The Manifestations and the Treatment of Temporomandibular Disorders in Patients with Chronic Whiplash-associated Disorders Grades 2 and 3

LUCIANO KLOBAS
Abstract

The main aim of this project was to encircle the subtype of temporomandibular disorders (TMD) present in patients with chronic whiplash-associated disorders (WAD) and study the debut of TMD symptoms, the provoking factors and the outcome of conservative TMD treatments. The results could add to the aetiological discussion about TMD mainly as being part of chronic WAD pain or not.

The subjects were referred patients with chronic WAD at a specialized rehabilitation centre where they were diagnosed using a standardized classification of WAD diagnosing that resulted in approximately 20% WAD grade 2 and 80% WAD grade 3. In Studies I and II, a total 136 individuals with chronic WAD were found to have a significantly higher prevalence of pain associated with TMD compared to a control group of 66 general dental patients. The symptoms debuted approximately six months after the whiplash injury and were most often provoked by stress. In Study III, the effect of a therapeutic jaw exercise (TJE) program on TMD was studied over six months in patients with chronic WAD and TMD, randomized to TJE (25 subjects) or not (30 subjects). TJE had no effect on TMD. In Study IV, patients with chronic WAD and TMD were found to have a mainly myogenous origin of TMD pain. Five months of stabilisation appliance therapy (SAT) equally resulted in an almost complete perceived reduction of jaw pain and frontal headache in patients with chronic WAD and TMD (n=14) and TMD patients without WAD (n=10). In the long-term, TMD was significantly lower in patients with chronic WAD who were treated compared to patients with chronic WAD and TMD who were not treated (n=9).

TMD in patients with chronic WAD grades 2 or 3 may be the same kind of musculoskeletal disorder as in TMD patients without WAD, and not primarily part of the WAD pain. A functional TMD examination as well as assessment of perceived stress can be recommended as part of the standardized screening procedure for patients with chronic WAD grades 2 and 3. Patients with symptoms and signs of TMD could be recommended SAT. Patients with symptoms of frontal headache alone should also be considered as candidates for SAT.

Keywords: Temporomandibular, TMD, Muscle, Whiplash, Whiplash-associated disorders, WAD, Chronic, Prevalence, Treatment

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urn:nbn:se:uu:diva-198420 (http://urn.kb.se/resolve?urn=nbn:se:uu:diva-198420)
This thesis is dedicated to the patients who will benefit from it in the future; to the therapists who will be dedicated to helping them; to the patients who agreed to take part in the studies in the thesis and contribute in turning experiences into knowledge; and also

to Claudia, Erik, Florian and Isabella, I love you

to Gioconda and Paolo, grazie

and

in memorial of Bjöör Wiberg, outstanding inspirer!
Cover illustration: Charles A Goulding, "Tomten som går nedför trapporna i ett vintrigt Majorna".
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List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.


IV Klobas, L., Hansson, T. L. and Söderlund, A. Stabilization appliance therapy has an equally extensive alleviating effect on jaw pain and frontal headache in patients with myogenous temporomandibular disorders (TMD), with or without chronic whiplash-associated disorders (WAD) grades 2 and 3. Submitted.

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<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CNS</td>
<td>Central nervous system</td>
</tr>
<tr>
<td>JEG</td>
<td>Jaw exercise group</td>
</tr>
<tr>
<td>NEG</td>
<td>No jaw exercise group</td>
</tr>
<tr>
<td>QTF</td>
<td>The Québec task force</td>
</tr>
<tr>
<td>SAT</td>
<td>Stabilization appliance therapy</td>
</tr>
<tr>
<td>TJE</td>
<td>Therapeutic jaw exercise</td>
</tr>
<tr>
<td>TMD</td>
<td>Temporomandibular disorders</td>
</tr>
<tr>
<td>TMJ</td>
<td>Temporomandibular joint</td>
</tr>
<tr>
<td>TTH</td>
<td>Tension-type headache</td>
</tr>
<tr>
<td>WAD</td>
<td>Whiplash-associated disorders</td>
</tr>
</tbody>
</table>
1. Introduction

1.1 Whiplash-associated disorders

Whiplash, a term used since at least 1928 (1) is “an acceleration-deceleration mechanism of energy-transfer to the neck” (2) and may result in a whiplash injury, a term used since at least 1958 (1). Whiplash-associated disorders (WAD) are the clinical manifestations of whiplash injuries (2). The cardinal symptoms are neck pain and reduced neck mobility, both in acute WAD (2) and in chronic WAD (3–5). Other common acute symptoms from a broad spectrum of symptoms (2) are headache (2,6–8), pain in the upper extremities (8) and low back pain (6,9). In patients with chronic WAD, symptoms of temporomandibular disorders (TMD) (10,11) and increased response to noxious stimuli and/or pain response to non-noxious stimuli (hyperalgesia, allodynia) (12–16) are also often present. Post-traumatic stress disorder (PTSD) has been suggested (17,18) as also common in patients with chronic WAD.

WAD became the most common medical term of the clinical entities after the Québec Task Force (QTF) on WAD in 1995 (2), when the current knowledge was summarized and a proposal for a classification was made. The classification is a clinical presentation of WAD 0–4 (WAD grades 1/2/3, complaints/musculoskeletal signs/neurological signs but no fracture or dislocation) with a time axis of <4 days, 4-21 days, 22-45 days, 46-180 days and >6 months from time of the injury. WAD present more than six months after the time of the injury is denominated “chronic” (2). Considering WAD grades 1-3, grade 3 is rare in the acute phase (≤5%) (2) but approaches 10% in patients who are symptomatic after one year (19).

The incidence of WAD in Western Europe and North America is 3/100,000 (20), and approximately 60% of patients are women (6,9,21). One year after injury, about 50% of patients still have neck symptoms (3); 30% of patients continue to have moderate to severe pain or disability (22–24); and 10% of patients have chronic neck pain or significant health impairment (3,7,25). Of individuals with initial neurological signs, 90% still had symptoms after one year (23). Other predictors for poor recovery are high initial pain level, catastrophizing, post-traumatic stress symptoms and not expecting to recover (26,27). Age and gender are of minor prognostic value (20).

The scientific reports on WAD up until today all point in the direction of a multifactorial aetiology in the development of WAD. Cervical strain develops during whiplash (28) and may be an etiologic factor, at least in the
acute phase (2). The development of new car seats has lowered the incidence of WAD (29–31) indicating, along with other evidence (12,28), that tissue injury may be a factor. There is evidence that the zygapophysial joints are a source of pain in 30 to 60% of patients with WAD (32–34). Other possible factors in the development of WAD, possibly resulting from and/or interacting with an eventual tissue injury, are altered central pain processing (32) and physiologic stress responses (17,35). These potential latter conditions may in turn interact with eventual psychosocial and/or socio-cultural factors (27).

1.2 Temporomandibular disorders

TMD is the embracing term for the musculoskeletal disorders of the masticatory muscles, the temporomandibular joints (TMJs) and their associated structures (36). They are commonly divided in the main subgroups (36) muscular disorders and articular disorders, which in turn are subdivided and include systemic diseases affecting the stomatognathic system. Jaw pain and headache are common symptoms (36). Pain conditions perceived in the areas may also arise from nerve tissue damage (37,38) of the muscle’s/TMJ’s nervous supply, be secondary muscular pain to a primary TMJ or cervical disorder (36) or referred pain from adjacent areas (36,39,40). Functional alterations in the central processing of sensory input resulting in hyperexcitability of the CNS and alterations in the endogenous pain modulations (32,37) may affect the pain manifestation of all mentioned levels.

