsule and the disc.

Synovial fluid analysis: Another added advantage of an athroscopic approach is the

accessibility to potential biomarkers such as cytokines, proteolytic enzymes and proteoglycan breakdown products that may be useful for diagnosing various intracapsular temporomandibular joint diseases and disorders and as part of a pharmacologic therapeutic approach.

Open surgery: Consist of surgical procedures where bone recontouring or condylar reduction may occur, through an incision in the preauricular region with a deep subfascial approach. The anterior superior slope of the condyle is removed and the articular surface reshaped. Discal repositioning by traction of the posterior ligament, and repositioning and suturing of the lateral ligament is also possible.

Dyscectomy: Excision of the disc through a preauricular incision, any irregularities are smoothed without the need to use any alloplastic replacement materials or autogenous materials as problems related to joint damage as a result of material breakdown as well as inconsistent results with autogenous tissues replacement [55].

A recent Cochrane review [154] on effectiveness of surgery in TMD treatment did not find any difference in pain outcome between surgical and non-surgical treatments at 6 months. Similarly, pain outcome at 12 months was improved with both arthroscopic and arthrocentesis procedures but no statistical difference between the two techniques was found. Arthroscopy provided better maximum inter-incisal opening after 12 months than atherocentesis but open surgery resulted in better pain report in the VAS and the symptom severity index (SSI) after 12 months of follow up. These results were not different from results with arthroscopic surgery for mandibular function and parameters of clinical evaluation such as opening range, protrusion range, clicking, crepitation, tenderness of jaw and muscle palpation. The systematic review revealed insufficient studies to support any specific recommendations. However, it should also be noted that some of these studies with very low number of subjects were also assessed to be of moderate to high risk of bias.

1.11 EVIDENCE FOR TREATMENT EFFECTIVENESS

In the early 1990s, David Sackett and colleagues from McMaster University, Hamilton (Ontario, Canada) introduced the concept of evidence-based medicine (EBM), defined as "*the conscientious, explicit and judicious use of current best evidence in making decisions*

about the care of individual patients" [157]. Evidence may come in difference level as depicted in the pyramid below (Figure 33):

Figure 33. Evidence pyramid.
Accessed http://ebp.lib.uic.edu/nursing/node/12, 4/9/12

The pyramid describes the quality of evidence in a hierarchical order as well as denoting their quantity in the literature. As can be seen, the best evidence to guide clinical decision-making is a systematic review where selected primary studies that fit pre-specified eligibility criteria are critically analysed to formulate an answer for a specific research question [158]. Systematic reviews have rapidly gained an important place in medicine and dentistry in aiding clinical decision-making. This type of review focuses on a clinical question related to health care. It uses explicit, systematic methods that are selected with a view to minimizing bias, thus providing more reliable findings from which conclusions can be drawn and decisions made [159]. Therefore the quality of a systematic review depends on the strength of evidence from its included studies.

Key characteristics of a systematic review are summarised below [160]:

1. a clearly stated set of objectives with pre-defined eligibility criteria for studies;
2. an explicit, reproducible methodology;
3. a systematic search that attempts to identify all studies that would meet the eligibility criteria;
4. an assessment of the validity of the findings of the included studies, for example through the assessment of risk of bias; and

5. a systematic presentation, and synthesis, of the characteristics and findings of the included studies.

Systematic reviews may contain meta-analyses but this type of statistical summation of result is not an absolute requirement and is sometimes inappropriate in the presence of serious publication and/or reporting biases in the primary studies. By combining information from all relevant studies, meta-analyses can provide more precise estimates of the effects of health care than those derived from the individual studies included within a review. They also facilitate investigations of the consistency and differences of evidence across studies [161].

The assessment of primary trials is an important process that requires validated constructs to ensure a systematic review is reliable. There have been numerous scales or instruments developed for assessment of quality of trials, however, Jadad and co-workers developed a scale which consists of 3 main criteria, trialed in the pain literature, is the only one that has been through a systematic development process [162-164]. The 3 criteria include randomization, double blinding and report of withdrawals and dropouts. The authors also advocated blinding assessment as it was shown to have consistent and lower scores than open review. It was suggested in the light of contradicting results elsewhere [163, 165] that blinding could perhaps be helpful to remove bias in manuscript selection. It has also been suggested that cut-off scores should be used in selecting studies. Jadad and co-workers said that high reporting quality (3-5) and high validity should be the criteria to include the selected papers. Some critics of the Jadad score believe it gives more weight to the quality of reporting rather than the methodology as well as a tendency for lower inter-rater reliability of the Jadad score [163, 166].

Systematic reviews were introduced in the 1960s as a new paradigm of clinical research after work preceded by pioneers such as Archie Cochrane, Austin Bradford Hill, Richard Doll, Richard Peto and Ian Chalmers who advocated for higher level of scientific rigor and challenged dogmatic and authoritative practice [159]. This remains to today the highest level of evidence for clinical research. Nonetheless the quality of these reviews is dependent on the primary or original clinical experimentations.

In the light of variations on TMD diagnosis and management, in particular, conservative therapeutic modalities such as exercise therapy, a systematic review was deemed necessary and prudent to answer the question of the therapeutic effectiveness of exercises for TMD.

1.12 PURPOSE OF THE STUDY

Despite the high prevalence of TMD signs and symptoms in the population, most patients present to the general dentist with less complex problems and an even smaller percentage actually need treatment [167, 168]. There is an inevitable delay in transferring research findings to clinical application, especially in the TMD and orofacial pain areas for several reasons. Firstly, it is difficult for any practicing clinician to keep abreast of the rapidly expanding volume of literature and secondly, research in complex TMD and orofacial pain topics generally involves patients who have more complex problems, with or without a psychological component, associated with their presentations.

Such transfer of research knowledge on pain into dental education curricula has been explored by schools around the world [169] with recommendations for a minimal core component in pain education in undergraduate training for Dentistry, Physiotherapy and Occupational therapy by the International Association for the study of Pain (IASP) in 1993-4 [170]. A recent survey by Borromeo and Trinca from the Melbourne Dental School [169] reported that 63% of practicing dentists in Melbourne (year of graduation 1950-2006) perceived their current level of knowledge of pain is insufficient for clinical needs. The dentists were asked to complete a 16-question modified pain questionnaire and were able to answer only 48.67% correctly. Two other comparison groups (4^{th} and 5^{th} year undergraduate students) scored 46.71% and 58.22% respectively. Another survey of 45 dental schools in Canada and the United States revealed only 11% have some form of separate course dealing with TMD and Orofacial pain in their undergraduate programs with no evaluation process [169].

For Australia, planning is underway for postgraduate training in orofacial pain (The Australian and New Zealand Academy of Orofacial Pain, from personal communications). A pilot study (Figure 34, unpublished information) was carried out at The University of Adelaide surveying a sample of 30 qualified dentists aged between 21-70. The response rate was 77%. Results revealed over 40% of respondents believe their knowledge and skill was “inadequate” or “sometimes inadequate” to manage TMD. On the question regarding exercise therapy, 19% do not prescribe exercise, only 14.3% of respondents said they would always prescribe exercises with instructions and demonstrations whereas 33.3% would only occasionally give instructions. Only 9.5% would “always” give advice on self-care, and 14.5% never or rarely give self-care advice. Interestingly, a majority (86%)

would make a splint for TMD patients. Furthermore, 57.1% said they are unsure of how effective exercise therapy is for TMD management.

17. From your clinical experience, how effective do you find jaw exercises in TMD management?

	Response Percent	Response Count
Effective	38.1%	8
Not effective	4.8%	1
Unsure	**57.1%**	**12**
If unsure, please give reason		8
answered question		**21**
skipped question		**2**

Figure 34. Pilot survey. Bui and Richards, 2011. Unpublished data.

This overview of current management options by a group of dentists/ teaching staff in South Australia is a reflection of the variation seen in the practicing population, the complexity in research and the gap in dental education, together making the topic of TMD management less appealing and harder to understand. General TMD management given by dentists is largely successful with conservative, self-care advice, occlusal treatments or even fixed or removable prostheses when indicated (the latter are generally as an exception not a rule).

It is important to be equipped with some knowledge of chronic orofacial pain in order to recognize symptoms and signs of conditions beyond the general dentist's ability and to ensure an appropriate referral process [167]. Concurrently, it is also important that clinical practice is evidence-based in this day and age. Even though most published trials have shown that exercise therapy used as a single treatment modality or in combination with other conservative health care measures can result in moderate improvement for certain outcomes in patients with TMD, the variation between these results are difficult for clinicians to critically analyse and apply this efficiently in the clinical setting. This is even more challenging given that an "ideal" set of exercises for each particular TMD subtype has not been defined and there are no guidelines for example:

1. What type of exercise?
2. What is the number of repetitions to be performed?
3. How frequent they should be performed?
4. How can symptoms be monitored?

Dental education curricula around the world recognize that basic TMD education must be incorporated in undergraduate dental training [167]. Thus with the assumed training in basic science including head and neck anatomy, it is not beyond basic expectation that dentists should be able to prescribe exercises and relevant postural advice for the majority of TMD patients who present with functional problems related to the orofacial region. A survey of Swedish dentists revealed that clinicians rated highly of the importance of understanding TMD and Orofacial Pain (score 9-10 out of 11 on an 11-point numerical rating scale) and 59 out of 60 dentists (of 8-10 years experience) have already been treating patients with TMD. Of these, one third expressed the need for further training [171].

Thus, the purpose of the study is to gain a better understanding of exercise therapy and its application as a conservative modality for TMD management in the general dental setting where the majority of common TMD conditions are managed.

1.13 AIMS

To evaluate the level of effectiveness of exercise therapy for more commonly encountered TMD conditions of muscle and disc origins compared with no treatment controls or other conservative methods of management.

To formulate a guide to specific exercises that could be used by general dentists who manage patients with TMD signs and symptoms.

1.14 HYPOTHESIS

The null hypothesis is that exercise therapy with or without other conservative, non-surgical treatments is *not* effective for managing patients with temporomandibular disorders.

The alternative hypothesis is that exercise therapy with or without other conservative and/or non-surgical treatments *is* effective for managing patients with temporomandibular disorders.

CHAPTER 2. THE EFFECTIVENESS OF EXERCISE THERAPY PROGRAM FOR TEMPOROMANDIBULAR DISORDERS. A SYSTEMATIC REVIEW.

2.1 ABSTRACT

Background: Therapeutic exercises have been used by physiotherapists to manage musculoskeletal disorders, specifically Temporomandibular Disorders (TMDs) for some time but it is less commonly used in dental practice. The current evidence to support home exercise programs to treat TMDs is weak despite some generally recognised benefits such as low cost, reversibilitty and reinforcement of the patient's coping skill, essential for management of chronic conditions like TMDs.

Objective: To evaluate the effectiveness of home exercise programs used as part of dental management for TMDs.

Search methods: A search of the Cochrane Central Register of Controlled Trials (Cochrane Library Issue 7, 2012), Medline, Web of Knowledge and Scopus databases (January 1966 to February 2012) and reference lists of articles.

Selection criteria: Only randomized and quasi-randomised controlled trials published in English that compare exercise therapy to treatments without exercise therapy for TMDs were included.

Data collection and analysis: Two authors independently assessed the suitability of trials for final inclusion and also contacted study authors for additional information as required.

Results: Eleven trials involving 688 people were included. Two trials compared exercise programs to no-treatment control subjects for Anterior Disc-Displacement with Reduction (ADDwR). A significant risk ratio of 0.44 (0.29-0.59) (44% improvement rate) for

improvement in clicking after at least four weeks of exercise therapy was revealed. Three trials compared exercise programs for Anterior Disc-Displacement without Reduction (ADDwoR) with no-treatment control subjects. An overall improvement in the pain-free range of maximal mouth opening with exercise intervention was observed although not statistically significant in one of three trials. Six trials compared exercise programs for Myofascial Pain patients with no-treatment controls. A standardised mean difference in jaw pain score of 0.73 (95% CI -0.63 – 2.10) indicates no effect from exercise therapy for this TMD subgroup.

Conclusion: Within the limitations of the studies, exercise therapy appears to be effective for treatment of some TMD subcategories and unlikely to present any adverse outcomes.

2.2 BACKGROUND

Therapeutic exercises have been used by physiotherapists to manage musculoskeletal disorders, specifically TMD for some time but it is considered a relatively "new" concept in dental practice [172]. Exercise can improve joint lubrication by the stimulation of collagen fibres [151] without causing irreversible changes and this makes it an appealing modality for temporomandibular disorder management. Many forms of TMD therapeutic exercise have been evaluated and described in the scientific literature. These include: Range of motion; isometric; postural; relaxation; strengthening; and aerobic exercises. They are designed to stretch, relax, and improve posture and strength of the muscles, with the goal of improving tenderness, pain, function, and health [173].

The efficacy of exercise therapy, used alone or in combination with other treatments for specific TMD diagnoses, is currently unknown despite evidence of some level of effectiveness. With significant heterogeneity in study parameters and exercise specifications amongst published studies, the true effectiveness of exercise therapy in TMD management requires further clarification.

General dentists often feel that their competency level in TMD management correlates with their rating of their dental training [171]. Exercises following orthopaedic principles require specifications such as type of exercise, frequency and repetitions, aiming at improving joint mobility, muscle coordination, strength and length of muscles.

According to the commercial website of a popular oral health brand has the following advice (which is endorsed by the Faculty of Columbia University College of Dental Medicine):

"..do a few simple stretching exercises, like this one:

1. *Put your left thumb under your upper front teeth.*
2. *Put your right index and middle fingers on top of your lower front teeth.*
3. *Gently pull the jaw apart using your hands, not your jaw muscles."*

http://www.colgate.com/app/CP/US/EN/OC/Information/Articles/Oral-and-Dental-Health Basics/Common-Concerns/Temporomandibular-Disorders/article/Treatment-of-Temporomandibular-Disorder.cvsp. Excerpt accessed 1/9/2012.

Living in the internet age, patients are able to source this online information about their condition with different levels of reliability and inevitably utilize the information to address the discerned problem. The content of this website is an example of the level of ambiguity in dentist-prescribed exercises and may result in (i) confusion (ii) lack of confidence in the therapeutic effect and therefore lack of compliance from the patient (iii) poor monitoring of the treatment outcomes.

Past and recent systematic reviews on the effectiveness of exercise therapy are numerous, but these reviews are physiotherapy-focused [150, 174, 175]. Whilst there are recent good quality randomised trials, to the best of the authors' knowledge of the work of Fricton and co-worker in 2009 on exercise and headache as a primary condition, there has not been a systematic review performed with the dentist-clinician focus.

It has been demonstrated in the literature that TMD can be managed by the restorative general practitioner whose primary interest may not be in TMD or orofacial pain because "it is not difficult and adds to the comfort of the patient and possibility to the success of the restorations" [176].

2.3 OBJECTIVE

The objective is to systematically review randomised controlled trials that assess the effectiveness of exercise therapy compared with other non-surgical modalities used in the management of TMDs for outcome measures such as pain, range of movement, joint sounds and jaw function.

2.4 METHODS

Preparing for a review involves making many judgments which could be biased, for example, by the reviewer's prior experience since the process is by nature a post-hoc analysis [161].

A protocol was formulated before the search began to avoid being influenced by findings of the studies and involved two reviewers who participated in selecting and analysing the literature. Some experts suggest publishing the protocol prior to reviewing the studies as a means of reducing biases and promoting transparency of the methods and processes [161], this review was carried out following the established protocol and any changes made were documented and reported.

The protocol outlined objectives of the review, study design, intention and type of meta-analysis, method of assessment for clinical and methodological diversity (heterogeneity) using guidelines from the Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (March 2011) [177].

2.4.1 Criteria for Considering Studies for This Review

2.4.1.1 Types of Studies

Any randomised controlled trials or quasi-randomised trials that evaluated effectiveness of therapeutic exercise for TMD with a study duration of at least four weeks were included in this review. As the question pertains to the effects of health care, randomised studies were considered as they offer the benefit of preventing systematic differences between the groups known as confounders [178]. Cross-over randomised controlled trials, non-

randomised trials or other forms of case studies were excluded as it was considered that such study designs have potential high risks of bias. Restriction to English language was necessary as a feasibility factor.