The prevalence of pain associated with TMD symptoms in the normal population has been shown to vary between 6.3 to 15% in women and 3.2 and 10% in men, and is highest among young and middle aged adults (41). The variation may have been influenced by how the prevalence questions were formulated in different studies. TMD often fluctuates over time, and the treatment need in the population is estimated to be approximately 5% (41). The majority of patients seeking care for TMD have a muscular disorder (42).

In general, factors potentially contributing to the development of TMD are biomechanical, neuromuscular, neurobiological and psychosocial (43–45). The factors can be classified as predisposing, initiating, perpetuating and aggravating (43,46).

Disequilibrium of the components in a musculoskeletal system can be caused by bone and soft tissue remodelling and changed muscle tone regulation, which may occur through trauma including microtrauma, altered function, and systemic factors, and they result in compromised adaptability (36). Microtrauma might be caused by sustained and repetitive loading, which in the field of TMD is often discussed as through parafunction/bruxism (36). The discussion of the aetiology of myogenous TMD is focused on micro-
trauma, parafunctional activity/bruxism, muscle hyperactivity, emotional distress, response to life stressors, and comorbidity with chronic pain or stress-related disorders (36). The role of perceived stress, a biopsychosocial or physical/medical factor that is considered a threat or challenge to the individual that exceeds her/his resources (47,48), has been found to be an important factor in explaining TMD (49–58). But the causality of the role of stress on TMD in predisposing, triggering and worsening is not yet clear (43,59).

It has been suggested that stress provokes increased neuromuscular activity in the stomatognathic system (60–64) and thus increased oral parafunctional activity including/not including bruxism (defined (65) as clenching and/or gnashing and/or grinding of the teeth). Teeth clenching is capable of provoking pain associated with TMD in individuals without signs of TMD (66,67), and has also been found contributing to the development of masticatory myofacial pain (68). Bruxism, here not divided between clenching and grinding, has been suggested as being associated with facial pain (52,69,70). The discrimination of muscle tension may be compromised in chronic musculoskeletal patients (71), aggravating the control of daytime teeth clenching or even being aware of it. Pain associated with TMD symptoms may therefore be a result of biopsychosocial factors that are potent in initiating and perpetuating neuromuscular activities, and in combination with predisposing biomechanical risk factors may be aggravating.

1.3 Temporomandibular disorders in patients with WAD

The presence of TMD symptoms in patients experiencing whiplash injury has been reported since the 1960s (72,73). There are numerous studies on patients who have experienced trauma from motor vehicle accidents (74–77), but very few on patients diagnosed as having WAD. The incidence and prevalence of TMD in patients with acute WAD is reported to be low (78–82) and found on levels that are equal with the general population (79–81). Only one study has reported a high prevalence of clinical signs of TMD in patients with acute whiplash injury (83). In patients with chronic WAD grades 2 and 3, the prevalence of symptoms (10) and also signs (11) of TMD is significantly higher than in individuals without WAD. Clinical studies describe TMD in patients with chronic WAD as mainly experiencing jaw/facial pain and reduced mouth opening capacity (10,84,85), and also reduced jaw musculature endurance (86,87).

Studies on chronic WAD have discussed that the aetiology of TMD might be different or at least more multifactorial than it is in patients without WAD. It has been proposed that the TMD is due to a widespread pain condition with a hypersensitivity of the central nervous system (CNS) (10,11,87), and/or because of connections in the CNS between the neck and the jaw.
region (10). Also, since a functional connection between the movement of the mandibula and the neck has been shown (the atlanto-occipital joints take part in the gaping (88)), a reduced neck extension can also cause a reduction in the jaw opening capacity.

1.4 Treatment of TMD in general and in patients with WAD

TMD is a broad spectrum of disorders, and many treatment modalities for it have been described: e.g. physical therapy (jaw exercise programs, thermal therapies, hydrotherapy, electrical stimulation, laser therapy, massage, manual therapy), acupuncture, cognitive behavioural interventions, reversible occlusal treatments (dental appliances), irreversible dental occlusal treatments, orthodontics and surgical treatments, besides pharmacological treatments (36,89,90). The most common conservative treatments for TMD are physical therapy, including jaw exercise programs, and different kinds of dental appliances, of which some types are often called splints or stabilization appliances (89).

In clinical studies, therapeutic jaw exercise (TJE) has been shown to alleviate various symptoms of TMD (91–99). In one of the studies, the effect of TJE on myogenous TMD was comparable to the effect on TMD in a comparison group treated with stabilization appliance therapy (SAT) (99).

The impact from SAT on TMD has been investigated in many studies, with very different results (100–102). However, contributing reasons for these differences may be the methodology of how the diagnosis was set, how the appliances were designed, how the treatment was administrated and that the time point at which the evaluation was made varies between studies.

For SAT through full-arch, flat surface appliances that give stability for the mandible in centric relation and that are used during sleep, several studies show a substantial reduction of jaw pain (99,103–106). One five-year clinical follow-up study (107) reported a median estimated reduction in jaw pain of 100% in individuals whose TMD therapy initiated with a stabilization appliance that gave stability for the mandible in the individual retruded position of the mandible, guided by side with the greatest mandibular vertical height.

Only a few studies have been published on the treatment of TMD in patients associating symptoms to a trauma with whiplash. Until now, only a preliminary report on the treatment of jaw and head-neck disorders in patients with chronic WAD through “education, motor learning and intraoral appliance” indicated an improvement of mandibular and head-neck mobility (108). Studies including the most common conservative treatment method for TMD, interocclusal appliances (89), have also been performed on pa-
tients who experienced whiplash-injury who were recruited by newspaper advertising (109), and on patients with TMD linked to trauma, “mainly whiplash accidents” (110). Krogestad et al. (109) found a statistically significant decrease in muscle tenderness on palpation in the patients with “whiplash”, while the TMD patient controls also had a significant decrease in symptoms of headache and TMD. de Boever and Keersmaekers (110) found no significant difference between trauma and non-trauma TMD patients in the reduction of symptoms and signs of TMD, at the one-year evaluation.

1.5 Rationale and scope of this thesis

What has been shown until now concerning TMD in patients with chronic WAD, diagnosed in grades as proposed by the QTF, is that the prevalence of TMD seems to be higher than in the general population, and in patients with acute WAD, that their main symptom is jaw pain, and that the clinical picture is a decreased mouth opening capacity, along with a lowered endurance of the masticatory muscles.

WAD are homogenous conditions concerning physical and psychosocial characteristics, but the picture varies between patients’ symptoms and disability (111). Defining group characteristics helps in interpreting the results. Information is still lacking about the topic of TMD in patients with chronic WAD, partly because of unmeasured group characteristics in previous studies. The only study on TMD in patients with chronic WAD (all grade 2) where the method of WAD diagnosing has been described is the Visscher et al. study (11). However, group characteristics of time since whiplash injury and general disability were not specified in this study. Another clinical study (10) using QTF grades include the group characteristic of referred patients with chronic WAD grades 2 and 3 and suspected jaw pain and/or functional disabilities of the jaw, but they do not disclose how they gained the information about the WAD diagnosis or the percentage of patients in grades 2 or 3. No study so far has attempted to estimate the time point for the onset of TMD symptoms, and very little has been revealed (108) about the treatment perspectives of TMD in patients with WAD grades 2 and 3.

Therefore, this thesis aims at adding knowledge to the topic of TMD in patients with chronic WAD by studying groups with a homogenous methodology for WAD diagnosing, specified duration of WAD, and a defined disability. The prevalence of specific symptoms and signs of TMD, as well as factors provoking the symptoms, shall be studied in these groups. Because to our knowledge it has never been investigated before, also an attempt to probe the debut of the TMD after the incident associated with the WAD will be done. Finally, studies about treatment for TMD will hopefully help in reducing the suffering of patients with chronic WAD. The results of the treatment studies may contribute new knowledge to the issue of whether the
TMD is primarily a part of the chronic WAD pain or a regional musculo-skeletal disorder of the masticatory muscles and/or the TMJs.
2. Aims

The main aim of this project was to encircle the subtype of TMD present in patients with chronic WAD and study the debut of TMD symptoms, the provoking factors and the outcome of conservative TMD treatments.

The specific aims of this thesis on patients with chronic WAD were to

- describe the symptoms and clinical signs of TMD and their prevalence compared with patients without WAD (Papers I and II)
- describe the main origin of TMD pain (Paper IV)
- describe the onset of the TMD symptoms and the neck pain in the time after the injury associated with the WAD (Paper II)
- describe factors provoking symptoms of TMD and neck pain (Paper II)
- study the predictive value of provoking factors on symptoms of TMD and neck pain in comparison to patients without WAD (Paper II)
- evaluate the outcome on symptoms and signs of TMD for two conservative treatment methods: therapeutic jaw exercise and stabilization appliance therapy (for the latter therapy, also in comparison to patients with TMD but without WAD) (Papers III and IV)
3. Methods

3.1 Designs
In Papers I, II and IV, a descriptive and comparative design was used. In Paper II a correlative design was also used. Paper III was conducted with a prospective, randomized controlled design.

3.2 Origin of samples
The thesis papers are based on five samples of patients. Three of the groups were patients from a rehabilitation centre (Papers I-IV); one was constituted of patients attending at a public dental clinic for an ordinary dental examination (Papers I and II); and the fifth group was constituted of TMD patients from a specialized TMD clinic at a university hospital (Paper IV). The diagnosis of chronic WAD (2) was an inclusion criterion for all patients from the rehabilitation centre.

Most patients with chronic WAD had extensive difficulties in returning to work and were referred by regional social insurance offices and county councils from all over Sweden for functional evaluation and special rehabilitation. The rehabilitation centre accepted approximately 64 patients each year during the period when the samples were collected (2000-2003). The patients arrived at the centre in groups of eight, and there were eight groups each year. The patients first stayed at the centre for a period of four weeks and then returned for an additional follow-up week approximately six months later. All patients followed the centre’s general rehabilitation program consisting of physical therapy, occupational therapy and training in pain management. On the second day at the centre, the patients were examined by a consultant physician who specializes in rehabilitation medicine. The physician set the WAD diagnosis and worked independently of this project. Patients found in need of TMD treatment were referred to a specialized TMD clinic in the county where they were resident.
3.3 Samples

Sample WAD A (Papers I and II)
The first chronic WAD sample (WAD A) consisted of patients who had been accepted for rehabilitation during the year 2000. Sixty-four individuals with whiplash-related conditions were admitted to the rehabilitation centre during that year. All the patients gave their informed consent to take part in the study before their stay at the rehabilitation centre. Ten were excluded by the medical examination after receiving a diagnosis other than WAD (e.g. status post commotio or status post neck distortion). For diagnosis information, see Table 1.

Sample WAD B (Papers II and III)
The second chronic WAD sample (WAD B) consisted of the 94 individuals with whiplash-related conditions who were admitted to the rehabilitation centre from January 2001 through April 2002. The patients were informed about the study by letter and invited to participate before their stay at the centre. All the patients except one gave their informed consent. Of the remaining 93 patients, 82 patients were diagnosed with chronic WAD and thus were included. For diagnosis information, see Table 1.

Sample WAD C (Paper IV)
The third chronic WAD sample (WAD C) included all the consecutive patients with chronic WAD who were referred from the rehabilitation centre to the specialized TMD clinic in their county of residence, which was the county where the study resulting in Paper IV was performed. They had been referred by the consulting physician at the centre from January 2000 through June 2003. Retrospectively, all the referrals within the period were reviewed. Out of the 32 referrals, 30 patients came to the clinic for an examination (baseline examination, EXA1). Two of the 30 examined patients did not have the diagnosis WAD but another neck diagnosis, and were therefore excluded. For diagnosis information, see Table 1.

Sample Control (Papers I and II)
The fourth sample was composed of the age- and sex-stratified control group (Control) collected for comparison to WAD A during the year 2000. The Control consisted of 66 individuals attending at a public dental clinic for an ordinary dental examination. All the individuals in the Control were verbally asked about participation in association with the dental examination, and all agreed to participate and gave their informed consent.
Sample TMD (Paper IV)

The fifth sample (TMD) was the comparison group for WAD C. The criteria determined for inclusion in this comparison group (TMD) was that they were examined (EXA1) between 16/06/2004 and 15/10/2004 and treated by the same dentist and at the same TMD clinic as WAD C1 (treated patients from WAD C), accepted treatment with a stabilization appliance, had not received other treatments for TMD during the period, were age 16 years or older (if younger than 18 with parents’ consent), did not have WAD, and returned for a follow-up examination (EXA2) approximately five months after the start of the stabilization appliance treatment. It was further decided that these patients should have a diagnosis of mainly myogenous origin of jaw pain, since a summary of the TMD diagnoses from the EXA1 of WAD C1 was found to be predominantly pain of a mainly myogenous origin (see Paper IV, Table 3). Forty-three patients were examined during the period, and 11 of them met with the inclusion criteria. Ten of the 11 patients gave their informed consent.

For demographic data from all samples, see Table 1.

3.4 Measures

Papers I, II, and III

The standardized TMD examination was comprised of an anamnestic part and a clinical part. The anamnestic part (verbal) included identification of the presence of specific TMD symptoms (TMJ sounds, feeling of fatigue or stiffness in the jaws, difficulty in opening the mouth wide, pain on mandibular movements, TMJ locking or luxation), jaw pain, neck pain and the awareness of oral parafunction and/or bruxism. When a patient reported a symptom, she/he was asked to specify the debut time of the symptom and about factors precipitating and/or accentuating the symptom (provoking factors). The patients were not limited to multiple choice answers. Their statements about what was precipitating/accentuating their symptoms were reviewed by the authors and sorted into categories. The categories were not predefined. The review of the answers resulted in the following categories: “normal jaw activity” (e.g. talking, chewing, yawning), “oral parafunction and/or bruxism”, “stress and/or concentration”,

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Table 1. The percentage or median for gender, age, WAD diagnosis and the time elapsed between the accident and the WAD diagnosis set at the rehabilitation centre.