2.4.1.2 Types of Participants

The criteria for considering types of participants should be sufficiently broad to ensure diversity of studies and narrow enough to allow meaningful analysis [177, 178]. Studies that included adults were preferable but no age-limiting criteria were placed as TMDs have been shown to occur from pubertal growth to adulthood [33]. For the primary trial to be eligible, the report needed to explicitly state the primary TMD diagnosis (being at least one or more from three broad TMD subgroups - articular, muscular and disc disorders) without a major effect from neurologic or psychiatric co-morbidities. No limitation was placed on classification system used to derive the main diagnosis. With regard to the setting and characteristics of participants, no restriction was placed on the recruitment process but for characteristics of participants, exclusion criteria included systemic causes including inflammatory and idiopathic arthritides; regular medications such as analgesics; anti-depressants and psychotropics that would otherwise indicate a significant psychological/psychiatric component; and a history of whiplash injury.

2.4.1.3 Types of Interventions

The interventions included any exercise programs that dentists can prescribe for TMD patients to perform at home as a stand-alone treatment or in conjunction with other treatments (e.g splints and self-care). The comparative intervention was either non-treatment control (also known as wait-list control) or any conservative treatments without exercises that may include physical medicine modalities.

Simple exercises are defined as those that can be prescribed by a dental practitioner without the use of an external or mechanical device for support or need for further musculoskeletal training beyond basic undergraduate knowledge of the orofacial and neck regions. As exercise therapy is used in the subacute phase with the therapeutic objective being change in joint and muscular function, a duration less than 4 weeks was deemed inadequate for any real effects to be detected. However, there is currently a lack of

evidence in the literature on specific minimal exercise duration before follow up for TMD patients.

2.4.1.4 Types of Outcome Measures

A wide range of TMD symptoms may be present individually or in combination, including pain; reduced or deviated range and path of movements; tension headache; postural-stiffness; para-functional habit; and stress or psychosocial effects. Amongst these, pain severity is the most important treatment-seeking symptom and is a common outcome measure despite evidence that retrospective pain recall may not be the most reliable indicator [110]. Other outcome measures considered are joint sound and joint range of movement. In order to maintain a broad range of studies for analysis, actual outcome measures were not considered part of the inclusion or exclusion criteria in this review. The focus on functional deficits (limitation of daily function) as an indicator of treatment outcome was justifiable, in part at least for this approach as methods and outcome measures were not strictly standardised between studies. Primary outcomes were predetermined to include subjective or objective reports of joint and muscle pain level, range of movement, joint sound, and function or dysfunction and secondary outcomes were defined as reports of pain-related disability and psychological effects as described by RDC-TMD Axis II components. A table of inclusion and exclusion criteria is attached in the appendices. (Appendices 2.9.2)

2.4.2 Search Methods for Identification of Studies

The PICO format (Population, Intervention, Comparison, Outcome) was followed where a research question was formulated. Only parallel group randomised controlled trials that met the inclusion criteria were included in this review. In this study, the PICO question was "In adult patients with temporomandibular disorders, how effective is exercise therapy compared to other conservative interventions in reducing TMD symptoms?"

2.4.2.1 Electronic Searches

To identify trials to be included for this review, a systematic search was performed on one bibliographic database (MEDLINE via Pubmed) and two citation index databases (Web of knowledge (WoK) and Scopus) from 1966 to January 2012 with the assistance of a librarian expert in the field.

The Cochrane Oral Health Group Trials Register and Cochrane Central Register of Controlled Trials (CENTRAL) were also searched. The search strategies for each main databases are shown in the attached tables. (Search terms for Pubmed, WoK, Scopus are attached in Appendix 2.9.1). Both free-text and subject headings were used as well as filters for randomized trials on the respective databases.

2.4.2.2 Searching Other Resources

Additional keyword searches using other resources including Google Scholar, FDI web page, Trip-database, Clinical trials registries of Hong Kong, Indian, Japan, Active register of Controlled Trials with "Temporomandibular Disorders/Temporomandibular joint disorders" and "Exercise" as key words.

To ensure broader coverage (sensitivity) in the process of identifying studies, a physiotherapy database[4] was also accessed for additional related studies.

Conference abstracts were included for follow up with the publication authors to minimize publication bias. Bibliographic search of the included papers and review papers were screened for additional studies.

[4]Accessed 31/5/2011
http://search.pedro.org.au/physiotherapy_choices/browserecord.php?recid=1927

2.5 DATA COLLECTION AND ANALYSIS

Electronic searches were screened by Reviewer 1 (methodologist) to identify eligible results. At the first and second search stages, screening was based on titles and abstracts to determine eligibility of the study and where they appeared relevant, full text versions were retrieved for further assessment. From the third stage, screened trials were selected independently by Reviewers 1 and 2 (experienced reviewer) and a formal measure of agreement (kappa statistics) was calculated. Values of kappa between 0.40 and 0.59 have been considered to reflect fair agreement, between 0.60 and 0.74 to reflect good agreement and 0.75 or more to reflect excellent agreement [179].

A further bibliographic search by Reviewer 1 was carried out from the selected trials and other topical reviews. Independent assessment of eligibility of additional trials was agreed between reviewers.

Oxman demonstrated that there is a positive correlation between level of expertise and strength of prior opinion (0.55, p= 0.03) and this relationship also occurs with a smaller amount of time spent for preparing a review (-0.40, p = 0.045), with quality of review being affected (-0.52, p = 0.004) [159]. In this review, reviewer 1 is a postgraduate student with limited research and clinical experience in TMD. Reviewer 2 is a senior prosthodontist in the area of removable prosthodontics. Therefore it is believed that this relationship should not cause significant biases with respect to expertise impact on the synthesis of primary data.

2.5.1 Selection of Studies

Decisions about which studies to include in a review are among the most influential decisions that are made in the review process. Hence, to reduce selection bias and for reproducible result, a second reviewer was involved in the final process of selection of studies into the review. It is recognised that using at least two authors may reduce the possibility that relevant reports are discarded especially when screening large volume of titles and abstracts [180]. For practical reasons, the second examiner was involved at a later stage after preliminary studies had been screened. It was planned that should any disagreement arise, an experienced practitioner, as a third examiner would be consulted.

However, this process was not required. No attempt at blinding the trial authors' names was made as it was decided that assessment of content and correspondence with authors would be sufficient to come to a decision for the final inclusion.

Steps taken to select studies are summarised as follow:

- Search results were recorded and irrelevant or duplicate reports were removed.
- Full text of potential studies were retrieved.
- Full-text reports were examined for compliance of studies with eligibility criteria.
- Excluded studies were assessed and recorded.
- Correspondence with potential trials' authors to clarify and obtain missing information was carried out.
- Final decisions on study inclusion was agreed between both reviewers (kappa statistics = 1)

2.5.2 Data Extraction and Management

Data collection was performed by Reviewer 1 using a data collection form which include details such as study ID (principal author name and year of publication), study methods (study design, duration, components of risk assessments), participants (characteristics of participants, setting), interventions (number and size, specific details of exercise protocols), outcomes (time points collected and units of measurement), missing data and statistical analysis method, estimate of effect with confidence interval, funding source and miscellaneous entries such as trial and review authors' comments.

2.5.3 Assessment of Risk of Bias in Included Studies

Risks of bias were assessed using the Cochrane Collaboration's domain-based evaluation tool. The core assessments of risks-of-bias were: Randomisation, Allocation, Concealment of participants and trial authors, Reporting and Attrition biases. Additionally, it was decided that assessment of precision, which although does not contribute to internal validity of a study, does give additional information on the assessment of the strength of the evidence should quantitative analysis not be feasible for example, due to heterogeneity of the included studies.

There are no recommended tools for methodology assessment, however, to assess the validity and applicability of a trial, there are core criteria that must be assessed and it was decided that criteria listed above were sufficient and valid.

The Cochrane Collaboration guide discourages the use of tools that give summary score on assessment of risks of bias (such as Jadad's score).

2.5.4 Measures of Treatment Effect [181]

The effect measure chosen was absolute mean difference (MD) for pre-specified continuous data and risk ratio (RR) for dichotomous data.

Mean difference measures the absolute difference between mean values of control and experimental group in a clinical trial. This can only be used as a summary statistics in meta-analysis if the data were measured on the same scale. Where studies differ in their measures of the same outcome, it is necessary to standardize the result of each study by dividing the mean difference by the standard deviation of outcome among participants to obtain a common unit of measure in order for comparisons to be made between studies.

For dichotomous data, some common effect measures in clinical trials are:

1. Risk ratio (RR) which is also called relative risk
2. Odds ratio (OR)
3. Risk difference (RD) which is also called absolute risk reduction
4. Number needed to treat (NNT)

In this review, RR was chosen as an estimate of effect measure as it is a more familiar concept to patients in health care. The risk is defined as the chance or probability with which a health outcome (improvement in pain level, range of movement, absence of joint sounds) will occur. The results of a clinical trial can be calculated as follow:[5]

[5] Cochrane Handbook for Systematic Reviews of Interventions, version 5.1.0, Box 9.2a

	Event (**S**uccess)	**No event** (**F**ail)	**Total**
Experimental intervention	SE	FE	NE
Control intervention	SC	FC	NC

Where SE, SC, FE, FC are the numbers of participants with each outcome ("S" or "F") in each group ("E" or "C").

The following RR statistics can be calculated:

$$RR = \frac{\text{risk of event in experimental group}}{\text{risk of event in control group}}$$

$$= \frac{SE/NE}{SC/NC}$$

2.5.5 Unit of Analysis Issues

Studies with multiple treatment groups were assessed independently at the time of analysis and treated appropriately without combining the outcomes.

2.5.6 Dealing with Missing Data

Missing data can encompass the following [182]:

- Missing studies due to publication bias or insufficient search
- Missing outcomes from original study or from reporting bias
- Missing summary data from incomplete or bias reporting
- Loss of subjects (lack of intention to treat/attrition from study)
- Missing study-level characteristics of subgroups from not being measured or incomplete report thereof.

Any missing data that would prevent a study from being included in the review was requested from the primary authors by e-mail correspondence and meta-analysis was only carried out with the available reported data when appropriate.

2.5.7 Assessment of Heterogeneity

For any meta-analysis performed, an assessment of consistency or heterogeneity between studies was performed using Cochrane Collaboration Review Manager version 5.1.0 (March 2011) which produces I^2 statistic, a measure of the impact of heterogeneity on the meta-analysis where I^2 =(Q –df/Q) x 100%, Q= Chi-squared statistic and df is its degrees of freedom.

A rough guide to interpretation of the score is as follows:

- 0% to 40%: might not be important
- 30% to 60%: may represent moderate heterogeneity*
- 50% to 90%: may represent substantial heterogeneity*
- 75% to 100%: considerable heterogeneity*

*The importance of the observed value of I^2 depends on (i) magnitude and direction of effects and (ii) strength of evidence for heterogeneity (e.g. P value from the chi-squared test, or a confidence interval for I^2).

2.5.8 Assessment of Reporting Biases

The risk of bias in studies with more than two groups of outcomes/interventions was assessed by looking at whether the data presented for each outcome and whether there was any risk of selective reporting of outcomes of the intervention arm.

There are many types of reporting biases including publication bias, time-lag, multiple publication bias, location bias, citation bias, language bias, and outcome reporting biases. A funnel plot was produced to test for small-study effects, a tendency for intervention effects estimated in smaller studies to differ from those estimated in larger studies. Note however that a funnel plot with asymmetry does not equate with publication bias [183]. To reduce the risk of reporting biases, we also ensured comprehensive searching as much as possible including screening grey literature (generally means the literature that is not formally published in sources such as books or journal articles) and bibliographic records.

2.5.9 Data Synthesis [181]

The choice of meta-analysis was made on the basis of the available data reported in the trials using outcomes including: maximum pain-free mouth opening; jaw joint pain; limitation of function and pain on masticatory function. These outcomes were selected base on the available data that satisfied the requirement for pooling. The random-effects model was used because of possible heterogeneity between the studies assuming a normal distribution of the mean effect with the spread being the degree of heterogeneity. The random effects model does not account for the actual degree of heterogeneity but assumes that data follow a random pattern. It does not describe the width of the distribution, but describes the mean and the confidence intervals. A small interval indicates higher confidence even though there may be large heterogeneity.

2.5.10 Subgroup Analysis and Investigation of Heterogeneity

Subgroup analysis is an intentional assessment of subsets of outcomes, as a means to investigate for heterogeneity or to answer specific questions about a particular condition or patient group. This systematic review did not explore variables of outcomes beyond the main outcomes mentioned in the previous section.

2.5.11 Sensitivity Analysis

A systematic review involves making many decisions, which may be difficult and can potentially affect the findings of the review. A sensitivity analysis is a repeat of the primary analysis or meta-analysis, substituting alternative decisions or ranges of values for decisions that were arbitrary or unclear [181]. Some sensitivity analysis can be pre-specified but many issues are only identified after reviewing the included studies in greater details. In this review, sensitivity analysis was not required as the majority of studies were analysed qualitatively rather than through statistical calculation of summary of effects.

2.6 RESULTS

2.6.1 Results of the Search

From multiple databases and trial registers as well as using keyword searches a total of 1464 published titles were identified. Screening to identify unsuitable publications and removal of duplicates of the same study was performed which resulted in 62 potential studies for assessment. Examination of their full text content yielded 25 published trials that appeared to meet the pre-specified eligibility criteria. At this stage, further independent assessment by Reviewers 1 and 2 resulted in 100% agreement on five trials eligible to be included for final analysis. Table 21 lists the 20 excluded studies and brief reasons for their exclusion. Additional bibliographic search identified six studies and two abstracts. Both reviewers independently assessed and agreed on inclusion of the six studies, which brought the final total to 11 studies included in the review. Two conference abstracts were not included for final analysis due to missing protocol details and because the results remain unpublished. Therefore the final total number of included trials was 11 studies. An overview of the study identification and inclusion can be seen in Figure 35.