<table>
<thead>
<tr>
<th>Sample</th>
<th>WAD A (n=54)</th>
<th>WAD AB (n=136)</th>
<th>WAD B (n=82)</th>
<th>JEG (n=25)</th>
<th>NEG (n=30)</th>
<th>WAD C1 (n=14)</th>
<th>WAD C2 (n=9)</th>
<th>Control (n=66)</th>
<th>TMD (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, females, per cent</td>
<td>59</td>
<td>60</td>
<td>61</td>
<td>72</td>
<td>70</td>
<td>71</td>
<td>78</td>
<td>61</td>
<td>90</td>
</tr>
<tr>
<td>Age (range), years, median</td>
<td>37 (23-64)</td>
<td>38 (20-64)</td>
<td>38.5 (20-61)</td>
<td>37 (24-60)</td>
<td>34.5 (21-55)</td>
<td>34.5 (20-48)</td>
<td>40 (28-49)</td>
<td>38 (19-62)</td>
<td>45.5 (16-73)</td>
</tr>
<tr>
<td>Diagnosis WAD grade 3, per cent</td>
<td>72</td>
<td>79</td>
<td>84</td>
<td>88</td>
<td>83</td>
<td>86</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months elapsed between WAD diagnosis and associated accident, (range), median</td>
<td>28.5 (8-200)</td>
<td>30 (8-216)</td>
<td>31.5 (10-216)</td>
<td>29 (10-159)</td>
<td>26 (10-201)</td>
<td>26.5 (10-114)</td>
<td>32 (19-92)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“neck pain”, “general body loading and/or physical activity” and “I don’t know”.

The clinical part of the examination included measurements of mandibular mobility, pain during mandibular movements, pain on palpation of masticatory muscles, pain on palpation of the TMJs, and TMJ clicking. The mandibular movements were measured with a ruler. Four masticatory muscles were palpated on seven sites: posterior, anterior, and insertion part of the temporal muscle; superficial and profound part of the masseter muscle; and lateral and medial part of the pterygoid muscles. In order to calculate a masticatory muscle score, one point was given when the individual reported unilateral pain from a muscle site or when a clear autonomous reaction, i.e. a palpebral reflex or evasive action, was provoked. The highest value of the masticatory muscle score was thus seven points.

Pain on lateral palpation of the TMJs was registered by “Yes” or “No” when the patient reported unilateral pain and/or when a clear autonomous reaction (i.e. a palpebral or a withdrawal reflex) could be seen. TMJ clicking was registered by lateral palpation of the joints during the opening and closing of the mouth. Variables from Papers I, II and III are listed in Table 2.

Paper IV

A verbal clinical history led by standardized non-categorical questions was taken, including the presence of jaw pain, frontal headache and parafunction/bruxism, and was followed by a functional examination of the stomatognathic system according to a standardized protocol: the same in EXA1, EXA2 and EXA3 (different time point for examination; see below in section 3.5). The examination included measures of the active mouth opening capacity with a ruler (112) and dynamic/static tests of the TMJs and the masticatory muscles (112–118). The tests were performed for five directions: opening and closing of the jaws, bilateral laterotrusion of the mandible and protrusion of the mandible. Presence of pain was registered with yes/no answers for the right and the left side separately, and an index (107) was calculated for the dynamic pain and static pain separately from 0 (no pain in any direction) up to 10 (yes for bilateral pain for all five directions).

The tests resulted in a diagnosis of a mainly arthrogenous or a mainly myogenous origin of pain (112,113,116,119). If dynamic pain was present and perceived by the patient as more intensive than an eventual static pain, the diagnosis was set to a mainly arthrogenous origin of pain. If static pain was present and equally or more intensive than an eventual dynamic pain, the diagnosis was set to a mainly myogenous origin of pain (116,119).

At the second (EXA2) and third examinations (EXA3), the patients were also asked to estimate an evidential difference in jaw pain and frontal headache between EXA1 and EXA2/EXA3 as a percentage between 0 and 100. Variables from Paper IV are listed in Table 3.
Table 2. *Studied variables in Papers I, II and III.*

<table>
<thead>
<tr>
<th>Anamnestic</th>
<th>Clinical</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMD symptoms</td>
<td>Maximum active mouth opening capacity (mm)</td>
</tr>
<tr>
<td>-TMJ sounds</td>
<td>Mandibular movements pain (yes/no)</td>
</tr>
<tr>
<td>-fatigue/stiffness in the jaws</td>
<td>Masticatory muscle pain on palpation (score 0-7)</td>
</tr>
<tr>
<td>-difficulty in opening the mouth wide</td>
<td>TMJ pain on palpation (yes/no)</td>
</tr>
<tr>
<td>-pain on mandibular movements</td>
<td>TMJ clicking (yes/no)</td>
</tr>
<tr>
<td>-TMJ locking/luxation</td>
<td></td>
</tr>
<tr>
<td>Pain symptoms</td>
<td></td>
</tr>
<tr>
<td>-jaw pain</td>
<td></td>
</tr>
<tr>
<td>-neck pain</td>
<td></td>
</tr>
<tr>
<td>Oral parafunction/bruxism awareness</td>
<td></td>
</tr>
<tr>
<td>Symptom debut</td>
<td></td>
</tr>
<tr>
<td>Symptom provoking factors</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. *Studied variables in Paper VI.*

<table>
<thead>
<tr>
<th>Anamnestic</th>
<th>Clinical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaw pain</td>
<td>Maximum active mouth opening capacity (mm)</td>
</tr>
<tr>
<td>Frontal headache</td>
<td>Dynamic/static tests of the TMJs/masticatory muscles (yes/no index 0-10)</td>
</tr>
<tr>
<td>Oral parafunction/bruxism awareness</td>
<td></td>
</tr>
</tbody>
</table>

3.5 Procedures and interventions

All patients were examined by the same therapist (LK, dentist), except for two patients in the WAD C who were examined (first examination) by other therapists at the same clinic.

Clinical signs of TMD (Paper I)

Sample WAD A was compared with sample Control. Both groups underwent a standardized TMD examination including the registration of clinical TMD signs.
Origin of the TMD pain (Paper IV)
Sample WAD C was compared with sample TMD. The groups underwent a standardized TMD examination including orthopaedic dynamic/static tests of the TMJs and the masticatory muscles.

Symptoms of TMD, the TMD symptoms’ debut time after the injury associated with the WAD and factors precipitating and/or accentuating the symptoms of TMD and of neck pain (Paper II)
Samples WAD A and WAD B were combined for study purposes (WAD AB) and compared with sample Control. On the second day of the four-week stay at the rehabilitation centre, all 136 patients in WAD AB attended a standardized TMD examination performed by a dentist. The examination included an interview using a standardised questionnaire.

Procedure and therapeutic jaw exercise intervention (Paper III)
Sample WAD B was studied. The inclusion criteria for the study were the diagnosis chronic WAD and clinical signs of TMD. The criteria for TMD were at least a score DiII on the dysfunction index of Helkimo (Di) (120) and/or at least three points on the masticatory muscle score (see 3.4 above). The dysfunction index of Helkimo (Di) grades clinical signs of TMD: Di0 represents no signs, DiI mild signs, DiII moderate signs, and DiIII represents severe signs.

In total, 12 consecutive groups of eight patients were invited to participate in the study. The groups of eight patients were randomized by a secretary at the centre into being given TJE or not before the set of WAD and TMD diagnosis. The randomization procedure was performed with four groups and repeated three times: before the arrival of the first, fifth and the ninth groups. After the examinations, 38 patients were excluded because they did not fulfil the inclusion criteria. The jaw exercise group (JEG) came to consist of 25 patients, and the control group (no jaw exercise group, NEG) came to consist of 30 patients. For further description, see Table 1.

The examiner of the stomatognathic system never discussed the patients with the staff at the centre and was blinded to group assignment throughout the study.

The standardized TMD examination was repeated for the included patients after three weeks and at the six-month follow-up. At the follow-up, patients also answered a written questionnaire enquiring about their cooperation at home with exercises (including TJE), eventual change in TMD symptoms and how they managed daily activities. The questionnaire was answered during the patients’ appointment with the physical therapists at the
centre, and the authors of Paper III were blinded to the answers during the study.

TJE was administered in addition to the physical therapy given at the centre. Thus, each patient had the physical therapy, and the JEG also had the TJE. The TJE consisted of relaxation; small active mandibular movements; maximum active mandibular movements; active movements against resistance with six seconds of static resistance at the end of the movement; rest; mouth closing against resistance with six seconds of static resistance halfway on mouth closing; rest; five seconds of stretching at maximum mouth opening; and relaxation. Each part of the program was repeated 5-10 times, and the program was to be performed three times daily. If the patients experienced pain during the TJE, they were instructed to exclude the painful part from the program and try to reintroduce it after one week.

The physical therapists at the centre administered the TJE through verbal and written instructions to the patients. Every day during the patients’ whole stay at the centre, the physical therapists encouraged compliance and instructed and motivated the patients to continue the TJE at home.

Procedure and stabilization appliance therapy intervention (Paper IV)

Samples WAD C and TMD were studied.

The 28 retrospectively identified patients (WAD C) had been offered stabilization appliance therapy after EXA1. The patients were divided into two groups based on chosen treatment: 16 patients were treated with stabilization appliance therapy (WAD C1), and 12 patients were not treated at all (WAD C2). The patients in the WAD C1 were followed during the first months of the treatment, re-examined after five months (examination two, EXA2) and thereafter recommended to use the appliance for an undetermined length of time. It was prospectively decided that all of the included 28 patients would be asked about participation in the study and invited for a long-term follow-up examination (EXA3).

For the group WAD C1, the inclusion criteria at EXA3 was that they had not received treatments for TMD in other healthcare establishments since EXA1 and they were age 16 years or older (if younger than 18 with parents’ consent). Two patients were excluded since they had just started treatment, and the WAD C1 group finally came to consist of 14 patients. All patients gave their informed consent to participate in the study.

For the group WAD C2, the inclusion criteria at EXA3 was that they had not received any treatment for TMD since EXA1 and they were age 16 years or older (if younger than 18 with parents’ consent). In WAD C2, two patients did not give their informed consent to participate in the study. Of the
10 patients who gave informed consent, one was excluded for being treated with a stabilization appliance at another dental clinic during the period since EXA1. WAD C2 finally came to consist of nine patients. In WAD C2, six patients had declined the SAT for economic reasons, and three had not wanted to try the therapy.

The prospectively invited group TMD was examined (EXA1), treated with a stabilization appliance and re-examined (EXA2) after approximately six months.

Comparisons between WAD C1 and WAD C2 were made with retrospectively identified data (EXA1) and with prospectively collected data (EXA3). Comparisons between WAD C1 and the group TMD were made with retrospectively identified data (WAD C1) and with prospectively collected data (group TMD).

The ethics committee of Uppsala University was asked for permission for the study to be conducted. The committee answered that no permission was necessary for the described study design due to the ethical regulations in force at the time.

Treated patients wore a full-arch upper-jaw stabilization appliance made of heat polymerized acrylic that gave stabilization for the mandible in the individual retruded position during the part of the day or night when jaw pain or frontal headache was usually provoked, which for all patients was during sleep. See Klobas et al. for a detailed description of the stabilization appliance treatment (107).

### 3.6 Data analysis

The statistical analyses used in the papers are listed in Table 4. For details, see the respective papers (I, II, III, IV).

<table>
<thead>
<tr>
<th>Statistical analysis method</th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student’s t-test</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Chi-square test</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Chi-square test for trend</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exact tests</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exact chi-squared test</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mann-Whitney U test</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisher’s Exact test</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-parametric Friedman’s test</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ANOVA</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logistic regression</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
4. Results

4.1 Symptoms and clinical signs of TMD (Papers I and II)

The symptoms of TMD in the combined WAD A and B groups (WAD AB) were compared with the group Control (Paper II). The TMD symptoms feeling of fatigue/stiffness in the jaws, difficulty in opening the mouth wide, pain on mandibular movements, and jaw pain were significantly more frequent in WAD AB than in Control. Jaw pain was more than ten times as prevalent in WAD AB compared with Control: 54.9% and 4.5%, respectively (see Paper II, Table 1).

For clinical signs of TMD, the sample WAD A was compared with the sample Control (Paper I). The maximum active mouth opening capacity was significantly smaller, and the other clinical signs (except for TMJ clicking) were significantly more common in WAD A. Pain on mandibular movements was present in 30.3% of individuals in WAD A and in 3% in Control (see Paper I, Table 2).

A comparison between patients in WAD A who were exposed to whiplash injury ≤2 years (n=25) and >2 years (n=29) before the TMD examination revealed that the group with the longest time from injury had a significantly smaller maximum active mouth opening capacity and a significantly higher muscle palpation score (see Paper I, Table 3).

4.2 Diagnosis of the main origin of TMD pain (Paper IV)

The origin of TMD pain was studied through descriptive data from the first functional examination of the stomatognathic system of WAD C. Eighteen out of 22 patients were diagnosed as having a mainly myogenous origin of pain. No patient had a mainly arthrogenous origin of pain at EXA1 (see Paper IV, Table 3).
4.3 The debut of symptoms of TMD and neck pain (Paper II)

The debut of symptoms was studied in sample WAD AB through descriptive data. Most TMD symptoms, jaw pain and the awareness of bruxism, debuted approximately six months after the accident associated with the WAD, while the neck pain debuted immediately (see Paper II, Table 2).

4.4 Factors provoking symptoms of TMD and neck pain (Paper II)

Anamnestic data from sample WAD AB was analysed. Stress/concentration and neck pain were reported as the most common factors precipitating/accentsuating symptoms of TMD, jaw pain, neck pain and the awareness of oral parafunction/bruxism. General body loading/activity was found to provoke neck pain in 81.7% of the patients. For details see Table 5.
Table 5. *Chronic WAD patients (per cent of WAD AB)* who reported different factors precipitating/accentuating their symptoms as well as the results of the logistic regression analyses between factors precipitating/accentuating the symptoms as independent variables entered separately in the equation, and TMD symptoms, jaw pain, neck pain, and awareness of bruxism as dependent variables.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Normal jaw activity (%)</th>
<th>Oral parafunction/bruxism (%)</th>
<th>Independent variables</th>
<th>Neck pain (%)</th>
<th>General body loading/activity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling of fatigue/stiffness in the jaws (n=104/tot=136)</td>
<td>17.3</td>
<td>11.5</td>
<td>Stress/concentration (%)</td>
<td>26.9</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.8</td>
</tr>
<tr>
<td>Difficulty in opening the mouth wide (62/136)</td>
<td>6.4</td>
<td>6.4</td>
<td></td>
<td>16.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pain on mandibular movements (60/136)</td>
<td>31.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.7</td>
<td></td>
<td>16.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
</tr>
<tr>
<td>Jaw pain (45/82)</td>
<td>11.1</td>
<td>6.7</td>
<td></td>
<td>28.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24.2</td>
</tr>
<tr>
<td>Neck pain (82/82)</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0/82&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>17.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>81.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Awareness of oral parafunction/bruxism (77/136)</td>
<td>0/77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6</td>
<td></td>
<td>41.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>36.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.3</td>
</tr>
</tbody>
</table>

<sup>a</sup>=no analyses possible  <sup>b</sup>=statistically significant individual predictor (p<0.001)
4.5 The prediction of symptoms of TMD from the precipitating/accentuating factors (Paper II)

The prediction of TMD symptoms and awareness of bruxism by the provoking factors and group belonging (to the WAD group) for both WAD AB and Control groups together

When entered in the logistic regression equation, the independent variables stress/concentration, neck pain, and group belonging (WAD AB or Control) significantly shared their individual variance with the dependant variables: feeling of fatigue/stiffness in the jaws, difficulty in opening the mouth wide, and pain on mandibular movements, respectively. For more details, see Table 6.