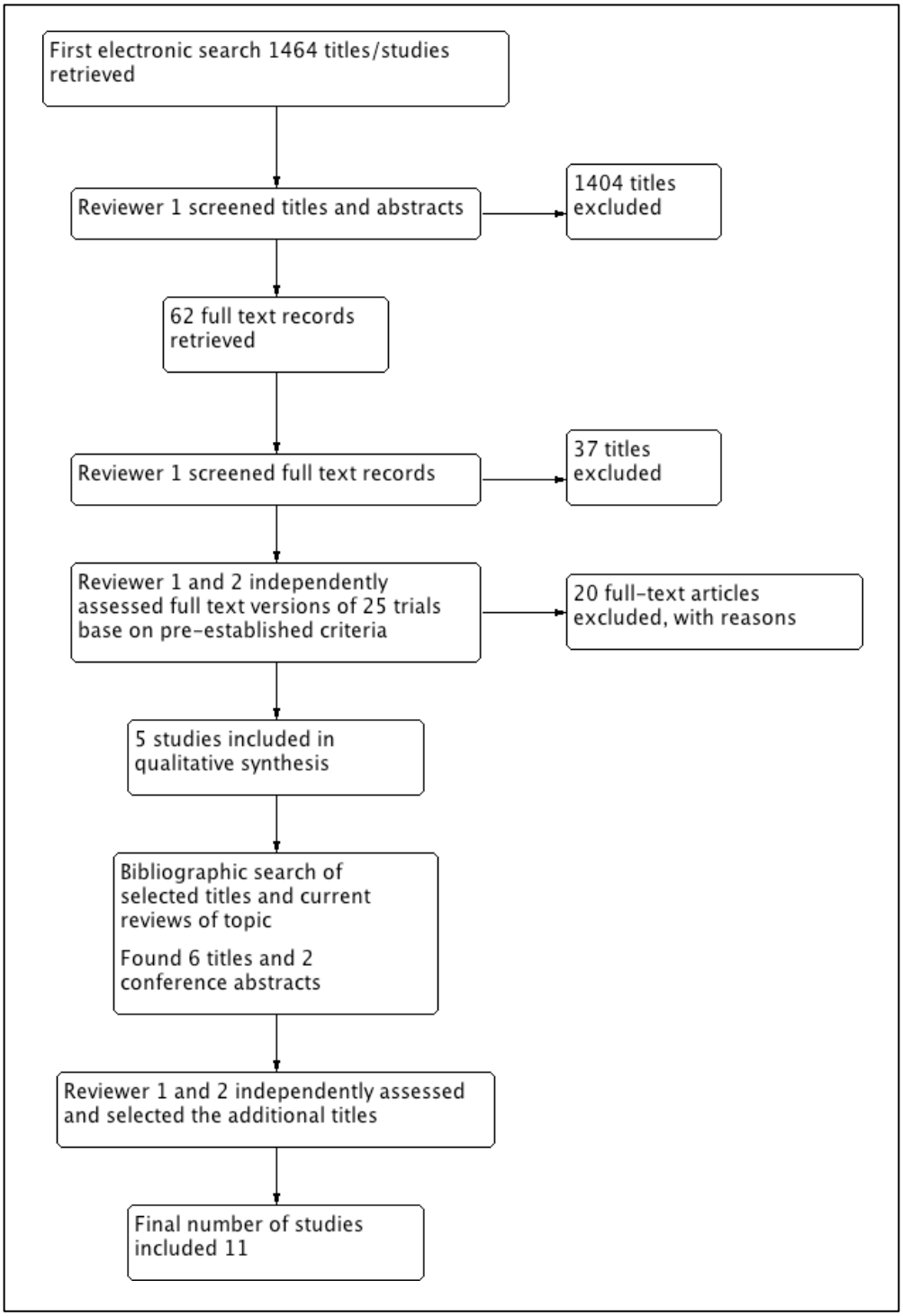


Figure 35. Search flow diagram

2.6.2 Description of Studies

Eleven randomised controlled trials (RCT) investigating the effectiveness of exercise therapy for three groups of TMD subtypes met the inclusion criteria. Three trials by Haketa and co-workers, Minakuchi and co-workers, Yuasa and co-workers [184-186] studied

the effect of exercise on patients with disc displacement without reduction (ADDwoR). Six trials by Gavish, Magnusson, Michelotti, Mulet, Truelove, Wright and their respective co-workers [63, 86, 187-190] examined the effect of exercise therapy on patients with myofascial pain and two trials by Au and Yoda and their respective co-workers [172, 191] were performed for patients with disc displacement with reduction (ADDwR). Randomisation was explicitly stated in all studies for a total of 688 subjects with TMD referred into tertiary hospital, teaching institutions or TMD speciality clinics in Japan, North America, Sweden and Naples. For study details see Appendices section: 2.9.3 Characteristics of study.

2.6.3 Included Studies and Effects of Interventions

Details of the 11 studies were tabulated in a table of Characteristics of studies and data were analysed using the Review Manager 5.1 (RevMan 5.1, Cochrane Collaboration, 2011) program with the main results of the study presented separately for ADDwoR, ADDwR and myofascial pain subtypes.

2.6.3.1 Anterior Disc Displacement Without Reduction (ADDwoR)

From three randomised controlled trials, a total of 173 subjects (150 females, 23 males) age range between 16-75 years old (mean = 36, median = 28) with MRI-confirmed ADDwoR were randomly divided into exercise therapy (experimental) and no-treatment (control) groups [185, 186] except for 25 subjects in one trial who received intra-oral splint as a comparator [184]. The trial by Minakuchi and co-workers [185] differed from the other two trials by having two treatment arms with the second parallel experimental group receiving splint, exercise therapy and joint-mobilisation as multi-treatments. The first treatment arm consists of self-care advice and exercise therapy only. For this review, the treatment group of interest is the single treatment comparator.

One of the trials [184] excluded subjects less than 18 years old. The different eligibility criteria used between the studies is a potential issue that would require further sensitivity analysis beyond the present review to detect the exact influence of missing younger subjects. The studies are not consistent in their reported averages for example, Yuasa and co-workers [186] reported median age and the trials by Minakuchi and Haketa and their co-workers reported mean age [184, 185].

The criteria defined for inclusion of subjects in the trials are:

- Complaint of unilateral pain on chewing and opening with severity rating at least 10/100mm on a 100mm-visual analogue scale [185] or moderate to severe TMJ dysfunction on the modified TMJ Criteria of the American Association of Oral and Maxillofacial Surgeons and International Association of Oral and Maxillofacial Surgeons [186]
- Range of opening less than 40mm [184]
- Duration of symptom at least 2 weeks [184, 186]

Table 10 describes the classification used by Yuasa et al, 2001.
More details of the included trials can be reviewed in Appendices 2.9.3

Table 10. Scale of measurement of joint dysfunction.

Modified version of American Association of Oral and Maxillofacial Surgeons and International Association of Oral and Maxillofacial Surgeons, adapted Yuasa et. al. 2001. [186]

Degree of TMJ dysfunction	Maximal mouth opening (mm)	Maximal value of visual analogue scales (0-100)
None	≥ 40	0
Slight	35-39	1-33
Moderate	30-34	34-66
Severe	≤ 29	67-100

Regarding MRI diagnosis, one trial [185] used Orsini criteria (1999) for ADDwoR diagnoses on MRI whereas the other two trials did not specify diagnostic criteria.

Common exclusion criteria are: Myofascial pain [186], recent treatment within previous 4 weeks [185, 186], edentulousness [185]), partial denture wearer [184], serious systemic diseases [185], unwilling to receive treatments including exercise and follow up [184, 185] and regular analgesics, anti-anxiety, antidepressants and psychotropic drugs [184].

Intervention exercises included self-care advice consisting of:

- A hot/cold packs, soft diet and small range/gentle mouth opening exercises [185] or,
- Daily exercise protocol 4 sets of 3 stretches, each with 30 seconds hold [184] or,
- Another daily protocol including active-assisted mouth opening exercises in straight opening, protrusion, and lateral movements at a frequency of 4 sets per day of 10 repetitions and 10 seconds hold for each repetition [186].

All three trials prescribed NSAID three times per day during the study period [184-186].
The main outcomes measured include:

i. Changes in pain-free range of opening (in millimetre) [184, 185]
ii. Maximal active range of opening compared between baseline to different end points (initial exam, 0 week, 2 weeks and 4 weeks) [184-186].

Other outcome measures include self-reported current maximum daily pain intensity [184] and joint pain levels at rest as well as on chewing measured using the visual analogue scale on a 0-100mm line [185, 186].

Additionally, limitation of daily function or daily life interference was measured with several scales including the "Limitation of Daily Functions for the TMD Questionnaire" that consists of 10 questions relating to daily functions each to be graded on a scale of 1-5 for ascending level of difficulty with a total score range from 10-50 [184]. For the same outcome, Minakuchi and co-workers [185] used another scale devised by Clarke et al in 1989, which consists of 18 questions rated from 0-4 in ascending level of limitation of daily functions and collected at five time points (initial examination and 0, 2, 4, 8 week). The trial by Yuasa and co-workers [186] used the VAS scores to measure this outcome.

Outcome 1. Changes in range of mouth opening

An improvement in mean range of mouth opening, both to comfortable range and at maximum range occurred over time (time progress P-value = 0.001) [184, 185]. Statistical significant improvement were reported in maximal mean ranges of opening with or without pain after 4 weeks with stretching exercise; gentle opening exercise; or repetitive opening and lateral movements compared to the comparison splint or no treatment groups. Improvement in passive opening range was also evident, however the observed differences were not statistically significant [185]. This means that small gentle exercises for ADDwoR

TMD alone resulted in improvement in active mouth opening range but not the passive range.

A breakdown of the levels of statistical significance suggest that time-progress contributed more to the final result of improvement in range of mouth opening [185]. The study by Yuasa's group reported a similar pattern with exercises (active assisted exercises) producing significant improvement compared with the control group (P-value= 0.005) for ADDwoR TMD. A summary of effects of exercise for ADDwoR TMD is as shown in Tables 11 and 12.

Table 11. Changes in comfortable mouth opening from baseline to 4 weeks

Study	Mean of comfortable opening range from baseline to 4 weeks	P-value (time and group interaction)	P-values of separate group interaction and time-progress
Minakuchi (palliative group)	32.4-37.0 mm	0.034	Group difference P = 0.700 Time-progress P < 0.001
Haketa	26.5-35.1 mm	0.03	Time-progress P < 0.001

Table 12. Changes in maximum active mouth opening from baseline to 4 weeks

Study	Mean/median of maximal opening range from baseline to 4 weeks	P-value (time and group interactions)	P-values of separate group interaction and time-progress
Minakuchi (palliative group)	36.1-39.1 mm	0.012	Group difference P = 0.733 Time-progress P < 0.001
Haketa	32.2 – 39.3 mm	0.02	Time-progress P < 0.001
Yuasa	29-37.5 mm	0.005	---

Outcome 2. Change of pain levels

Two trials [185, 186] reported improvements in pain level during chewing function for ADDwoR TMD subjects after four weeks of exercise with either:

- 4 sets x 10 repetitions 10 seconds hold for straight opening and lateral movements or
- Gentle opening exercises with hot/cold applications as required

Due to heterogeneity between the studies in their use of mean and median as average scores, pooling of the results was not possible and an estimate of effect size was not calculated. The effect of gentle exercise and self-care activities did not result in statistically significant improvement in pain level at rest and similarly time-progress did not influence resting pain for ADDwoR TMD subjects over four weeks (Table 13).

Table 13. Changes in pain levels at rest and on chewing

Study	Mean/median pain levels at rest from baseline to 4 weeks	P-value	Pain levels on chewing from baseline to 4 weeks	P-value
Yuasa	0	0.711	53.5 – 25.5	0.001
Minakuchi	11.4 – 5.7	0.486 Time-progress P = 0.490	55.8 – 26.2	0.286 Time-progress P < 0.001 Group difference P = 0.849

For maximal daily reported pain intensity, stretching exercises (4 sets x 3 stretches x 30 seconds hold) resulted in a clinical reduction in maximal pain report but the results were not statistically significant with P-value = 0.12 [184] (see Table 14).

Table 14. Changes in current maximal daily pain intensity

Study	Maximal pain intensity from baseline to 4 weeks (VAS)	P-value
Haketa	63.1-33.1	0.12 Time-progress P < 0.001

Outcome 3. Changes of limitation of daily functions

All three trials reported significant improvement in self-reported level of daily activity with exercise therapy (P-value < 0.05) at four weeks regardless of the influence of time progress (P < 0.001).

Table 15. Changes in perceived limitations of daily function

Study	Mean/median score from baseline to 4 weeks	P-value
Haketa	24-20	P < 0.001 Time-progress P < 0.001
Yuasa	46.5-22	0.001
Minakuchi	5.6-3	0.029 Time-progress P = 0.001

2.6.3.2 Anterior Disc Displacement with Reduction (ADDwR)

Two randomised controlled trials [172, 191] were retrieved and included for analysis. A total of 86 subjects between 12-59 years of age were randomly divided into exercise and control groups. Forty-four subjects were patients who attended tertiary hospital clinic for painless clicking jaw joints. The other 42 subjects were student recruits [191]. The method of randomisation was reported in one study [172] whereas additional information for the second study was obtained via personal communication with the first author of the second trial. There is insufficient data in one report [191] for the characteristics of the control group and therefore mean age and gender ratio cannot be reported for this review. In this trial, subjects were assessed to have ADDwR TMD using a Doppler auscultator and classified as having soft or hard clicks at any particular locations of the opening path - near, middle, wide as defined by Watt and McPhee. Similarly, the second study by Yoda and co-workers [172] selected their subjects by clinical examination (joint palpation) and using MRI according to the Ozawa displacement criteria (3=severe, 2=moderate, 1=slight displacement) and Tasaki deformity categories (biconcave or deformed). Inclusion criteria were painless unilateral or bilateral joint clicking [191] eliminated by protrusion [172]. The participants were excluded if they had recent treatment for TMD within four weeks, TMJ pain, MRI-confirmed bilateral disc displacement with or without reduction [172]. The trial by Au and Klineberg did not specify any exclusion criteria.

The intervention exercise includes disc repositioning mandibular positions recommended to be performed three times daily for 5 minutes and maintaining the position all day except

during meal time and sleep [172] or, "moderate" constant resistance against mouth opening and lateral excursive "isokinetic" movements [191]. In both studies, the control group received no-treatment allocations. An additional control group of healthy subjects without TMD were also assigned to perform the same set of exercises in Au and Klineberg's study. Figures 36 and 37a, b, c demonstrate the two exercise protocols.

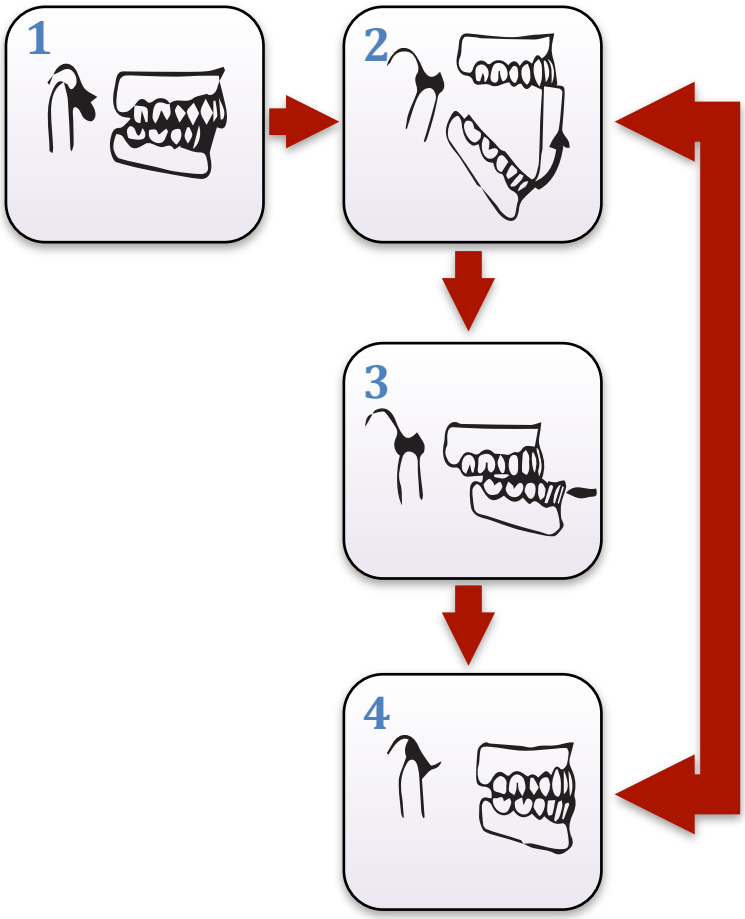


Figure 36. Disc Repositioning Mandibular Position exercise. Adapted from Yoda et al. 2003

Disc-repositioning exercise method:

1. Intercuspal position: the disc is anteriorly displaced.
2. Open the mouth maximally with the opening-click.
3. Close the mouth along the protrusive border movement path. Contact the teeth at the protruded position. At this point, the disc is thought to be on the condyle.
4. Retrude to a contact position just before the click would happen. This position is called the disc repositioning mandibular position. Open the mouth maximally again without the opening click.