When the six independent variables were entered in the logistic regression all together, all four dependent variables’ Omnibus Tests of Model Coefficients were significant ($p<0.001$ in all analyses), proving the validity of the models. The independent variable group belonging (to WAD AB group) alone was a significant predictor of the dependent variable difficulty in opening the mouth wide.
Table 6. Results (p-values) for all the patients (WAD AB and Control) of the logistic regression analyses between factors precipitating/accentuating the symptoms and group belonging to the WAD AB group as independent variables entered separately in the equation, and three TMD symptoms and the awareness of bruxism as dependent variables.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Normal jaw activity (%)</th>
<th>Oral parafunci-</th>
<th>Independent</th>
<th>General body load-</th>
<th>Group belonging (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>tion/bruxism (%)</td>
<td>Stress/concentration (%)</td>
<td>Neck pain (%)</td>
<td>activity (%)</td>
</tr>
<tr>
<td>Feeling of fatigue/stiffness in the jaws (n=104/tot=136)</td>
<td>&lt;0.001</td>
<td>ns</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>ns</td>
</tr>
<tr>
<td>Difficulty in opening the mouth wide (62/136)</td>
<td>ns</td>
<td>ns</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>a</td>
</tr>
<tr>
<td>Pain on mandibular movements (60/136)</td>
<td>&lt;0.001</td>
<td>ns</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>ns</td>
</tr>
<tr>
<td>Awareness of oral parafunc-</td>
<td>a</td>
<td>ns</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>ns</td>
</tr>
<tr>
<td>tion/bruxism (77/136)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a=no analyses possible   ns=non significant
The prediction of TMD symptoms, the awareness of bruxism, jaw pain and neck pain by the provoking factors in the WAD AB group (Paper II)

When entered in the logistic regression equation, the independent variable normal yaw activity was a significant individual predictor of the dependent variable pain on mandibular movements. When entered in the logistic regression equation, the independent variable stress/concentration was a significant individual predictor of the dependent variables difficulty in opening the mouth wide, pain on mandibular movements, awareness of oral parafunction/bruxism, and jaw pain, respectively. When entered in the logistic regression equation, the independent variable neck pain was a significant individual predictor of the dependent variables difficulty in opening the mouth wide and awareness of oral parafunction/bruxism, respectively (Table 5).

When the five independent variables were entered in the logistic regression all together, all five dependent variables’ Omnibus Tests of Model Coefficients were significant ($p<0.001$ in all analyses), proving the validity of the models. For the dependent variable neck pain, no analyses were possible because all patients had the symptom.

4.6 Effect on TMD by the therapeutic jaw exercise program (Paper III)

Clinical findings

Within groups, only the maximum active mouth opening capacity in the NEG changed significantly, first decreasing at the three-week follow-up examination and then increasing at the six-months follow-up. Between groups, no parameters changed significantly (see Paper III, Table I).

The questionnaire answered at the 6-month follow up

During the period between the first and second stay at the centre, ten patients in the NEG (out of the 26 answering the questionnaire) had received a jaw exercise program from another therapist. The majority of patients in both groups did not perceive a change in jaw symptoms. The only significant difference between groups was that the patients in the JEG performed TJE more often compared with the NEG (see Paper III, Table III).
4.7 Effect on TMD of the jaw stabilization appliance therapy (Paper IV)

Comparisons between WAD C1 and TMD

At EXA1 and EXA2, the groups did not significantly differ in the awareness of jaw pain and frontal headache, the estimated reduction of jaw pain and frontal headache, the maximum active mouth opening capacity, the dynamic or static indexes, or in the awareness of bruxism (see Paper IV, Table 2).

Comparisons between WAD C1 and WAD C2

At EXA1, the groups did not significantly differ in the measured parameters. At EXA3, there was a significant difference between WAD C1 and WAD C2 in the perceived jaw pain reduction (80% and 0% median reduction respectively) and in the perceived frontal headache reduction (75% and 25% median reduction, respectively).

At EXA3, there was also a significant difference in the static pain index with a median value of 0 in WAD C1 and a median value of 4 in WAD C2 (Table 7). The number of patients with a myogenous origin of pain was significantly higher in WAD C2 at EXA3 (see Paper IV, Table 3).
Table 7. Variables (values in frequency or median) at the baseline examination (EXA1) and at follow up approximately 20 months later (EXA3) in the treated WAD group (WAD C1) and in the non-treated WAD group (WAD C2), as well as p-values for group differences (Mann-Whitney U test, Chi2 test, and Fisher’s Exact test). For variables presented in median values, the interquartile range is given. ns=non significant.

<table>
<thead>
<tr>
<th>Variable</th>
<th>EXA1 WAD C1 (n=14)</th>
<th>WAD C2 (n=9)</th>
<th>p-value</th>
<th>EXA3 WAD C1 (n=14)</th>
<th>WAD C2 (n=9)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients aware of jaw pain, n</td>
<td>14</td>
<td>9</td>
<td>a</td>
<td>11 (n=13)</td>
<td>9</td>
<td>ns</td>
</tr>
<tr>
<td>Perceived jaw pain reduction between EXA1 and EXA3, median (per cent)</td>
<td>80.0 (n=13)</td>
<td>0.0</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interquartile range</td>
<td>38</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients aware of frontal headache, n</td>
<td>8</td>
<td>9</td>
<td>&lt;0.05</td>
<td>7 (n=13)</td>
<td>8</td>
<td>ns</td>
</tr>
<tr>
<td>Perceived frontal headache reduction between EXA1 and EXA3, median (per cent)</td>
<td>75.0 (n=10)</td>
<td>25.0</td>
<td>&lt;0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interquartile range</td>
<td>70</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum mouth opening capacity, median (mm)</td>
<td>46.0</td>
<td>47.0</td>
<td>ns</td>
<td>49.0 (n=13)</td>
<td>51.0</td>
<td>ns</td>
</tr>
<tr>
<td>interquartile range</td>
<td>9</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic pain index, median</td>
<td>0.0 (n=13)</td>
<td>0.0 (n=7)</td>
<td>ns</td>
<td>b</td>
<td>0.0</td>
<td>ns</td>
</tr>
<tr>
<td>interquartile range</td>
<td>0</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static pain index, median</td>
<td>2.0 (n=12)</td>
<td>2.0 (n=7)</td>
<td>ns</td>
<td>0.0 (n=13)</td>
<td>4.0</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>interquartile range</td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients aware of bruxism, n</td>
<td>10 (n=12)</td>
<td>6 (n=8)</td>
<td>ns</td>
<td>12 (n=13)</td>
<td>5 (n=9)</td>
<td>ns</td>
</tr>
</tbody>
</table>

a=no analyses possible due to all patients in WAD1 being aware of the variable jaw pain.
b=no value
5. Discussion

A majority of the patients with chronic WAD grades 2 and 3 had symptoms associated with TMD pain. Symptoms of TMD (except for TMJ sounds and locking/luxation) were significantly more common among individuals with chronic WAD grades 2 and 3 compared with patients from a public dental clinic who did not have WAD. Also, the measured clinical signs of TMD, especially signs with pain, were significantly more common in the patients with chronic WAD compared with the group of dental clinic patients without WAD. The individuals with chronic WAD who were in need of TMD treatment had TMD pain of a mainly myogenous origin.

The patients with chronic WAD estimated the debut of the TMD symptoms as approximately six months after the start of accident-related neck pain. The patients also identified stress/concentration and neck pain as the most common factors provoking TMD symptoms. In the analysis of the provoking factors as predictors of TMD symptoms, the provoking factor stress/concentration could predict the presence of most TMD symptoms.

The two most common conservative treatments for TMD were evaluated in separate studies. First in a randomized controlled trial, a therapeutic jaw exercise program had no effect on TMD symptoms or signs in patients with chronic WAD grades 2 and 3. Second in an observational and comparative study, a stabilization appliance therapy in the short term eliminated pain associated with TMD symptoms and signs, and frontal headache in most chronic WAD patients. The stabilization appliance therapy decreased pain in chronic WAD patients to the same degree as in TMD patients with a myogenous origin of pain but without WAD. After approximately 18 months of the stabilization appliance therapy, the pain decreasing effect was mainly maintained in the patients with chronic WAD, and their TMD symptoms and signs were significantly less prevalent compared with patients with chronic WAD grades 2 and 3 who were not treated with the stabilization appliance therapy.

These studies are unique in investigating TMD in groups with approximately 80% of patients with chronic WAD grade 3. The median time elapsed from the injury associated with WAD and the TMD assessment was approximately 30 months (two and a half years). The sui generis results of our study showed that the symptoms of TMD debuted, according to patients, about six months after the start of the accident-related neck pain. Other prevalence studies of TMD in patients with chronic WAD (10,11) show higher
frequencies of symptoms associated with TMD pain than studies on WAD patients in the acute phase (79–82). Visscher et al. (11) measured the prevalence of TMD pain based on oral history. They compared patients with chronic WAD grade 2 in a rehabilitation centre for chronic WAD with chronic neck pain patients, and a group without neck pain. Of the patients, 52% with chronic WAD reported TMD pain, compared with 27% and 8% respectively in the two other groups. Häggman-Henriksson et al. (10) compared the symptoms of jaw/face pain in patients with chronic WAD grades 2 and 3, who were referred to a TMD clinic with healthy subjects. The median time from whiplash injury to TMD examination was three years. They found that the median frequency of jaw/face pain was “every week” in the chronic WAD patients and “never” in the controls.

Further, on signs of TMD, Paper I showed that patients examined more than two years after the accident associated with their WAD had a significantly smaller mouth opening capacity and a significantly higher score on muscle palpation, compared with patients examined less than two years after the accident. Visscher et al. (11) examined the patients in their study using the same method of diagnosis as in our Paper IV and found that approximately 17% of patients had TMD pain provoked by dynamic/static tests (0% in the other groups).

Putting together the previous studies with our results, we suggest that the prevalence of TMD symptoms and signs is higher with persisting WAD and higher with higher grades (grades 1-3) of chronic WAD. The subsequent question is whether this increasing manifestation of TMD is a whiplash-associated disorder, e.g. due to a sensitization of the nervous system that developed with chronicity, or whether it is TMD pain precipitated by longstanding triggers?

Possible causes of the TMD pain that are not caused by a systemic disease could be microtrauma in the stomatognathic system (36), pain secondary to a condition in an adjacent area (36), referred pain e.g. from the neck (40) and/or a sensitization of the nervous system (37,121). In our study, stress/concentration was found as the most common provoking factor for TMD symptoms, as well as the factor capable of predicting the presence of most TMD symptoms. The perceived stress, defined as a biopsychosocial factor that is considered as threat or challenge that exceeds the individual’s resources (47,48), has been found to explain TMD pain in several studies (49–58).

The influences of psychosocial factors are a common feature of both chronic TMD and chronic WAD. In a cohort of patients with chronic WAD, psychosocial factors have been found to be more pronounced than physical/biomedical factors (122). Psychosocial factors (e.g. catastrophizing, perceived injustice, and post-traumatic stress symptoms) probably have a significant role in the progression towards chronicity after whiplash injury (27). Stressful daily activities (123), fear-avoidance behaviour (124) and per-
ceived stress (125,126) have been found to co-vary with the outcome after whiplash injury. Psychosocial factors also have value as predictors of the return-to-work rate (127).

The two factors that most commonly provoke symptoms of TMD of a myogenous origin in patients with chronic WAD grades 2 and 3 can both be derived from the chronic WAD itself. Studies have shown that stress provokes increased neuromuscular activity in the masticatory muscles (60–64), and thus triggers or enhances oral parafunctional activity and/or bruxism. It seems that bruxism in general is one of the factors associated with TMD pain (52,69,70), and teeth clenching, in particular, has been proven as capable of inducing TMD pain in individuals without TMD (66,67) and also found as a contributing factor for masticatory muscular pain (68). Knowing from the results of our observational study (IV) that an extensive and lasting alleviation of TMD-associated pain can be achieved by interocclusal treatment, the aetiology of TMD in patients with chronic WAD could, with predominant probability, be stress-related overload causing microtrauma in the stomatognathic system. Therefore, a hypothesis could be that the longstanding stress with WAD turning into chronicity precipitates and perpetuates TMD pain of a myogenous origin. We propose that future studies of TMD in association with chronic WAD also measure psychosocial factors, in particular stress and stress-coping.

Since myogenous TMD is responsive to SAT, it is also possible that this regional musculoskeletal condition, if left untreated, is loading the CNS with nociceptive pain. It has been shown in patients with chronic WAD that anaesthetic blockade in myofascial trigger points of the trapezius muscle and of the zygapophyseal joint decreases signs of sensory hypersensitivity, indicating that peripheral sources of pain may be capable of modulating central hyperexcitability (128,129). Since there may exist nociceptive pathways between the trigeminal and the cervical neck area (130), future studies on the treatment of TMD in patients with chronic WAD should include measuring symptoms and signs beyond the temporomandibular area.

Patients with chronic musculoskeletal pain can have a deficit in discriminating muscle tension (71), which makes it more difficult for controlling bruxism even in patients who are aware of performing this behavior. In the present study, both stress and neck pain were individual predictors of the awareness of parafunction/bruxism. Thus, in order to prevent the precipitation of TMD if WAD is turning into chronicity, it is important to assess patients’ perceived level of stress and the possible presence of bruxism, defined as parafunctional activities of grinding and/or clenching the teeth (65), with the goal of reducing it, or its consequences. However, the best way of preventing the development of TMD after whiplash injuries is most likely by intensifying research aimed at decreasing the development of acute WAD into chronic.
TJE did not seem to be a successful treatment method for TMD in patients with chronic WAD grades 2 and 3, while SAT did. In the cohorts of patients with TMD treated with SAT, the only indication has been, according to the method used (107), for night-time use of the appliance. If the majority of chronic WAD patients with TMD symptoms and signs in our study overloaded their jaw muscles mostly during the night, this may have been a reason for the lack of effect treatment from the TJE program. The eventual effect of the TJE during the day time may not have been great enough to influence the muscles during the night. Since TJE has been shown to have an alleviating effect on TMD in patients with TMD but without WAD (93, 95, 98, 99), the lack of effect in this cohort of patients with chronic WAD may speculatively be dose-dependent, and/or the type of the exercise program might not have been the most optimal for patients with chronic WAD. Also, the extent of the bruxism may have been greater in these patients with chronic WAD compared with the patients with TMD but without WAD in the earlier studies of TJE. In the latter case, it may be that the working mode of TJE is not sufficient for management of TMD in patients with chronic WAD.