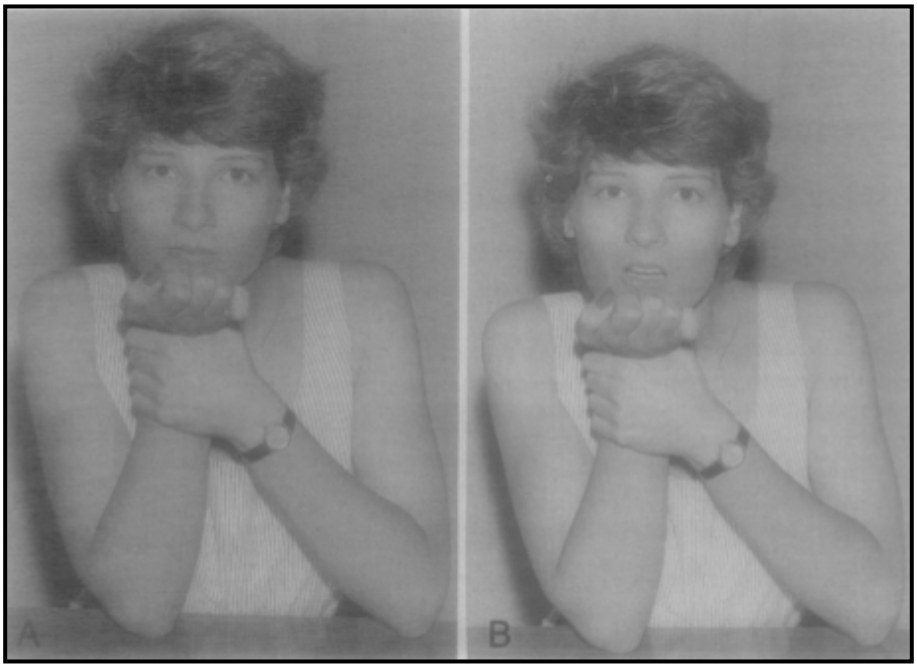


Figure 37a. Isokinetic exercise protocol

Adapted from Au and Klineberg, 1993

A. Frontal view of patient with jaw supported correctly and ready to begin exercise sequence.

B. View shows degree of jaw opening as hinge movement, while mild resistance is provided by hand supported at the elbow resting on a bench. Resistance only applied by the hand – not a retrusive force.

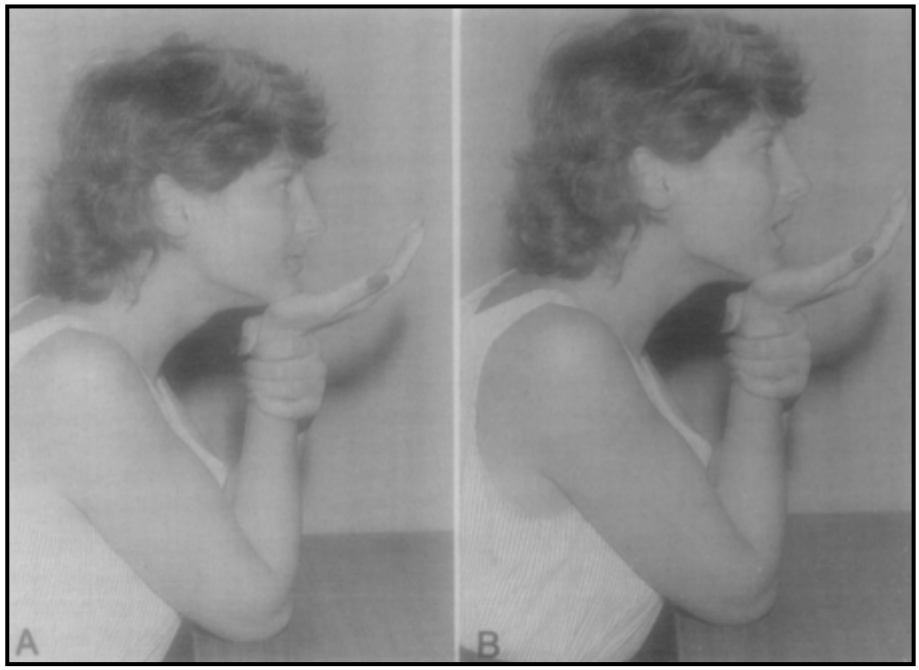


Figure 37b. Isokinetic exercise protocol

Adapted from Au and Klineberg, 1993

A and B. Lateral views of the patient indicate type of chin contact provided, in this case, by hand supported at the elbow resting on a bench.

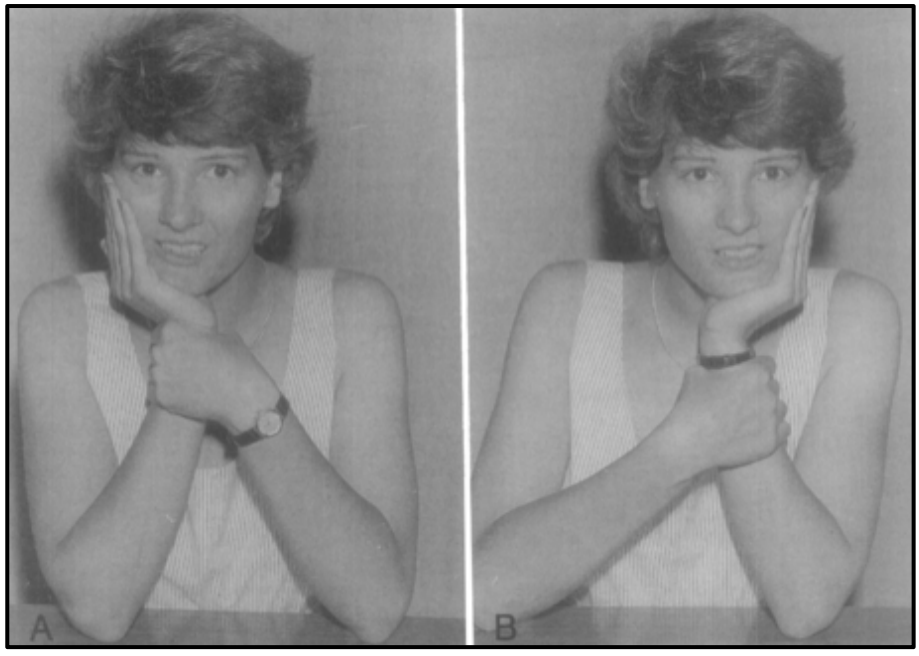


Figure 37c. Isokinetic exercise protocol

Adapted from Au and Klineberg, 1993

Frontal view of the same patient carrying out lateral jaw exercises to the right (A) and left (B). As before, moderate resistance is provided by hand supporting the chin with the elbow resting on a bench.

Outcome 1. Clicking

A common outcome measure between the two trials is the presence of joint clicking after exercise for four weeks. Au and Klineberg reported an improvement rate of 82% after 6 months with isokinetic exercise and Yoda reported 38% improvement after 3 months of mandibular repositioning exercises. The pooled data using Cochrane review Manager 5.1.0 produced a estimate average "risk" difference of 44% (improvement rate) with Z-value = 5.74, P-value = < 0.00001, heterogeneity assessment I^2=0% as can be seen in the forest plot below (Figure 38).

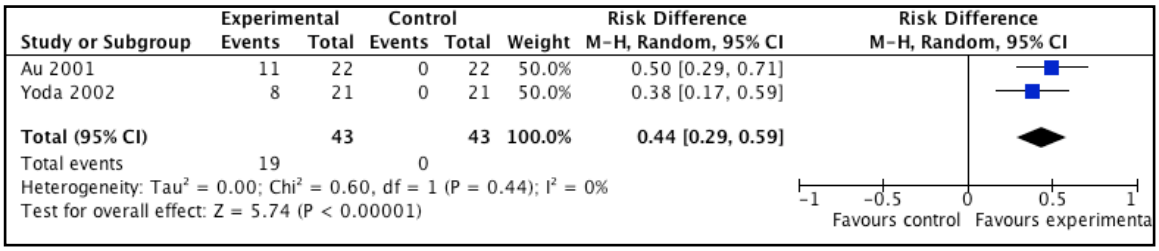


Figure 38. Forest plot of effect of exercise for outcome " joint clicking"

The estimate for Yoda trial is a conservative estimate chosen to remain consistent with the definition of successful outcome, which defines success as the absence of clicks at the end of time event (Table 16). Thus, by the definition specified in the report, only "excellent" cases were counted as "successful event" when incorporated the data for meta-analysis.

Table 16. The change of clicking and success rate

Adapted from Yoda et al. 2003.

	Exercise group (n=21) No. (%)	Control group (n=21) No. (%)
Excellent	8 (38.1)	0
Good	5 (23.8)	0
Successful	13 (61.9)	0
Fair	5 (23.8)	2 (9.5)
Poor	3 (14.3)	19 (90.5)
Unsuccessful	8 (38.1)	21 (100)

Observing different categories of reported clicking after three months, Yoda and co-workers classified “excellent” and “good” as successful treatment. Within the “unsuccessful” group, the reported level of interference with daily life caused by clicking slightly improved compare to the control group who had no changes after three months, however this did not reach statistical significance (P-value= 0.201) (Table 17). Additionally, despite evidence of success, MRI confirmed only three out of 13 cases of "successful" treatment whose discs recaptured which indicates that success does not equal a change of disc repositioning.

Table 17. Change in the discomfort and interference with daily life caused by clicking before and after exercise procedure in both groups

Adapted from Yoda et al 2003.

		Discomfort of clicking			Interference with daily life		
		Before (median)	After (median)	P-value	Before (median)	After (median)	P-value
Exercise group (n =21)	Successful	3	1	0.015	3	1	0.002
	Unsuccessful	4	3.5	0.201	4	3	0.138
Control group (n=21)	Unsuccessful	3	3	0.311	3	3	0.398

2.6.3.3 Myofascial TMD Pain

Six randomised controlled trials reported by Magnusson [188], Mulet [190], Truelove [192], Gavish [187], Wright [86], Michelotti [152] and their respective co-workers published between 1999-2007 were identified and included for analysis. A total of 411 subjects from six studies were referred to tertiary/university hospital orofacial pain centers [152, 187, 188, 190, 192] and Lackland Airforce Base in Texas [86]. Criteria used by the trials to diagnose myofacial pain include the RDC-TMD criteria [86, 152, 187, 190, 192]. Wright and co-workers used the Dworkin and LeResche technique to determine muscle tenderness. Magnusson and co-workers did not state specifically which type of criteria was used to diagnose their subjects but included any one with "main subjective symptom of tension-type headache and/or orofacial pain or non-neurogenic or non-dental origin". The Magnusson trial consisted of the following referral sources: 47.8% from medical general practitioners, 8.7% from other specialist dentists, 43.5% from general dentists, while subjects from other studies were recruited from University daily newspapers, flyers, and ongoing patients at university clinics. All the studies (except one by Mulet) reported mean age therefore we can only describe a range of age for these subjects between 16-67 years old and approximately 90% of total subjects are females although the study by Magnusson did not report the composition of the study subjects.

Additional to the diagnosis of myofascial pain, subjects also had to have met pre-specified inclusion criteria including:

- Subjects at least 18 years old with pain present at least 6 months, average pain intensity within last month ≥ 4/10 on the numerical graph rating scale (NGRS) and frequency must be over 3 days per week, taking NSAID 0-3 days/week and no limit of passive opening range [190].
- Moderate level of pain at least 6 months with no prior treatment and living within 90 minutes driving distance to the centre [86].
- Recurrent or constant pain over 3 months and spontaneous pain within last week ≥ 30/100mm on the VAS [152]
- At least grades 2-3 tenderness on palpation of masticatory muscles and pain at least 6 months [187]
- Diagnosed with RDC-TMD criteria for Axis Ia or Ib with or without concurrent diagnosis of Group IIa, IIIa and Axis II Grade I or II with minimal psychosocial interference [192]

All six studies excluded subjects with systemic causes of TMJ symptoms and various other exclusion criteria for each study are described in Table 18.

Table 18. Additional exclusion criteria

Study/Author	Additional exclusion criteria
Michelotti	TMJ arthritis, intra-articular pathology, orofacial pain, neurologic or psychiatric disorders, pain medication abuse habit and treatment for TMD within three months prior to study.
Mulet	Dental pathology; orofacial pain disorders; current intake of more than three days of over-counter analgesics; use of narcotics, hypnotic drugs, sedatives or muscle relaxants; ADDwoR; OA; major psychiatric disorders. Co-existing TMJ arthralgia, and disc displacement with reduction were not exclusion criteria in this trial.
Truelove	RDC-TMD Axis I, Group IIb, III; systemic arthritis or other serious medical complications; full dentures; major psychiatric disorders or non-English speaking; current "successful" use of splint.
Gavish	Joint disorders; systemic chronic disorders; continuous use of medications; trauma history to cervical and/or facial region; previous treatment within 6 months.
Magnusson	Malocclusion

Intervention exercise protocols vary widely between the trials as shown below.

Reciprocal inhibition with active-passive resistance against the direction of movement (Figure 39) performed at least three times per day for 2-3 minutes (Magnusson et al, 1999).

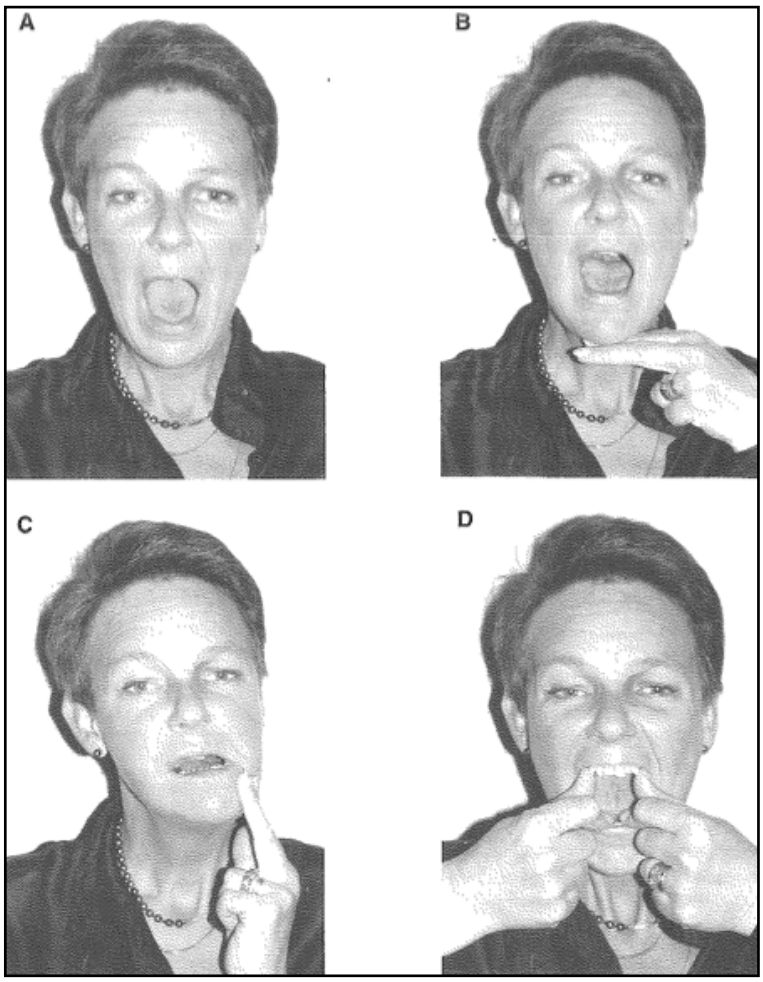


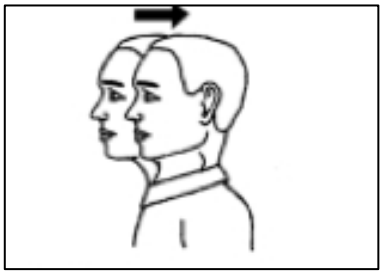
Figure 39. Exercise program prescribed by Magnusson and Syren, 1999
Examples of jaw exercises included in the training program.
A) Maximal opening without resistance.
B) Jaw opening towards resistance.
C) Laterotrusion to the left toward resistance.
D) Stretching.

Whereas Michelotti and co-workers prescribed a protocol that involves six active-passive mouth opening stretches to pain, then hold for one minute and coordination exercises performed three times, twenty repetitions every two hours. Michelotti's exercise protocol was also accompanied by emphasis on self-care such as relaxation, diaphragmatic breathing exercises, thermal application, soft diet advice and self-massage on the tender muscles, continued for 3 months regardless. Compliance was recorded in a diary and exercise instructions were given in written form.

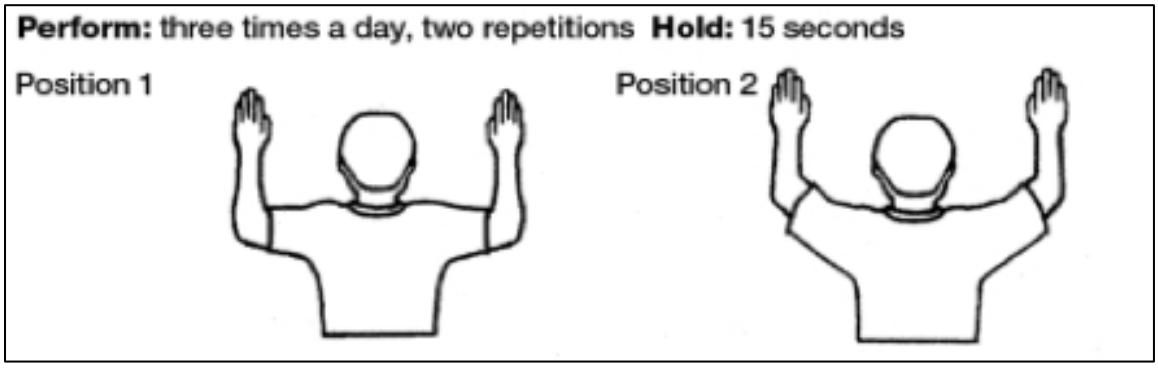
Two other trials by Wright and Mulet [86, 190] focus on exercise protocols to improve the posture and range of movements as well as coordination in the oral musculature.

Postural exercises [86]

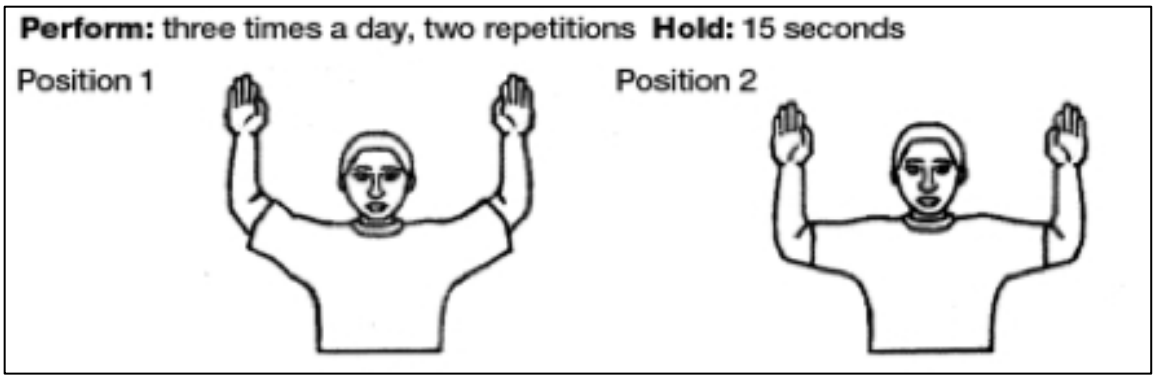
1. Chin tucks: Tuck chin back over the notch above the sternum so that the ear is in line with the tip of shoulder. Perform 10 times on the hour, hold 5 seconds each time.



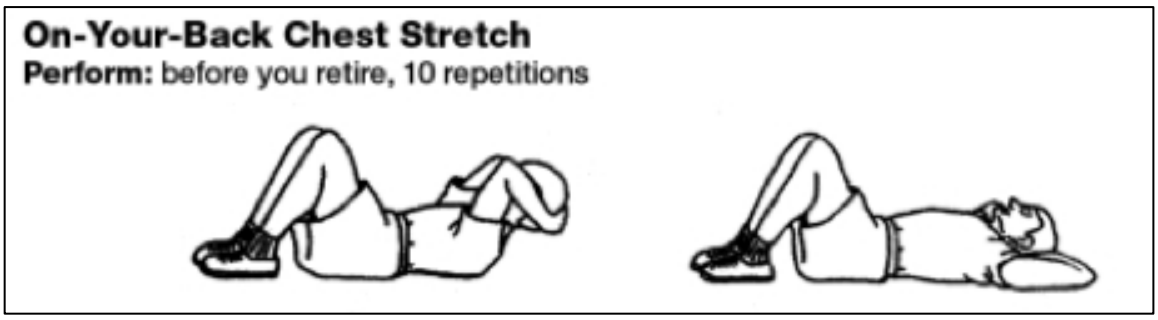
2. Chest stretch: Stand in a doorway or a corner, lean forward with hands on wall until you can feel a significant stretch across the front of your chest. Do this exercise with arms on both positions as shown in diagrams below.



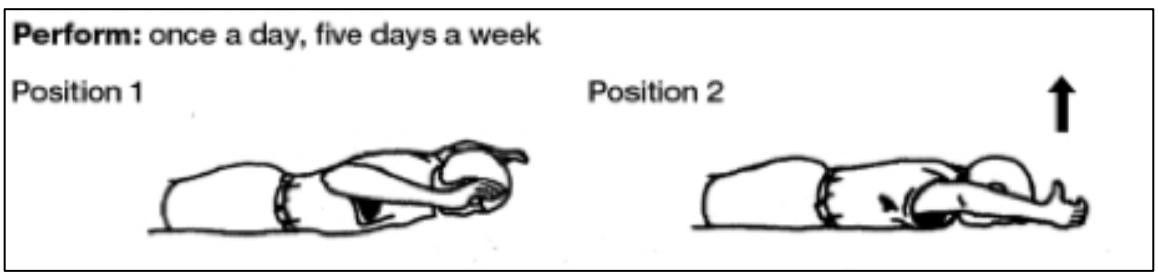
3. Wall-stretch: Stand with the back against a wall, arms positioned as diagram. Straighten upper back and flatten your lower back against the wall. Press your head back with your chin down and inward, then pull elbows back against the wall. Do this in both positions as shown in diagram below.



4. On your back stretch: Lie on your back with hands clasped behind head. As you exhale, slowly bring elbows together, touching in front of your face. As you inhale, slowly draw the elbows apart until they touch the floor. Perform 10 repetitions before you retire.



5. Face-down arm lifts. Lie on your stomach with elbows at shoulder level and bent at 90 degrees (position 1) and elbows at ear level (position 2). Lift your arms, head and chest off the floorand repeat until you move only 50% through the range or until you are fatigued; do this in both positions.



Mulet and co-workers described the Rocabado exercises as 6x6 which includes 6 exercise x 6 times per day x 6 repetitions [190].

Postural exercises - Rocobado's 6x6 exercises (Figure 40).

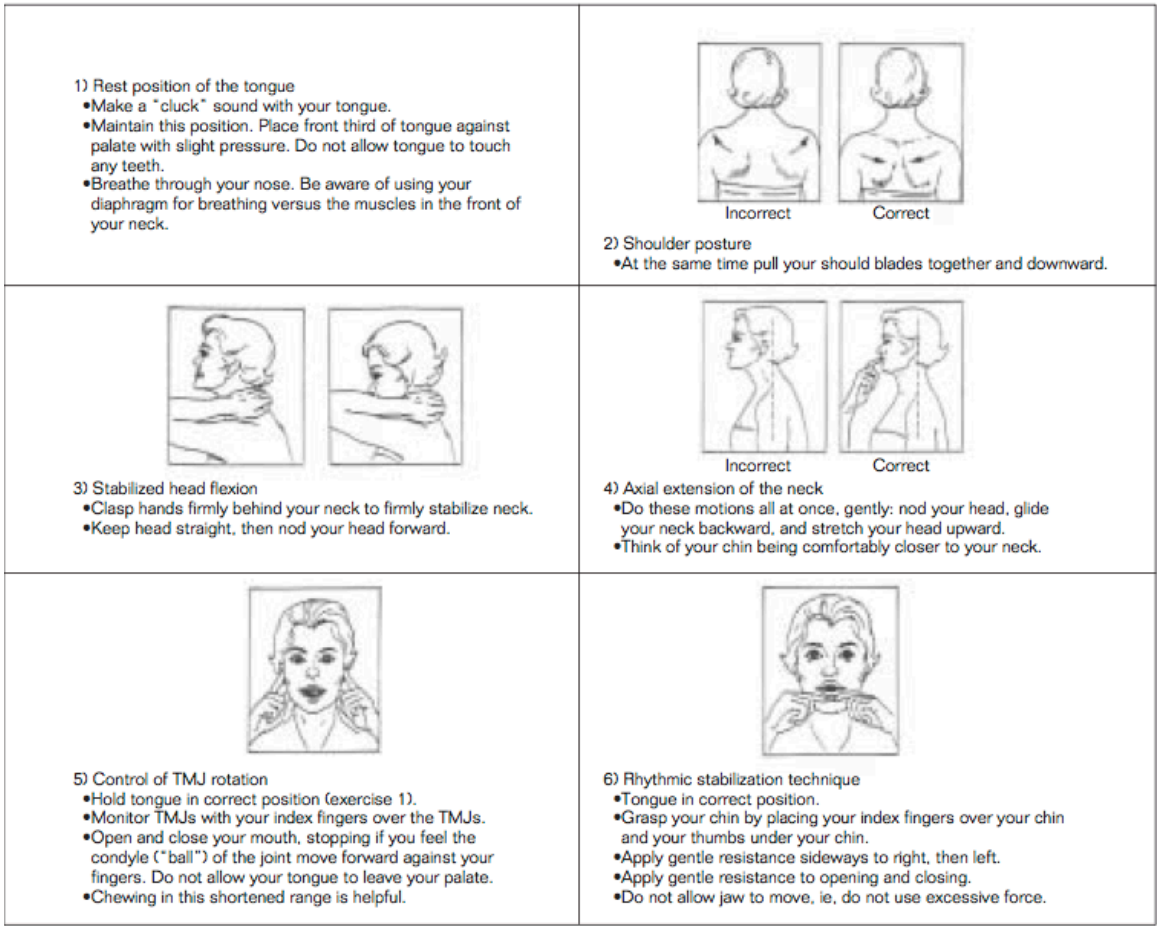


Figure 40. Rocabado's 6 x 6 exercises.
Adapted from Mulet et al, 2007

Chewing exercises [187]

The chewing exercise protocol described by Gavish and co-workers [187] includes chewing sugarless gum at increment of 10 minutes, three times daily in the first two weeks, then 20 minutes in the next two weeks and increased to 30 min three times daily in the last two weeks.

The last trial by Truelove [192] prescribed passive stretch exercises with the usual conservative self-care advice and no specific frequency.

Control group treatments vary between splint therapy [188] [192] self-care without exercises [86, 190] or support and encouragement only [187].

Outcome 1 . *Pain-free maximum opening*

Only two studies reported changes in the range of pain-free maximal mouth opening [86, 152]. The range of pain-free maximal opening significantly improved with three months of active–assisted and coordination exercise (P-value = 0.017) (Figure 41). This improvement is clinically significant according to Kropmans [193] with an improvement of more than 6-9mm. However, when comparing between successful and unsuccessful groups using mean scores of joint and muscle pain parameters, only the subjects who received both exercises and education had better pain-free mouth opening than those who did not do the exercise program.

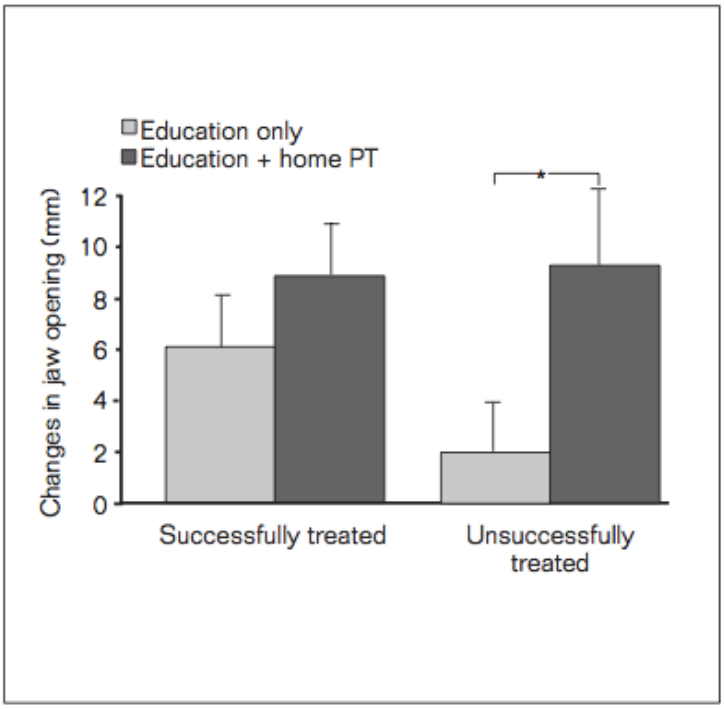


Figure 41. Jaw opening
Significant pain-free maximal jaw opening, P<0.05 in exercise group compared to controls in the less successful subjects.
Adapted from Michelotti et al 2004.

A similar finding was reported by Wright and colleagues [86] who found a mean increase in mouth opening range of 5.3mm compared with vs 1.2mm increase in the control group ($P < 0.5$).

Other outcomes measured in this study include pain intensity, pain on chewing, headache, and pressure pain threshold; all had clinical improvement but did not reach statistical significance.

A meta-analysis of the "pain-free maximal opening" outcome revealed the following summary effect (Figure 42).

A small improvement with either stretching, coordination, or postural exercises (Wright protocol) produced a clinical improvement of 4.43mm. However, according to Kropman [193] this is not clinically significant despite the statistical results $Z = 2.79$, $P = 0.005$ and a low heterogeneity score being $I^2 = 0\%$.

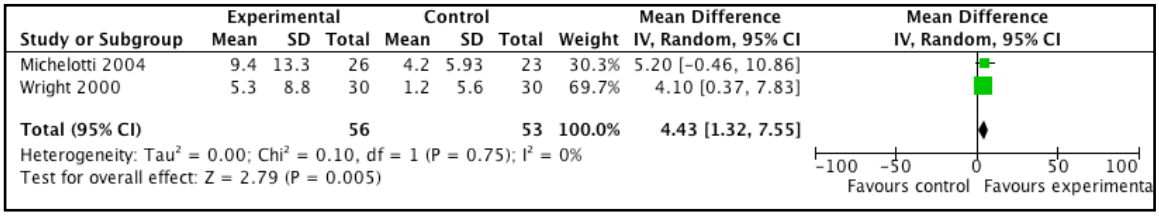


Figure 42. Forest plot of exercise effectiveness for "pain free maximal opening"

Outcome 2. TMJ pain score

Two studies [86, 190] measured joint pain/symptoms after exercise therapy. Mulet and co-workers [190] reported no statistical improvement with four weeks of Rocabado's 6x6 exercises. However, there was significant time-progress that influenced the observed clinical outcome (P value < 0.001). In contrast, Wright and co-workers [86]reported statistical improvement on the Modified Symptom Severity Index scores ($P = 0.05$). Pooled data from both trials resulted in non-significant result in pain level of the TMJ (mean 0.73 [-0.68, 2.11] $Z = 1.31$ (P-value = 0.31) although $I^2 = 91\%$ indicating significant heterogeneity between the results (Figure 43).

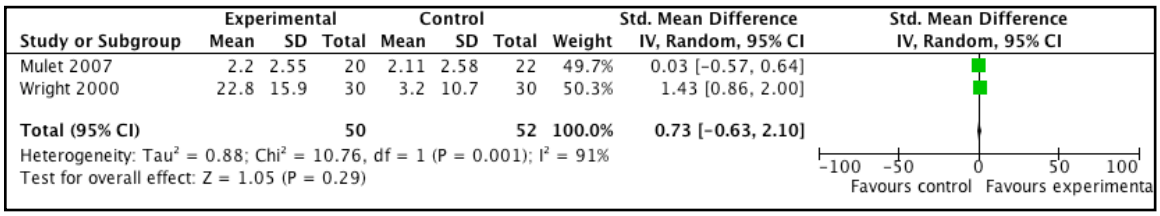


Figure 43. Forest plot of exercise effectiveness for "joint pain / symptoms"

Other outcomes

Gavish [187] reported an improved subjective pain intensity and disability scores as well as score of pain during chewing exercise ($p < 0.05$). A significant time course effect was reported for outcomes such as pain intensity and disability score. While other trials either did not report or reported no statistically significant difference between their exercise protocols and these outcome measures (Table 19).

Table 19. Changes in level of pain on chewing/ Limitation in chewing

Study	Changes in pain level or % of subjects from baseline	P-value
Truelove (3 months)	19-8	0.66
Michelotti (3 months)	23.3-10.8	NS
Gavish (2 months)	66-46	0.031

Although not pre-specified as outcome measures, number of sites tender to palpation, pressure pain threshold and pain on function were other outcomes reported in several studies (Table 20 and 21).

Table 20. Changes in number of tender sites to palpation from baseline

Study	Number of sites from baseline to follow-up	P-value
Michelotti (3 months)	15.0 – 8.27	Not significant
Truelove (3 months)	1.5 – 1.1	Not significant

Table 21. Changes in pressure pain threshold from baseline

Study	Masseter	Trapezius /Temporalis	P-value
Wright (4 weeks)	2.63-3.18	3.26-3.93 (Trap)	< 0.05
Michelotti (3 months)	141.5 – 138.5	152.1 – 161.4 (Temp)	NS

The study by Truelove and co-workers [192] compared usual care, which includes self-care and exercises of non-specific description to two types of splint (hard and soft). Outcome measures included TMJ symptoms such as clicks, popping, grating sounds, locking/catching, diurnal and nocturnal clenching and limitations in chewing. Due to the broad inclusion criteria, data from this trial could not be analysed with other trials in a meta-analysis. In dealing with missing data, the authors had pre-planned an intent-to-treat analysis and performed prior power calculation. Their results did not show statistical significance of treatment effects over 12 months on outcomes such as pain, joint sounds, clenching habits and limitation in chewing. Objective clinical measures such as joint sounds, pain on muscle palpation and joint pain also did not show difference between self - care and splint therapy. Changes of RDC-TMD diagnosis over 12 months revealed decrease number of subjects with Group Ia, Ib, IIa and IIIa but none reached statistical significance. The author concluded that using self-care strategies alone was as effective for TMD pain over time as other intra-oral therapy and is appropriate for patients with limited means or access to splint therapy.

Within this group of studies, a great amount of variation was present in the methods to measure outcomes. For example, pain of the masticatory muscles was measured with the NGRS 0-10; verbal rating scale of five descriptions and pressure point measurement different in the units of measure (kg/square centimetre). The study by Mulet and co-workers looked at primary outcome measures as self-reported levels of muscle pain using two scales: NGRS and VRS scales. Additionally, postural changes and grades of perceived change of symptom were recorded at designated time points 0, 1, 4 week. Subjects in this trial had an average of five years of chronic pain with over 70% subjects with concurrent arthralgia and over 57% demonstrated joint sounds (predominantly (88%) diagnosed as Group Ia) and on average taking more than one day of NSAID/week, and 19% were taking SSRIs. A significant difference was established between baseline and final measurements in exercise and control groups however no difference was evident when comparing the two

groups. Postural measurements that looked at cranial angle and neck angle were reported with statistical significance between baseline and final stages for the cranial angle but not the neck angle. Analysis of sway of the body and head were assessed and statistical significance was present for head sway (P=0.01) when compared to amount of body sway. In contrast, Wright and co-workers could not demonstrate a significant relationship between improvement in posture and their exercise protocol.

2.6.4 Excluded Studies

Table 22. Excluded studies and reasons

Study	Reason for exclusion
Burgess, 1998	Short term < 4 weeks
Carlsson,1999	Stretch program not appropriate for home use and < 4 weeks
Carmelli, 2001	Involves physiotherapy program
Furto, 2006	Involves physiotherapy program
La Touche, 2009	Involves physiotherapy program
Nikolakis 2001a	Cross-over trial
Nikolakis 2001b	Cross-over trial
Nikolakis 2002a	Cross-over trial
Nikolakis 2002b	Cross-over trial
Sato, 2008	Specific surgical procedure
Yoshida, 2011	Before-after trial
Xue, 2007	Involves alternative medicine
Zeno, 2001	Case study
Braun, 1987	Case report
Cleland, 2004	Case report
Santiesteban, 1989	Case report
Schmid-Schwap, 2009	Retrospective study
Sato, 2009	Special arch bars with exercise
Babadag, 2004	Before-after trial
Yoda, 1996	English abstract – full text in Japanese

2.6.5 Risks of Bias in Included Studies

Risks of bias were assessed using the Cochrane Collaboration's domain-based evaluation tool. The core assessments of risks-of-bias were: Randomisation, Allocation, Concealment of participants and trial authors, Reporting and Attrition biases. Additionally, it was decided that assessment of precision, which although does not contribute to internal validity of a study, does give additional information on the assessment of the strength of the evidence should quantitative analysis not be feasible for example, due to heterogeneity of the included studies.

There are no recommended tools for methodology assessment, however, to assess the validity and applicability of a trial, there are core criteria that must be assessed and it was decided that criteria listed above were sufficient and valid.

2.6.5.1 Allocation (Selection Bias)

Only two studies reported allocation concealment [184, 192]. The majority failed to report this data and we could not obtain more information from email correspondence with these authors. All studies with the exception of four studies [188, 191] [86, 187] specifically explained the randomization process (Table 23).

Table 23. Randomisation

Study	Quotes of randomization method stated in report
Minakuchi 2001	“computer generated false random number method”
Yuasa 2001	"randomly divided the patients into a treatment group and non-treatment group" using random permuted blocks within strata
Haketa 2010	table of random sampling numbers
Wright 2000	"The subjects were randomised into 2 groups.."
Michelotti 2004	balanced block randomisation
Gavish 2006	"randomly divided into two age-matched groups”
Truelove 2006	“randomly selected block sizes of 6,9,12 and stratified by provider”
Mulet 2007	“Stratified randomisation scheme using randomisation tables matched treatment groups for gender distribution and medications use 0-1days of NSAIDs per week vs 2-3 days per week”.
Au 2001	Author's correspondence described order of consignment as pseudo-randomised/quasi-randomised
Yoda 2002	Truncated binomial design, central randomisation center
Magnusson 1998	"patients were randomly assigned to receive either jaw exercises or interocclusal appliance therapy"

Correspondence with trial authors resulted in two responses and none others. The missing data were related to methodology.

2.6.5.2 Blinding (Performance Bias and Detection Bias)

Three studies [172, 186, 188] did not state whether examiners were blinded to the allocation of treatment and one trial [191] did not appear to ensure blinding of examiners. As lack of blinding did occur in some studies, the results are to be interpreted with caution.

2.6.5.3 Incomplete Outcome Data (Attrition Bias)

In this review, it was found that some studies reported and accounted for the loss of subjects with an intention-to-treat analysis while very few other studies did not (Figure 45).

2.6.5.4 Selective Reporting (Reporting Bias)

Since the original data could not be obtained from the authors it is difficult to judge whether a bias in reporting has occurred. However, it appears that there is a comprehensive report of pre-specified outcomes and it is likely that there is a low risk of selective reporting in the included studies. In accordance with the Cochrane Review manual guidance, we chose to designate the score as "uncertain" for this component of bias assessment.

2.6.5.5 Other Potential Sources of Bias

Two other risks of bias were added: precision and conflict of interest from sponsor bias to the table to assess for evidence of bias in the selected studies. See Figures 45 and 46 for an assessment of risks of bias.

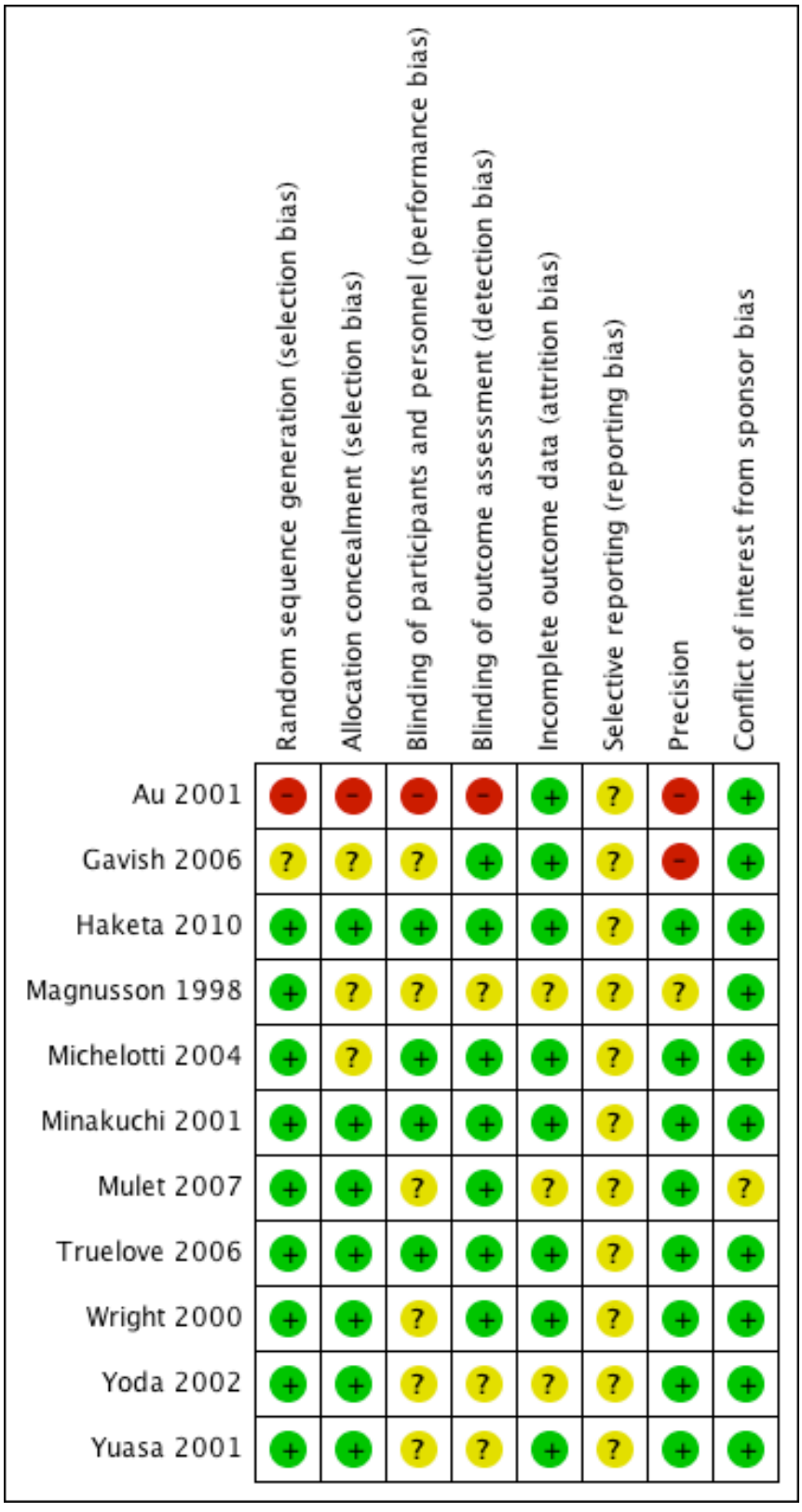


Figure 44. Risk of bias summary.

Review authors' judgements about each risk of bias item for each included study.

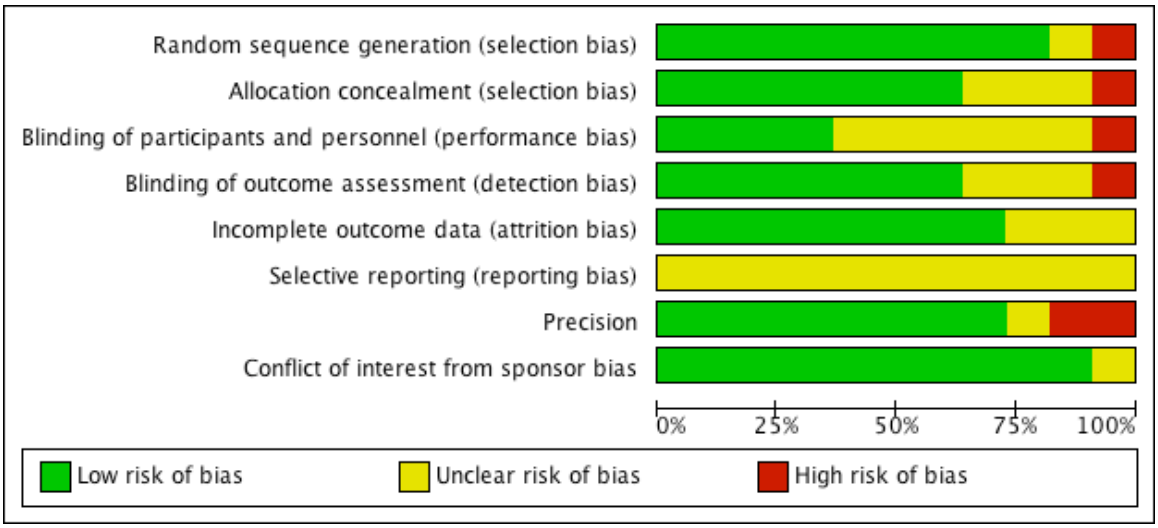


Figure 45. Risk of bias graph.
Review author's judgments about each risk of bias item presented as % across all included studies

2.7 DISCUSSION

2.7.1 Summary of Main Results

The area of Temporomandibular disorders is complex and arguably one of the most controversial topics in dentistry. The abundance of literature demonstrates an evolution of thinking behind their aetiologies, diagnosis and management. A paradigm shift from a mechanistic model to a biopsychosocial framework has recognized the important role of a behavioural approach in the holistic management [194]. The majority of patients will improve with time and with conservative management such as good self-care practices, exercises and physical medicine, all of which have been shown to be beneficial to some extent. It has been said that the gap is still present between researchers accepting this view and the practicing community hence guidelines have been published to facilitate transfer of knowledge into practice.

This review of the literature relating to the effect of exercise therapy intervention for TMDs systematically searched for the highest evidence (randomized controlled trials) that met pre-specified criteria. It identified eleven trials which were analysed according to 3 TMD subtypes: ADDwoR, ADDwR and myofacial pain.

For the ADDwoR group, there is consistent evidence to support the use of exercise therapy as an intervention with self-care advice for TMD patients where significant changes to the active mouth opening range, level of pain during chewing function and patient perception of improvement in daily life activity have been demonstrated. The types of exercise include stretching and repetitive movements to opening and lateral excursive ranges prescribed together with self-care. However, they are not effective for reducing self-rated daily maximal pain level and normal baseline resting pain. With time, most patients who have disc-derangement without reduction and associated pain for at least two weeks may show some improvement in function regardless of treatments with or without exercise. However, with exercise, a positive influence on perception in daily life activity may be helpful for patients to cope especially for chronic conditions.

For the ADDwR group, two different types of exercise protocols demonstrated moderate effect and resulted in disappearance of clicks after at least four weeks of exercises. In one study, subjects with clicking symptom (no emphasis on pain) were included. However, the presence of painless clicks is not an indicator for treatment therefore the applicability of this evidence is in question. The authors of two studies demonstrated that this improvement was significant.

For the myofascial pain group, the six included studies demonstrated three broad groups of exercises: (1) Stretch (active and passive) and coordination exercises with and without resistance; (2) Exercises to improve posture (3) Chewing gum exercise. The comparisons were either splint (soft and hard) or no treatment. The overall evidence provides support for postural exercises include stretching of chest and upper thoracic muscles and correcting cervical posture as they demonstrated positive effects on the pain-free opening range. Interestingly, the clinical improvement was not correlated with level of compliance, range of compliance 40-100% and mean 75%. The Rocabado 6x6 exercise protocol does not have a similar effect except for improving the head position and neck posture. Exercises that included stretch to open (active and passive), reciprocal inhibition of antagonist muscles and coordination movements to the sides significantly improve maximal pain-free range outcome. These exercises are also more likely to result in a higher compliance rate (73%). Patients with myofascial pain may report an improvement in pain relief with chewing exercises.

2.7.2 Overall Completeness and Applicability of Evidence

Overall, the evidence summarized through 11 selected studies address the initial research question on effectiveness of exercise therapy for patients with TMD. Individually, each trial demonstrated effectiveness through different outcomes for patients with three TMD subtypes. The published literature concerning exercise (amongst other conservative interventions including intra-oral splints) is considerable. However, the variation between the trials in study populations, the types and specificity of intervention exercises, and the selected outcome measures did not allow for calculation of summed effect.

The results of the review may be interpreted qualitatively for each diagnosis subtype and exercise protocol. Practitioners applying these exercises should use outcomes that have been shown to be effective for each respective diagnosis. It is important to keep in mind that exercise therapy is one of many conservative means of management for TMD and a combined approach is often preferred to protocols involving a single modality.

2.7.3 Quality of Evidence

The protocol prepared for this systematic review included randomised and quasi-randomised controlled trials and followed the Cochrane guidelines to assess design-specific criteria for internal validity and to control for risk of bias. There are reviewers who recommend that one should be opened to different study designs and separately assess the level of bias during the individual assessment of each study. In this review, it was decided not to include other designs in order to control for bias and reduce the potential for causal inference.

The results obtained are influenced by the heterogeneity present between studies. They are therefore not robust answers to the research question. The quality assessment of 11 randomised studies, represented by 688 patients with three TMD presentations: Disc-displacement with reduction, disc-displacement without reduction and myofascial pain revealed weaknesses in areas of blinding for both participants and examiners where seven studies were assessed as “uncertain” with regard to blinding of participants to the treatment received and four studies failed to show blinding of examiners in the outcome assessment stage. However, it is difficult to blind participants to the treatment due to the inherent nature

of the intervention but they were blinded from knowing other treatments in other groups. Another weakness is the uncertain nature of reporting where original reports were not obtainable and most authors were not contactable to gain additional information. Incomplete data from attrition was accounted in eight trials whereas three other trials did not report an intention-to-treat analysis for the missing subjects. Finally, despite the randomised process, three trials did not ascertain how concealment to the selection process was made and one trial definitely did not perform this process to prevent selection bias.

The results consistently demonstrated some effectiveness of exercise therapy for TMD as an adjunct modality with self-care advice and in some cases, intra-oral splints but these results are not robust enough to make conclusions regarding the individual value of exercise therapy alone for TMD conditions.

2.7.4 Potential Biases in the Review Process

This review involved two examiners who are not content experts which ensured a lower risk of bias from prior knowledge and belief. However, only one reviewer performed the process of screening and selecting studies and potential studies could have been missed.

Extraction of data was collated by Reviewer 1 and re-assessed by Reviewer 2. Information relied on the reported results was limited and potentially introduced biases with positive conclusions from some trials. Therefore, we did not perform meta-analysis for many outcomes, which would other wise have given clearer insight into the specific values of this intervention for TMD.

Publication of a protocol for a review prior to knowledge of the available studies reduces the impact of review authors' biases, promotes transparency of methods and processes, reduces the potential for duplication, and allows peer review of the planned methods (Light 1984). We did not follow this guideline for feasibility reasons but recognise the benefit of such process.

This review began with a protocol including studies that assess exercise effectiveness for at least six weeks. However, it was necessary to modify the inclusion criteria on duration to four weeks to obtain a meaningful number of studies.

2.7.5 Agreements and Disagreements with Other Studies or Review

As there have been no systematic reviews on the topic with a focus limited to dental application, we believe that this review fills this gap and supports the conclusion of reviews where exercises have been incorporated as a modality amongst many other therapeutic interventions for effective management of TMD.

2.8 CONCLUSIONS

2.8.1 Implications for Practice

On the basis of the analysis, it is concluded that the literature suggests there is some evidence for the use of simple exercise therapy by dentists to increase temporomandibular joint range, muscle coordination and, together with self-care advice, exercise therapy can result in the improvement in TMD symptoms by about four weeks.

The specific programs for each type of exercise may include 3-4 sets on a daily basis, and repetitions between 3-10 per set depending on the dentist assessment of the patient's likely compliance level.

The types of exercises to prescribe can be selected according to the dentist's assessment of each individual patient's treatment needs and level of compliance. Monitoring and follow up is recommended as is appropriate referrals when symptoms persist.

2.8.2 Implications for Research

Understanding that management for TMD requires a multidisciplinary and holistic approach can limit the involvement of some dental practitioners who may not be able to work within a multidisciplinary setting.

The benign but common TMD conditions presented by the dental patients require appropriate assessment and management by the dental professionals, often as the first point of contact. Thus it is appropriate to expect the general dentist to be able to manage the

majority of TMD patients with simple and conservative therapy including exercises. The effectiveness of exercise prescriptions by the general dentists requires further investigation at a clinical level. Future research to assess the effectiveness of incorporating TMD management including exercise prescriptions as part of undergraduate teaching is recommended. This review suggests the need for well conducted randomised controlled trials that pay attention to the method of blinding, allocation concealment and standardised treatment outcomes.

2.9 APPENDICES

2.9.1 Search Strategies

Pubmed search: *180 articles -> selected 5 from title and abstract search*

(temporomandibular joint disorders[mh] OR temporomandibular joint disorder*[tw] OR tmj disorder*[tw] OR temporomandibular joint dysfunction*[tw] OR tmj dysfunction*[tw] OR temporomandibular disorder*[tw] OR temporomandibular dysfunction*[tw] OR (tmd[tw] NOT total mood disturbance[tw])) AND (exercise therapy[mh] OR exercis*[tw] OR movement therap*[tw] OR muscle stretch*[tw] OR static stretch*[tw] OR passive stretch*[tw] OR relaxed stretch*[tw] OR isometric stretch*[tw] OR active stretch*[tw] OR dynamic stretch*[tw] OR proprioceptive neuromuscular facilitation stretch*[tw] OR resistance training[tw] OR strength training[tw] OR walking[tw] OR physical exertion*[tw])

Scopus: 997 articles -> selected 38 from title and abstract search

("temporomandibular joint disorder"OR "tmj disorder" OR "temporomandibular joint dysfunction" OR "tmj dysfunction" OR "temporomandibular disorder" OR "temporomandibular disease"OR "temporomandibular dysfunction") AND (exercis* OR "movement therapy" OR "muscle stretch" OR "muscle stretching" OR "static stretch" OR "static stretching" OR "relaxed stretch" OR "relaxed stretching" OR "isometric stretch" OR "isometric stretching" OR "active stretch" OR "active stretching" OR "dynamic stretch" OR "dynamic stretching" OR "proprioceptive neuromuscular facilitation stretch" OR "proprioceptive neuromuscular facilitation stretching" OR "resistance training "OR "strength training" OR walking) AND ("randomized controlled trial" OR "randomised controlled trial" OR "random allocation" OR "double-blind method" OR "single-blind method" OR "clinical trial" OR ((singl* OR doubl* OR trebl* OR tripl*) AND (mask* OR blind*)) OR (placebo* OR random* OR "comparative study" OR "evaluation studies as topic "OR "follow-up study" OR "prospective study" OR control OR controlled OR prospectiv* OR volunteer*) AND NOT (animals AND NOT human) AND "osteoarthritis" AND "osteoarthrosis"))

Web of Knowledge: 287 articles -> 17 selected from title and abstract search

("temporomandibular joint disorder" OR "tmj disorder" OR "temporomandibular joint dysfunction" OR "tmj dysfunction" OR "temporomandibular disorder" OR "temporomandibular disease" OR "temporomandibular dysfunction") AND (exercis* OR "movement therapy" OR "muscle stretch" OR "muscle stretching" OR "static stretch" OR "static stretching" OR "relaxed stretch" OR "relaxed stretching" OR "isometric stretch" OR "isometric stretching" OR "active stretch" OR "active stretching" OR "dynamic stretch" OR "dynamic stretching" OR "proprioceptive neuromuscular facilitation stretch" OR "proprioceptive neuromuscular facilitation stretching" OR "resistance training " OR "strength training" OR walking) AND ("randomized controlled trial" OR "randomised controlled trial" OR "random allocation" OR "double-blind method" OR "single-blind method" OR "clinical trial" OR ((singl* OR doubl* OR trebl* OR tripl*) AND (mask* OR blind*)) OR (placebo* OR random* OR "comparative study" OR "evaluation studies as topic " OR "follow-up study" OR "prospective study" OR control OR controlled OR prospectiv* OR volunteer*) AND NOT (animals AND NOT human)) AND (LIMIT-TO(SUBJAREA, "MEDI") OR LIMIT-TO(SUBJAREA, "DENT") OR LIMIT-TO(SUBJAREA, "PSYC") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re")) AND (LIMIT-TO(SUBJAREA, "MEDI") OR LIMIT-TO(SUBJAREA, "DENT") OR LIMIT-TO(SUBJAREA, "PSYC") OR LIMIT-TO(SUBJAREA, "MULT"))

2.9.2 Inclusion and Exclusion Criteria

Inclusion	Exclusion
1. Randomised protocol/Quasi-randomised 2. Program designed in conjunction with other primary interventions or as stand alone primary treatment/intervention. Other primary interventions may include: a. Dental management including splint therapy b. Allied health (manipulation and thermal/Ultrasound/electro-modalities) c. Counseling and self-care advice 3. Program to be performed at home without need for external support or mechanical assistance 4. Program can be used by dental practitioners for patients with temporomandibular joint symptoms. 5. Duration of study at least 4 weeks 6. All outcomes from intervention are considered 7. Diagnosis of TMD: a. Primary diagnostic groups: i. Disc displacements with or without reduction (joint sound); with or without pain; and with or without limitation of jaw opening. ii. Myofascial pain with or without limitation of jaw function iii. Joint pain on movement with crepitus indicative of degenerative joint process b. Secondary symptoms i. Headache ii. Toothache iii. Mild depressive symptom or effects on sleeping that does not require intervention 8. Defined diagnostic criteria including: a. RDC-TMD b. Other 9. No publishing year limitation	1. Non-randomised trials 2. Other systemic causes for TMD 3. Case study/report/series. 4. Regular medications including analgesics, anti-depressants, psychotropic drugs 5. Inflammatory/idiopathic arthritides 6. Whiplash injury 7. Language other than English 8. Program requires extensive background knowledge and training in musculoskeletal pathology and management

Table of Included Studies

Study ID	Population	Intervention	Comparator	Outcome	Other
Anterior Disc Displacement without Reduction					
Haketa, 2010	52 adults with ADDwoR, mean age 37.6 ± 14.9; minimum accepted age 18; 6 males, 46 females; Pain on affected side in opening movement more than 2 weeks after onset of ADDwoR; maximum opening < 40mm; MRI-confirmed diagnosis. Fourteen subjects dropped out, of these, 8 failed to return at first recall appointment therefore excluded from analysis. Data analysis with intention-to-treat, therefore, another 6 subjects with data extended to 8 week follow up. Total number analysed was 44 subjects (25 splint, 19 exercise)	Advice about condition based on MRI finding, general self-care protocol including good posture, soft diet, teeth apart. Additional exercise protocol: Warm up with small mouth opening and closing movements several times; Slowly pull the mandible down with fingertips placed on edge of mandibular incisors until pain occur on affected TMJ and hold for 30 seconds. Repeat 3 times (count as a set) Perform 4 sets per day one after each meal and one while bathing. NSAIDs 3 times per day.	Advice about condition base on MRI finding, general self-care protocol including good posture, soft diet, teeth apart. Maxillary occlusal splint 1.5mm thick, made from hard and clear acrylic, vacuum-adapted to maxillary cast, wore during sleep; contacts of mandibular teeth in centric relation and canine guidance for lateral movements. NSAIDs 3 times per day.	Maximum mouth-opening range with and without pain (in the TMJ-affected side) measured in millimeter. Maximum daily pain intensity measured with VAS 0-100mm scale. Pain-related limitation of daily functions measured with 10-items questionnaire* and graded on 1-5 point scale, total maximum possible score 50. *Both groups improved over time in range of mouth opening, maximum pain intensity and limitation of daily functions, however, only statistical significance in the opening range and daily function scores for exercise vs. splint with P-value < 0.001. Greater improvement in mean score of mouth opening with pain and without pain at 8 week and median rating of daily function in exercise group compared to splint.* *Time-progress was significant at P-value < 0.001 for all outcomes except splint (P-value < 0.01).*	Follow up at 4,8 weeks. No significant adverse effects from both groups. Certified clinical instructors measured outcomes, blinded, no calibration report. Sample calculation based on power 0.8, alpha-error 0.05. Reference to Yuasa 2001 improvement in maximum opening with pain in exercise group 7mm, control 1.5mm.

Study ID	Population	Intervention	Comparator	Outcome	Other
Yuasa, 2001	60 adults; Median age 28 (range 16-69); 80% female; unilateral moderate or severe ADDwoR confirmed with MRI; Pain at least 2 weeks; Classification of severity is modified version of American Association of Oral and Maxillofacial Surgeons and International Association of Oral and Maxillofacial Surgeons. Rating base on worst score out of 4 outcomes: maximal mouth opening and pain levels (VAS) at rest, during motion, chewing, interference with daily life. No dropout or adverse reaction cases.	NSAIDs once per day. Exercise protocol: Forced mouth opening with thumb on edge of maxillary incisors and index on edge of mandibular incisors, hold for 10 seconds. Repeat 10 times (a set). Perform protrusion and laterotrusive movements with same repetitions and hold as above for each set. Perform 4 sets per day, one after each meal, and one before bed time. Printed instructions.	No treatment control	Maximal opening in millimeter; Pain levels at rest, mandibular movements, during chewing and interference with daily life (VAS). Mean scores between 2nd and 4th weeks combined to categorise into dysfunction groups (none, slight, moderate, severe). Improvement rate and number-needed-to-treat were calculated. Cochran-Mantel-Haenszel test adjusted for age, closed-lock period, TMJ dysfunction used for comparing improvement rates between 2 groups, improvement rate 60%, P-value < 0.019, NNT = 3.75, 95% CI 2.013-65.935. Individual median was used in subgroup analysis revealed improvements in both groups for maximal mouth opening, joint pain on opening and closing and joint pain on chewing, however, treatment group showed statistically significant improvement over control in maximal mouth opening and interference with daily life rating.	

Study ID	Population	Intervention	Comparator	Outcome	Other
Minakuchi, 2001	69 adults with ADDwoR, mean age 34 ± 15.4; 7 males: 62 females; unilateral:bilateral 50:19; Complaints of pain on chewing and opening; Joint pain on opening at least 10/100 on visual analog scale; MRI-confirmed diagnosis on affected side (disc displacement criteria per Orsini et al, 1999). Eight subjects dropped out. Two of these requested rescue treatments (arthrocentesis). Total number analysed was 69 (control = 21; palliative care = 23; physical medicine = 25).	Group 1: As control group and self-care advice (hot/cold packs, soft diet, gentle mouth-opening exercises) plus NSAIDs and anti-gastric ulcer medication three times/day. Group 2: Self-care and NSAIDs as above; flat occlusal splint with maximal contacts in centric relation, balanced contacts in protrusion and canine guidance for lateral movements, splint worn only at night time; 20 minutes intermittent jaw mobilization at each follow up visit by a trained dentist (0,2,4,8 week).	No treatment except advice about condition base on MRI, prevalence and prognosis.	Pain at rest and during mastication, measured with VAS 0-100mm scale. Limitation of daily functions associated with TMD symptoms, 18-items questionnaire per Clarke et al, 1989, graded scale 0-4, maximal possible total score = 72. Three maximum mouth opening range: pain-free, passive and active range, measured in millimeter. Uniform force applied on passive range, measured with pressure algometer at 9.8N. *Outcome: Mean range of opening for maximum comfortable level, active and passive all showed positive improvement over 4 and 8 week, however not statistically significant. Physical medicine group has the highest improvement than control, the least was palliative treatment.* *Time progress was significant with P-value < 0.001.* *Self-care group showed the strongest effect of exercise on the mean daily limitation variable but only at 4 week and none other time points.*	Data analysis with intention-to-treat. $\alpha = 0.05$. Note the dropouts as follow: 1 after 2 weeks, 5 after 4 weeks, then 2 worsened (?) and requested arthrocentesis after 4 weeks. All dropouts were accounted with last reading carried forward per intention-to-treat analysis protocol.

Study ID	Population	Intervention	Comparator	Outcome	Other
Anterior Disc Displacement without Reduction					
Au, 2001	22 adults (14 male, 8 females); Mean age 21.4 (range 20-29); Unilateral or bilateral TMJ clicking classified according to Watt and McPhee as near-middle-wide depending on position of click during mouth opening and closing; TMJ Doppler Auscultator for sound amplification and recording via polygraph instrument.	Verbal instruction and demonstration of isokinetic exercises; home instruction sheet; Two main movements as follow: Jaw opening against a constant and moderate resistance provided by hand or fist, moving at a constant speed over 15mm for opening and 5mm for laterotrusions to the left and right sides without evoking joint sounds. Reinforcement to perform exercises at each follow up at 2 and 4 weeks, then monthly up to 6 months, and 2 year recall.	Control group 1: 12 subjects matched for age, sex and TMJ clicking did not perform exercises. Control group 2: 10 subjects without TMJ clicking, performed exercises as intervention group and reinforcement at each follow up.	Comparison between groups for presence of clicking at 4 week, 6 month and 2 year. 18 subjects had no joint clicking at 6 months, 11 of these resolved at 4 week time point; 16 of these remained click-free at 2 year recall; unresolved clicks were of bilateral joint clicking whereas relapse cases were due to trauma and parafunctional habit and low compliance.	Author comments on effect of exercise being greater for TMJ clicking of short duration and early onset due to no adaptive intra-articular changes to allow for restoration of optimal function. Author also concluded no effect of clicking location on improvement from exercise therapy. Lacking information of subgroup analysis.

Study ID	Population	Intervention	Comparator	Outcome	Other
Yoda, 2002	42 subjects (13 males, 29 females; Mean age 27 range 12-59) with painless unilateral reciprocal clicking (mean duration 42 ± 56 months (exercise), 26 ± 18 months (control) eliminated by a protrusive position of the mandible; ADDwR confirmed with MRI. Exclusion criteria include prior treatment for joint problem within 4weeks of study, pain, bilateral disc displacement detected in MRI. Clicking assessed by palpation; MRI detected disc position and classify severity (1 = slight displacement, 2 = moderate, 3 = severe) and disc shape as biconcave or deformed according to Tasaki criteria. 3 months observation.	Exercise protocol: Open the mouth maximally to click. Close the mouth along protrusive border movement path. Contact teeth in this position! Retrude to contact position just before the click occur (disk-repositioning mandibular position). Open the mouth again, maximally, but without a click. Repeat the closing path as described previously. Repeat for 5 minutes. Perform 3 times after each meal. Maintain disc repositioning mandibular position all day except meal and sleep times.	Information given on condition, no active treatment for 3 months.	Discomfort; interference with daily life (eating and speaking) measured with a questionnaire using 1-5 point rating scale. Clicking characters determine categorization of excellent, good vs fair and poor outcomes. Excellent and good are considered successful. See appendix for definitions of each category. Exercise group: 61.9% successful vs. 0% in control. Exercise group: 38.1% unsuccessful vs. 100% in control. In successful cases, 23.1% (3/13) disc was captured and 2 of these reported discomfort level 2 (out of 5). According to the criteria of clicking these were considered success cases.	Sample-calculation at 80%, $P < 0.05$; estimate of effects 50% for exercise and 15% for control groups. No dropouts. MRI confirmed all discs are bi-concave

Study ID	Population	Intervention	Comparator	Outcome	Other
Myofascial Pain					
Magnusson, 1996	26 adults (mean age = 37 for exercise group, 32 for splint) referred for main subjective symptom tension-type headache and/or orofacial pain non-neurogenic or non-dental origin; Referral source predominantly GDP, GMP and < 10% specialist dentists; Pain history at least 1 year; no previous treatment; exclusion criteria: systemic diseases causing masticatory muscles, malocclusion. 1993-1996 total 1344 patients examined at Stomatognathic Physiology department, 26 fulfilled criteria	TG – Therapeutic exercise three times per day, 2-3 min each time.	IG- Michigan splint, nocte use. CG – combined treatment, only if require further treatment after 3 months.	Clinical dysfunction index Anamnestic dysfunction index Reported tooth clenching Reported Analgesics intake Reported headache frequency Behaviour rating scale All frequencies had a descending trend on improvement in amnestic and clinical outcomes related to the joint and muscles either in static or function	Random assignment reported, no further details. 3 loss to follow up with reasons. 5/23 received complimentary treatment due to persistent symptoms.

Study ID	Population	Intervention	Comparator	Outcome	Other
Wright, 2000	60 adult patients referred to Air Force Base with moderate to severe TMD pain (muscle origin) at least 6 months; no prior treatment at the onset of study; Dworkin and LeResche clinical examination; RDC-TMD; 30 in control group (25 females, 5 males) mean age 32.7, range 18-60; 30 in exercise group (26 females, 4 males) mean age 32.7, range 18-56;	Posture training and TMD self-management instructions. Posture exercises include chin tucks, chest stretch, wall stretch, back stretch	TMD self-management instructions (resting muscle, awareness of parafunctional habit, apply heat or cold for painful muscle sites, over-the-counter medications,	Modified Symptom Severity Index (SSI) measured with VAS; Maximum pain-free opening (incisor to incisor, no specification on accounting for overbite) and pressure pain threshold (0.5kg/cm2/second) 1.8mm ∅ tip placed over trapezius and masseter mid-belly. Baseline measures also include head and shoulder translation in relation to vertical. Significant difference with postural exercise group (larger reduction of SSI score from baseline to final) compared to control. P-value < 0.01. Mean maximum pain-free opening improved by 5.3mm in exercise group vs. 1.2mm in control group, p-value = 0.05. Postural measurements were on the positive but not statistically significant. Perceived symptom change: Exercise group: 10% total TMD symptom improvement, 3% total cervical symptom improvement; 10% reported no improvement in TMD symptom and 20% in cervical improvement. Compliance: 40-100%, mean 75%, no correlation with TMD improvement.	

Study ID	Population	Intervention	Comparator	Outcome	Other
Michelotti, 2004	70 adults with myogenous TMD diagnosed by RDC-TMD criteria; recurrent or constant pain over 3 months; spontaneous pain within the last week > 30/100mm VAS; Mean age of control group 31.8 ± 13, exercise group 28.2 ± 8.8; 3 males, 31 females in control and 5 males, 31 females in exercise groups respectively; exclusion criteria (see appendix); 21 dropouts (11 from control; 10 from exercise group). After second visit (8 control, 6 exercise). After third visit (3 control, 4 exercise). Telephone review of dropouts (12 practical reasons and reduced pain; 5 with increased pain and changed dentist; 3 not reachable; 1 pregnant)	Education Home exercise program which includes: Relaxation exercises with diaphragmatic breathing 5 minutes every 2 hours and maintain throughout day; Self-massage of tense or painful masseters and temporalis using contralateral index, middle and ring finger-pads against thumb pressure placed on intra-oral side of cheek, with pressure modulated proportional to pain level on rolling motion; Heat pads (40-50°C bilaterally once per day for 10 minutes on painful muscle; Slow stretch to pain sensation and then passive-assisted opening with thumb-finger or tongue blades and hold for 1 minute; Coordination exercises 3 times x 20 repetitions of opening and closing with visual guide to maintain straightness of opening. Written instruction was given. Continue for 3 months even if pain-free. Compliance diary was used and ranked (good = performed > 2/3 of time; medium = between 1/3 -2/3; poor = performed < 1/3 of time). Reinforcement and review of exercises at follow up visits.	Education on aetiology, prognosis of problem, self-care of jaw musculature advice given by a dentist. Information on muscle function, prevention of overuse by diet modification, reduce stress, parafunctional habit, excessive movements and relaxed jaw posture "teeth apart"; use of feedback "stickers" at home; advice on chronic pain and psychosocial distress. Written instruction was given.	Anamnestic and clinical outcome variables measured at each visit 0,3,6,9,12 week. Treatment contrast used as a priori outcome measure for pain intensity and limitation of oral function. Pain intensity measured with 100mm VAS. Other scores use 0-4 scale. Minimum accepted baseline is ≥ 2. Average of 55% improvement (TC ≤ -0.379) over 3 months indicate success. Pressure pain threshold measured on right and left temporalis and masseter muscles; 20kPa/s rubber tip algometer on body of masseter; 2cm behind anterior border of temporalis and along an imaginary line from upper orbital margin and upper point of outer ear. PPT = mean of last 3 trials (first measurement discarded due to high level of variability). Reproducibility ensured via markers. Pain on chewing – 1 stick of chewing gum , bilateral chewing for 60 seconds and pain level scored on 100mm VAS. Pain-free maximal jaw opening – distance between upper and lower incisors + overbite. Only maximal pain-free mouth opening significantly improved in exercise group vs control; and subgroup analysis showed significant only in unsuccessful patients; All other variables including TC- based comparisons of success-unsuccessful categories did not find significant. Compliance rating: Good 73%, 91% Poor 27%, 9% in exercise/control groups respectively. PPT significantly different between baseline-final in success group only (0.09 < P < 0.039) Pain on chewing significantly lower in exercise group (unsuccessful cases) P = 0.035.	Sample calculation with 80% power estimate effect 45-60% improvement in pain intensity as clinically relevant., and pain-free maximal opening improvement >5mm according to Kropmans et al. Lack of non-treatment controls, hence reduce difference and effects between groups. 30% dropouts. Authors emphasise reinforcement improves patient's coping skill; beneficial if combined with other treatments. Speculative inference only.

Study ID	Population	Intervention	Comparator	Outcome	Other
Mulet, 2007	45 adults (43 females, 2 males), mean age 24 year-old; responded to flyers and news papers advertisements in University hospital clinic; NSAIDs 0-3 days/wk; diagnosed using RDC-TMD criteria; pain duplicated by palpation of masticatory muscles; at least 40mm mouth opening by passive stretching if active range was limited; co-existent joint arthralgia and ADDwR allowed; pain within last month at least 4/10 on NGRS; duration greater than 6 months; pain frequency at least 3 days/week; external meatus anterior to malleolus in sagittal plane; age range limits 18-65; exclusion criteria see appendix; if taking antidepressant required to have stable dose last 2 months; 3 withdrew (1 from control, 2 from experimental, no disclosure of loss of follow up)	Exercise and self-care advice: Rocabado 6 exercises performed 6 times per day and repeated 6 times each: Jaw rest and diaphragmatic breathing, shoulder girdle retraction, stabilized upper cervical flexion, control of TMJ movement by reducing translatory movement, rhythmic stabilization with reciprocal inhibition in opening, closing, side movements without chin movement, use fingers as resistance, no excessive force.	Self care: Optimistic counseling, information on TMD, rest, heat and ice, control maladadaptive behaviours such as tooth clenching, grinding, caffeine, gum chewing, stomach sleeping, resting jaw on hand and wide opening of mouth; implement pain-free diet, bilateral chewing and calcium intake.	Temporomandibular Index; Primary measure: self-reported pain intensity of jaw muscle and cervical muscles on NGRS scales 0-10cm; secondary measures VRS scale (masticatory muscle pain); Change of head position, Overall symptom improvement. Measurement at baseline week 1,4; compliance rate; postural measurements. Outcomes: Jaw muscles and neck muscles: Significant improvement from baseline to 4 weeks in both groups, but not between groups >2 and <2 points on NGRS, $P < 0.001$, $p < 0.002$ respectively. Outcome measures from VRS revealed similar trend. Head sway: Exercise group reduced head sway significantly more than control group. No difference between groups in trunk sway. Posture measurements: Cranial angle was improved in control group, statistically more than exercise group -1.49 vs +1.76, $P < 0.01$) No other changes with neck angle or head-shoulder difference. Overall change of symptoms: Control group had more subjects reported improvement than exercise group and lower proportion of subjects feeling worsened, no statistical significant difference noted between groups.	Subjects were rewarded$50 for participation. A difference of 2 points on NGRS is clinically significant as shown elsewhere. 1 subject requested further TMD care at end of study. Compliance with treatment group more variable than control group.

Study ID	Population	Intervention	Comparator	Outcome	Other
Gavish, 2006	20 females adults, mean age 27 year-old with MFP of at least 6 months, tender to palpation at least grade 2 to 3 (moderate to severe); diagnosed with RDC-TMD; 10 controlled gum-chewing exercise; 10 no treatment control, 8 weeks duration; no masseter muscle hypertrophy at maximal clenching; loss no more than 1 tooth per quadrant; no active caries or periodontal disease and chewing test with pain at least 15/100mm VAS. Exclusion criteria are included in appendix.	Exercise: Chewing 2 units of sugarless gum tds 10min 2 week then 15min for next 2 weeks and 20 min for 2 weeks after, 30min for last 2 weeks.	Support and encouragement only.	EMG activity: 0.8cm2 surface electrode, 1000Hz A/D, 12-bit resolution and conversion and amplified for final rectified full wave applied on painful masseters at predetermined locations; Muscle tenderness to palpation (0 = none, 1= mild, 2=moderate, 3 = severe) on insertions and origins of temporalis and masseters; Pain during rest and chewing test (wax) Disability score VAS – Pain intensity “worst”, “present”, “average in last month”. Significant reduction of pain intensity and disability score in exercise group over time and only pain relief scale was significant comparing between groups.	Random assignment 3 independent examiners Compliance – excellent. No loss to follow up.

Study ID	Population	Intervention	Comparator	Outcome	Other
Truelove	200 adults between mean 36 year-old, range 18-60; Average 86% female; University dental clinic setting, diagnosed with RDC-TMD criteria for Axis Ia or Ib with or without concurrent diagnosis of Group IIa, IIIa and Axis II Grade I or II with minimal psychosocial interference; exclusion criteria as in appendix; 64 (UT), 68(HS), 68 (SS). HS: Dental lab-processed hard acrylic flat plane maxillary splint, fitted by dentist. SS: Chairside-thermoplastic vinyl athletic mouthguard splint guided by dentist. Night time use and 2 hr daytime for both splints. Follow up 3,6,12 months.	"Hard splint" + UT "Soft splint" + UT	"Usual Treatment" Checklist of conservative self-care strategies (jaw relaxation, reduce parafunction, thermal packs, NSAIDs, *passive stretches*, reduce stress). Discourage narcotic analgesics, antidepressant medications and other use of splint.	Characteristic pain level: comparable reduction across 3 groups of average 2.4 points, $P < 0.0001$ for the change from baseline to 12 months, $P > 0.40$ for group comparisons. Pain duration (hours/day, days/month): Improvement across all groups over time but not between groups. Other TMD self-reported symptoms reported as often/always: Click/Popping, grating sounds, lock/catching, tinnitus, clenching – day and night, limited chewing, outcomes revealed no difference amongst the groups in their improvements over time and across the treatment interventions. The UT group had the lowest % with tinnitus and nocturnal clenching at 12 months ($P = 0.058$, 0.076 respectively). Jaw opening: Vertical and lateral deviations, for all groups, over 3,12 months, all showed improvements but no statistical significance between groups. Clinical findings with reduced muscle palpation pain in 16 extra-oral sites and none in 4 intra-oral sites, but no statistical significance was observed. Clinical finding on joint clicking varied insignificantly with time progress and amongst the interventions. Distribution of diagnosis varied with Group Ib, IIa, slightly reduced at 3,12 months but no significant differences.	Random blocks stratified to groups. Sample calculation carried out, 80% power to detect 35% difference (1.4) in characteristic pain intensity (CPI) levels between 2 groups, 0.05 significance level, common standard deviation 2.4. Intent-to-treat analysis for attrition loss (19). Compliance was higher in HS than SS.

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