Paper III is the first published study of TJE in patients with TMD and WAD. In future studies of TJE in patients with WAD and TMD, new methods for exercises and the time points at which they are conducted during the day should be investigated.

Paper IV is the first published study on SAT given to patients diagnosed with WAD according to the QTF. de Boever and Keersmaeker (110) compared the effect of a TMD therapy comprising interocclusal appliance therapy between TMD patients who experienced trauma (“mostly whiplash”) and those who had not. The results of Paper IV are in concordance with de Boever and Keersmaeker on equally positive results in non-trauma and trauma patients. However, another study (109) where patients with “whiplash” were recruited through newspaper ads found no relief of symptoms in patients with “whiplash” from a therapy including an interocclusal appliance in comparison with patients with TMD but without WAD. The differences in results between studies may depend on several factors, but it is difficult to analyse them since the definitions of the treated groups are different. For future TMD treatment studies in patients with chronic WAD, we propose that researchers use a current WAD diagnosis with QTF grade, state the time elapsed from the whiplash injury, make an assessment of the origin of TMD pain, and that they describe the methodology of the treatment.

The methodology, including the choice of an intermaxillary appliance, is probably of utmost importance for the effect of TMD treatment since studies on treatment including appliances show very different results (100–102). Besides Paper IV and the study with the same treatment methodology (107), other studies, all on stabilization appliances that give stability for the mandible in centric relation, also show a substantial alleviation of jaw pain.
and headache s(131–136) in patients with TMD but without WAD. It is not known whether the appliance used in Paper IV is a preferable treatment for patients with chronic WAD, since studies are lacking that compare an appliance that gives stabilization for the mandible in the retruded position guided by the highest mandibular side and an appliance that gives stability to the mandible in centric relation in patients with TMD but without WAD.

The reduction on frontal headache by the SAT is also interesting, since headache is a common symptom both in acute (2) and chronic (8,21) WAD. The presence of TMD is not common in acute WAD. Thus, the headache that is alleviated by the SAT is probably a condition precipitated by chronicity and is possibly originally associated with WAD. The patients with WAD in Paper IV all had symptoms of TMD. However, patients may exist who do not have other symptoms but headache and who might get relief through SAT. These results are important to remember – not to exclude patients with headache alone as candidates for SAT as a treatment to diminish suffering – when screening patients with chronic WAD for TMD.

This thesis has shown that the majority of patients with chronic WAD grades 2 and 3 have symptoms of TMD pain, and that it is possible to alleviate the pain to a wide extent with a reversible conservative treatment method. Due to the jaw being in the anatomic vicinity of the neck, there is a risk of patients and therapists not identifying TMD. Therefore it is advisable to screen patients with chronic WAD for TMD and also to consider stabilization appliance therapy in patients with chronic WAD and headache.

Strengths and limitations

The strength of this thesis lies in that it is based upon consecutive samples of patients from all over Sweden collected over long periods of time. Another strength regarding WAD is that all patients were diagnosed by the same experienced physician. However, the samples were restricted to patients with difficulties in returning to work who were at a rehabilitation centre that specializes in functional evaluation and rehabilitation. Among 140 patients with chronic WAD, only three refused to participate in the study. The clinical picture of the patients in which TMD was studied was longstanding neck pain with, in most patients, neurological signs. Thus this is unique material among studies on TMD and WAD that permits us to thoroughly describe the prevalence and manifestation of WAD in patients with chronic WAD, predominately grade 3.

The age- and sex-stratified control group (Control) of individuals attending a public dental clinic for an ordinary dental examination resembled the general population in neck pain (137,138) and TMD pain prevalence (41).
The main limitation of this thesis is the uncertainty regarding how the designs of the treatment studies might have affected the results. In Paper III, the randomization was done on the group level in order to lower the risk that individuals performing/not performing TJE and living together for weeks would influence each other. However, the randomization on the group level, together with the exclusion of patients after the randomization was done, resulted in a different number of patients in the two studied groups. Also, the fact that at follow-up more than one third of the patients in the NEG had tried some kind of TJE during the five months after their stay at the centre might have decreased the internal validity of the results in this study. In Paper IV, the distribution of patients into groups was not performed through randomization. The patients chose themselves if they wanted to have SAT. Also, the patients with WAD declined SAT for different reasons; thus the number of patients in the three groups were slightly different and small. The small sample sizes might have influenced both internal and external validity, especially in a study with long-term follow-ups. In long-term follow-ups of small samples, the risk of intra- and intergroup differences in general life events can affect the results more than they do in larger samples. On the other hand, the consistent results of nearly all measured variables in the treated patients in the present study, although small samples, strengthens the probability of having a true effect from the treatment. The results for the treated patients also resemble the results of the only published study with the same treatment methodology (107).

Another limitation is the data collection with an interview about events in the past. Such retrospective assessment of symptoms has been questioned in patients with WAD (139); therefore, the results should be interpreted carefully. However, the consistency of the answers from many individuals in Paper II about the debut of symptoms and the very similar answers from both patients with WAD and patients in the comparison group in Paper IV about perceived pain reduction, strengthens the credibility of the results. Also, a cross-sectional design has the limitation of only permitting a statistical prediction, not an actual causal one. The strength of a cross-sectional design is permitting research to be done with few resources. Only a small fraction of patients who suffer whiplash injury (less than 10%) develop chronic WAD grade 3 (3), and a prospective study gathering the same information as in e.g. Paper II would require much more time and funding compared with a study with a cross-sectional design.
6. Conclusions

This thesis on temporomandibular disorders (TMD) in patients with chronic whiplash-associated disorders (WAD) grades 2 and 3 concludes that

- jaw pain is the most common symptom of TMD, present in one out of two individuals,
- patients with chronic WAD grades 2 and 3 who are in need of TMD treatment predominately have a myogenous origin of TMD pain,
- the onset of jaw pain and most other symptoms of TMD seems commonly to be in conjunction with WAD turning into chronicity, approximately six months after the whiplash injury,
- stress/concentration and neck pain are the most common of factors provoking symptoms of TMD,
- a therapeutic jaw exercise program does not seem to affect symptoms or signs of TMD, and
- a stabilization appliance therapy aiming to provide stability for the mandible in the retruded position guided by the highest mandibular side during the time of day or night when the TMD pain is most often present, seems to have an extensive alleviating effect on both TMD pain and frontal headache.

Clinical implications

A functional examination of the masticatory muscles and the temporomandibular joints as well as assessment of perceived stress can be recommended as part of the standardized screening procedure for patients with chronic WAD grades 2 and 3. Patients with symptoms and signs of TMD could be recommended stabilization appliance therapy. Patients with symptoms of frontal headache alone should also be considered as candidates for stabilization appliance therapy.
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8. References


A doctoral dissertation from the Faculty of Medicine, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine.