CECILIA ABRAHAMSSON

Masticatory Function and Temporomandibular Disorders in Patients with Dentofacial Deformities

Studies before and after orthodontic and orthognathic treatment
Masticatory Function and Temporomandibular Disorders in Patients with Dentofacial Deformities
CECILIA ABRAHAMSSON

MASTICATORY FUNCTION AND TEMPOROMANDIBULAR DISORDERS IN PATIENTS WITH DENTOFACIAL DEFORMITIES

Studies before and after orthodontic and orthognathic treatment

Malmö högskola, 2013
Faculty of Odontology
Department of Orthodontics
Department of Orofacial Pain and Jaw Function
Publikationen finns även elektroniskt,
se www.mah.se/muep
INNEHÅLL

PREFACE .......................................................................................................... 9

ABSTRACT ...................................................................................................... 10
  Key conclusions and clinical implications: ........................................... 12

POPULÄRVETENSKAPLIG SAMMANFATTNING .................................. 13
  Klinisk betydelse: ..................................................................................... 15

ABBREVIATIONS AND DEFINITIONS .......................................................... 16

INTRODUCTION ................................................................................................. 18
  Dentofacial deformities ........................................................................... 18
    Definition ................................................................................................. 18
    Prevalence ............................................................................................... 19
    Aetiology ................................................................................................ 19
    Treatment strategies ................................................................................ 20
  Temporomandibular disorders ................................................................ 21
    Definition ................................................................................................. 21
    Prevalence ............................................................................................... 22
    Aetiology ................................................................................................ 23
    Research Diagnostic Criteria for TMD (RDC/TMD) ............................... 24
  Malocclusion and TMD ............................................................................. 25
  Orthognathic treatment and TMD .............................................................. 25
  Dentofacial deformities and mastication .................................................. 26

SIGNIFICANCE ................................................................................................. 28

AIMS .................................................................................................................. 29
  Paper I ......................................................................................................... 29
  Paper II ....................................................................................................... 29
<table>
<thead>
<tr>
<th>Paper III</th>
<th>29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper IV</td>
<td>29</td>
</tr>
<tr>
<td><strong>HYPOTHESES</strong></td>
<td>30</td>
</tr>
<tr>
<td>Paper I</td>
<td>30</td>
</tr>
<tr>
<td>Paper II</td>
<td>30</td>
</tr>
<tr>
<td>Paper III</td>
<td>30</td>
</tr>
<tr>
<td>Paper IV</td>
<td>30</td>
</tr>
<tr>
<td><strong>MATERIALS AND METHODS</strong></td>
<td>31</td>
</tr>
<tr>
<td><strong>SUBJECTS</strong></td>
<td>31</td>
</tr>
<tr>
<td>Ethical considerations</td>
<td>32</td>
</tr>
<tr>
<td><strong>METHODS</strong></td>
<td>33</td>
</tr>
<tr>
<td>Paper I</td>
<td>33</td>
</tr>
<tr>
<td>Paper II-IV</td>
<td>36</td>
</tr>
<tr>
<td>Paper III-IV</td>
<td>38</td>
</tr>
<tr>
<td>Paper IV</td>
<td>39</td>
</tr>
<tr>
<td>Statistical analyses</td>
<td>40</td>
</tr>
<tr>
<td><strong>RESULTS</strong></td>
<td>43</td>
</tr>
<tr>
<td>Systematic review – Paper I</td>
<td>43</td>
</tr>
<tr>
<td>Dentofacial deformities and frequency of TMD</td>
<td>43</td>
</tr>
<tr>
<td>The effect of orthognathic surgery on TMD</td>
<td>43</td>
</tr>
<tr>
<td>Quality analysis</td>
<td>44</td>
</tr>
<tr>
<td>New literature search</td>
<td>44</td>
</tr>
<tr>
<td>Paper II</td>
<td>47</td>
</tr>
<tr>
<td>Anamnestic findings</td>
<td>47</td>
</tr>
<tr>
<td>TMD diagnoses</td>
<td>47</td>
</tr>
<tr>
<td>Paper III</td>
<td>48</td>
</tr>
<tr>
<td>TMD diagnoses</td>
<td>48</td>
</tr>
<tr>
<td>TMD diagnoses in relation to different kinds of dentofacial deformities</td>
<td>49</td>
</tr>
<tr>
<td>Symptoms of TMD</td>
<td>50</td>
</tr>
<tr>
<td>Mandibular movement capacity</td>
<td>51</td>
</tr>
<tr>
<td>Occlusal interferences</td>
<td>52</td>
</tr>
<tr>
<td>Patients’ satisfaction with treatment</td>
<td>52</td>
</tr>
<tr>
<td>Level of anxiety</td>
<td>52</td>
</tr>
<tr>
<td>Paper IV</td>
<td>52</td>
</tr>
<tr>
<td>Self estimated masticatory ability</td>
<td>52</td>
</tr>
<tr>
<td>Factors influencing the self estimated masticatory ability</td>
<td>52</td>
</tr>
</tbody>
</table>
To Jonas, Klara, Alva and Henrik
This thesis is based on the following papers, which are referred to in the text by their Roman numerals.


The papers are reprinted with kind permission from the copyright holders.
ABSTRACT

About 30% of individuals in the Swedish population will at some stage during life have treatment with orthodontic appliances. In more severe cases, when orthodontic treatment is not considered sufficient enough to correct the malocclusion, the orthodontic treatment is combined with orthognathic surgery. For these cases, a satisfying jaw relation is achieved by surgically moving the maxilla and/or the mandible into a pre-planned position.

Patients due to be treated with orthognathic surgery often suffer from an impaired masticatory function, symptoms from the masticatory muscles or temporomandibular joints (temporomandibular disorders), headaches as well as dissatisfaction with their facial aesthetics.

Since orthognathic treatment is expensive, in many cases arduous to the patient and not without complications, it is important to assess the treatment outcome and if this is satisfying for the patients. Previous studies that have examined the outcome after orthognathic treatment have had diverging study designs and have come to different conclusions with regard to both temporomandibular disorders and masticatory function.

The overall aim of this thesis was to assess and compare the frequencies of temporomandibular disorders and the masticatory function in patients with dentofacial deformities before and after orthognathic treatment.

The thesis is based on the following studies:

**Paper I** is a systematic literature review aiming to, in an evidence-based approach, answer the question whether orthognathic treat-
ment affects the prevalence of signs and symptoms of temporomandibular disorders. The review encompasses the period from January 1966 to April 2006 and was further extended to May 2013 in the frame story of this thesis.

Conclusions in Paper I and the complementary survey
- There is insufficient scientific evidence for a decrease of subdiagnoses of temporomandibular disorders after orthognathic treatment.
- There is limited scientific evidence for a reduction of masticatory muscle pain on palpation after orthognathic treatment.
- There is insufficient scientific evidence for an effect on temporomandibular joint pain on palpation and temporomandibular joint sounds from orthognathic surgery.
- Further controlled, well-designed studies assessing temporomandibular disorders before and after orthognathic treatment are needed to consolidate strong evidence considering treatment outcomes.

Papers II and III are studies comparing frequencies of temporomandibular disorders in patients with dentofacial deformities with a control group. The patients were referred for a combined orthodontic and orthognathic treatment to correct their malocclusion. The control group comprised individuals with normal occlusion or minor malocclusion traits not in need of orthodontic treatment. In Paper III, temporomandibular disorders were longitudinally analysed by assessing and comparing frequencies before and after orthognathic treatment. All individuals in the studies were diagnosed according to the research diagnostic criteria for temporomandibular disorders.

Conclusions in Papers II and III
- Patients due to be treated with orthognathic surgery had more signs and symptoms of temporomandibular disorders and a higher frequency of diagnosed temporomandibular disorders compared with the age- and gender matched control group.
- Patients with dentofacial deformities, corrected by orthodontic treatment in conjunction with orthognathic surgery, had a positive treatment outcome in respect of myofascial pain and arthralgia.
After treatment the frequency of temporomandibular disorders in the treatment group was low and at an equivalent level of that in the control group.

**Paper IV** evaluates the self-estimated masticatory ability and the masticatory performance before and after orthognathic treatment in the same individuals as in Paper II and III.

**Conclusions in Paper IV**
- Masticatory ability and performance increased after orthognathic treatment.
- The number of occlusal contacts and severity of overall symptoms of TMD influenced both the masticatory ability and performance.
- Open bite had a negative effect on masticatory performance.

**Key conclusions and clinical implications:**
Patients with dentofacial deformities diagnosed with temporomandibular disorders do in most cases benefit from orthognathic treatment. In addition, masticatory ability and performance, which is impaired in patients with dentofacial deformities, improve after treatment. Thus, patients with dentofacial deformities that are to be treated with orthodontics in combination with orthognathic surgery can be recommended the treatment in order to relieve symptoms of TMD and impaired mastication.
Ca 30 % av Sveriges befolkning genomgår någon gång i livet behandling med tandreglering. I de fall där bettavvikelsen är mer omfattande är enbart tandreglering inte tillräckligt för att uppnå ett bra bett. Istället kombinerar man tandregleringen med en kirurgisk förflyttning av käkarna s.k. ortognat kirurgi. Dessa patienter besväras ofta, före behandling, av smärta och funktionsstörningar i käkar och tuggmuskler och är dessutom ofta missnöjda med sitt utseende. Då denna behandling är omfattande, kostsam och inte helt utan komplikationer är det av stort intresse att undersöka utfallet av behandlingen och om denna motsvarar förväntningarna hos patienterna.

Tidigare studier som har utvärderat utfallet av tandreglering i kombination med ortognat kirurgi har kommit fram till motsägelsefulla slutsatser vad gäller hur behandlingen har påverkat förekomsten av smärta och funktionsstörningar i käkar och tuggmuskulatur.

Det övergripande syftet med denna avhandling är att i en serie studier, före och efter ortognat kirurgi, utvärdera och jämföra förekomsten av smärta och käkfunktionsstörningar hos patienter med stora bettavvikelser.

Avhandlingen är baserad på följande studier:
Delarbete 1 är en systematisk litteraturöversikt med följande frågeställning:

Påverkar ortognat kirurgi förekomsten av smärta och funktionsstörningar i käkleder och tuggmuskulatur?

**Slutsatser i delarbete I**

- Det finns ett otillräckligt vetenskapligt underlag för om förekomsten av diagnostiserad smärta och funktionsstörning i käkleder och tuggmuskler minskar efter ortognat kirurgi.
- Det vetenskapliga underlaget är begränsat när det gäller en minskning av palpationsömhet i tuggmuskler efter ortognat kirurgi.
- Det finns ett otillräckligt vetenskapligt underlag för om förekomsten av käkledsljud påverkas av ortognat kirurgi.
- Det behövs ytterligare studier som är av hög eller medelhög kvalitet för att på ett evidensbaserat sätt kunna styrka behandlingsutfallet av ortognat kirurgi när det gäller smärta och funktionsstörningar i käkleder och tuggmuskler.

**Delarbetena II och III** är kontrollerade studier som undersöker förekomsten av smärta och funktionsstörningar i käkleder och tuggmuskler hos patienter med stora bettavvikelser, i jämförelse med personer med eller utan små bettavvikelser (ej i behov av tandrengöring). Patienterna var remitterade för behandling med ortognat kirurgi. I delarbete III, som är en longitudinell uppfölimingsstudie, analyseras hur förekomsten av smärta och funktionsstörningar i käkleder och tuggmuskler påverkas av behandlingen.

**Slutsatser i delarbete II och III**

- Patienter som ska behandlas med ortognat kirurgi har mer smärta och funktionsstörningar i käkleder och tuggmuskler jämfört med kontrollgruppen.
- Patienter som genomgått ortognat kirurgi har ett positivt behandlingsutfall avseende smärta från käkleder och tuggmuskler.
- Efter behandling är förekomsten av smärta och funktionsstörningar i käkleder och tuggmuskler låg och i nivå med den i kontrollgruppen.
Delarbete IV utvärderar den självupplevda tuggförmågan och den testade tuggprestationen före och efter ortognat kirurgi hos samma individer som i studie II och III.

**Slutsatser i delarbete IV**

- Patienter med stora bettavvikelser har innan ortognat kirurgi en sämre självupplevd tuggförmåga och testad tuggprestation jämfört med kontrollgruppen.
- Efter behandling förbättras både den självupplevda tuggförmågan och tuggprestationen.

**Klinisk betydelse:**

Patienter som har stora bettavvikelser och dessutom smärta och funktionsstörningar i käkleder och tuggmuskler har oftast ett positivt behandlingsutfall efter ortognat kirurgi. Dessutom förbättras den självupplevda tuggförmågan och den testade tuggprestationen efter behandlingen. Patienter med stora bettavvikelser som ska behandlas med tandreglering i kombination med ortognat kirurgi kan därför rekommenderas behandlingen för möjlighet till minskade besvär från tuggmuskler och käkleder samt förbättrad tuggförmåga.
ABBREVIATIONS AND DEFINITIONS

ANB The angle between point A in the maxilla and point B in the mandible in relation to nasion - describing the sagittal relation between the jaws

BSSO Bilateral Sagittal Split Osteotomy

CI Confidence Interval

DC/TMD Diagnostic Criteria for TMD

EMG Electromyography

IVRO Intraoral Vertical Ramus Osteotomy

ICP Intercuspation position

RCP Retruded contact position

Masticatory ability Self evaluated masticatory function

Masticatory performance Tested masticatory function

ML Mandibular plane (extending from gnathion to gonion)

ML/NSL The angle between ML and NSL

MPI Masticatory Performance Index

MeSH Medical Subject Heading

NIH National Institutes of Health

NSL Nasion-Sella line (extending from Nasion to Sella)

Orthognathic Treatment Orthodontic treatment in conjunction with orthognathic surgery
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>Percentiles</td>
</tr>
<tr>
<td>RDC/TMD</td>
<td>Research Diagnostic Criteria for TMD</td>
</tr>
<tr>
<td>RCT</td>
<td>Randomized Controlled Trial</td>
</tr>
<tr>
<td>SBU</td>
<td>The Swedish Council on Health Technology Assessment</td>
</tr>
<tr>
<td>TMD</td>
<td>Temporomandibular Disorders</td>
</tr>
<tr>
<td>TMJ</td>
<td>Temporomandibular Joint</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual Analogue Scale</td>
</tr>
</tbody>
</table>
INTRODUCTION

Dentofacial deformities
Definition
Malocclusion has been defined as a deviation in intramaxillary and/or intermaxillary relations of teeth that presents a hazard to the individual’s well being. (1)

More severe forms of malocclusion have been termed dentofacial deformities (Figure 1). The suggested definition of dentofacial deformities is a malformation of the dentofacial complex with resulting disabling disharmony in size and/or form (1) or as clearly described in PubMed (2); An abnormality of the jaws or teeth affecting the contour of the face.

Figure 1. Different kinds of dentofacial deformities a) Open bite b) Deep bite c) Class II d) Class III
Prevalence

Deviations from a normal occlusion are common and it has been estimated that about 74 % of Swedish schoolchildren have some form of malocclusion. (3)

The most prevalent malocclusions, according to Thilander and Myrberg 1974(3), are:
- Postnormal occlusion (14 percent)
- Prenormal occlusion (4 percent)
- Open bite (4 percent)
- Deep bite (8 percent)
- Cross-bite: uni- and bilateral (11 percent)
- Anterior Cross bite (11 percent)
- Overjet $\geq 6$ mm (8 percent)

These prevalence figures for malocclusions include the prevalence figures for dentofacial deformities. Assessing the prevalence of severe skeletal malocclusions requiring orthognathic surgery is difficult (4) since dentofacial deformities can merely be regarded as a more severe form of malocclusion. (4) It has been estimated that 5 % of all Class II, 33 % of Class III and 25 % of all open bites needs orthognathic treatment. (5)

Aetiology

Malocclusion and dental deformities are in most cases caused by moderate distortions from normal development. They are the result from a complex interaction among multiple factors and it is in most cases not possible to describe a specific factor. In a population it has been reported that, about one third has a normal occlusion, 60 % has a malocclusion with unknown cause and 5 % has a malocclusion with a known cause. (6)

Skeletal growth disturbances such as Pierre Robin sequence and hemifacial microsomia are known to cause mandibular deficiencies. (6) Another factor known to affect craniofacial growth is muscle dysfunction. Muscular dystrophy, one kind of muscle dysfunction, leads to a decrease in muscle tonus allowing the mandible to drop downward, resulting in an increased facial height and development of an open bite. (7)
Other more well-known and common causes of malocclusion are oral habits such as sucking on fingers or pacifiers. (8)

Genetics has a strong influence on facial appearance and certain types of malocclusion like a Class III malocclusion runs in families e.g. the Habsburg jaw. (6) The relative influence of environment and heritability in the development of malocclusions with both skeletal and dental components is unclear. (6) However, it has been suggested that the heritability is high for craniofacial characteristics but low for dental characteristics. (9) So, it is therefore likely that a hereditary component is present in the aetiology of dentofacial deformities.

**Treatment strategies**

In Sweden, the reported need for orthodontic treatment in individuals between 8 and 20 years of age varies between 24 and 46 %. (10-12) In cases, when there is a good skeletal jaw relationship, the malocclusion can be corrected by orthodontic treatment using orthodontic appliances. In more severe cases, when a skeletal jaw discrepancy is involved, there are three treatment possibilities; a) growth modification, i.e. dentofacial orthopaedics that is applicable on growing individuals; b) camouflage treatment (orthodontic positioning of the teeth to compensate for the jaw discrepancy), not always resulting in an acceptable dental occlusion or satisfying facial aesthetics; c) orthodontic treatment in conjunction with orthognathic surgery in order to reposition the jaws, or the dentoalveolar segments, or both.(4)

Orthognathic surgery can be done either in the maxilla or in the mandible separately, or as bimaxillary surgery involving both jaws. Maxillary osteotomies are primarily performed as a LeFort I osteotomy, which allows the maxilla to be moved in both vertical and sagittal directions (Figure 2).

Bilateral sagittal split osteotomy is used for mandibular advancement in Class II cases or for setback in both Class II and Class III cases. The vertical ramus osteotomy is an alternative to sagittal split osteotomy when treating Class III deformities. A lower incidence of neural damage and fewer complaints of TMD are mentioned as some of the advantages with the vertical ramus osteotomy.(4, 13, 14)
The indications for treatment of dentofacial deformities by orthognathic surgery are mainly facial aesthetics, functional problems and temporomandibular disorders (TMD). The importance of the various individual indications varies between genders and between different parts of the world due to cultural differences and economical aspects. (15, 16) During 2012, 97 patients underwent orthognathic surgery in Lund University hospital. Unfortunately, there is a lack of data regarding the total number of orthognathic treatments performed per year in Sweden, which makes it impossible to validate the impact in oral health care.

![Figure 2. A patient, diagnosed with an open bite, before and after orthognathic treatment.](image)

**Temporomandibular disorders**

**Definition**

TMD is a collective term describing musculoskeletal disorders arising from the masticatory structures (Figure 3), (17) and has been identified as “a major cause of nondental pain in the orofacial region and are a sub-classification of musculoskeletal disorders”. (17)

The most important feature of TMD is chronic musculoskeletal pain. Palpation tenderness of the muscles of mastication and the temporomandibular joints is also frequently reported. Impaired range of motion (leading to difficulties when eating, e.g. apples or hamburgers) and various joint sounds elicited by mandibular excursions are associated with certain types of TMD. (19) Patients with TMD often also describe a feeling of fatigue of the jaws and symptoms of pain and dysfunction affecting ears, eyes and/or throat and headaches. (20)
**Prevalence**

The prevalence of TMD has been found to be high, albeit of a mild character, already in childhood. (21, 22) It then seems to increase, in a fluctuating pattern, from adolescence (23) to middle age and then to decrease in old age. (24) TMD is therefore primarily seen as a condition of young and middle-aged adults. (25)

TMD pain is common, occurring in about 10-14% of the population over the age of 18 (25, 26) and is about twice as common in women as in men. (25)

TMJ clicking is even more prevalent and is found in 20-30% of the adult population. (17, 25, 27, 28) There is evidence that TMJ sounds alone are frequent and a natural phenomenon in the general population and that they fluctuate longitudinally, but they are also recognized as a sub diagnosis of TMD. (19) Disc displacement with reduction diagnosed according to Research Diagnostic Criteria for TMD (RDC/TMD) (19) is present in 12-18% of the adult population. (26)

*Figure 3. Schematic picture of the masticatory structures. (18)*
In a meta-analysis by Al-Jundi et al (29) it was estimated that the treatment need for TMD in adults, is in the region of 16 %, which indicates that TMD can be considered as a major health problem.

**Aetiology**

There is uncertainty as to the actual underlying aetiology of TMD. (25) Even if there are similarities with musculoskeletal disorders and pain disorders in general, the stomatognathic system is also unique with the upper and lower jaw, and occluding teeth, between bilaterally functioning temporomandibular joints, which has led to a need for a multifactorial etiologic approach. (30)

Contributing factors are often discussed in respect of the aetiology of TMD. These factors are divided as predisposing, initiating and perpetuating. Predisposing factors can increase the risk of developing a condition, initiating factors can cause the onset of the condition and perpetuating factors contribute to the maintenance or persistency of the condition. (30)

**Psychosocial and biomedical factors**

Every time a pain signal reaches the central nervous system the information in the impulse is processed and influenced by different areas of the brain, for example the limbic system, thalamus and cortex. (30) Beside age and gender, psychosocial factors like stress, depression and the presence of multiple somatic symptoms are therefore seen as possible risk factors in the development of TMD. (25, 31) Actually, psychological disorders have been shown to be a major contributing factor in chronic TMD. (30)

It has also been argued that biomechanical factors such as functional impairments of the TMJ’s, muscles and occlusion are involved in the aetiology of TMD. (20) Also behavioural factors such as tooth clenching or grinding have been discussed, (23) together with the possible influence from occlusion, (31-33) external trauma including whiplash injury (34) and micro-trauma due to overloading of the masticatory system. (30)

The various factors involved have led to a multidimensional perspective regarding TMD with an appreciation that a combination of physical, psychological and social factors can contribute to the overall presentation of this disorder. According to NIH Consensus
Conference (1997) it is hypothesized that the two cardinal features of TMD are pain and dysfunction, incorporating individual variability (Figure 4).

**Figure 4. Aetiological factors in TMD. The cardinal features of temporomandibular pain and dysfunction.** (20)

**Dysfunctional central pain modulation**
It has been emphasized that the development of chronic musculoskeletal pain in the case of the TMD diagnoses myofascial pain and arthralgia starts with peripheral trigeminal pain and inflammation, which has been proceeded by long-standing, repetitive muscular load. (35) This pain and inflammation in turn leads to a peripheral nociceptive hyper-excitability in the dorsal horn neurons in the spinal cord, i.e. primary hyperalgesia. This condition is normally reversible but in some individuals a central sensitization may develop due to functional (neurochemical) and structural (neuroanatomical) changes in the dorsal horn neurons and in other parts of the central nervous system as a consequence of the repeated and/or continuing peripheral noxious output. The condition can then result in a long-standing and refractory pain disorder, i.e. secondary hyperalgesia. (35) The structural changes can include development of dendrites and activation of latent synapses, which may cause spread, and referral of pain often seen in patients with TMD. (35)

**Research Diagnostic Criteria for TMD (RDC/TMD)**
The RDC/TMD were introduced in 1992 and was primarily developed for research purposes. There was a need for standardized research methods to enable comparisons of findings between different clinical investigators. The RDC/TMD has, since then, been
used in a large number of studies and it is now a well-accepted diagnostic tool. The diagnostic system in RDC/TMD is non-hierarchical and allows for the possibility of multiple diagnoses for a given subject. (19)

**Malocclusion and TMD**

An association with TMD and certain malocclusions has been reported. In a case-control study Henrikson et al. (33) found more TMD among girls with a Class II malocclusion compared with controls with a normal occlusion. (33) This finding was confirmed in a study by Miller et al. (36) who concluded that severe retrognathia was a risk factor for TMJ pain disorders in women.

Other malocclusions that have been suggested to be of importance in the development of TMD in some individuals, are unilateral cross-bite (32, 37) and crowding (38). There is however a general consensus that occlusal variables alone are not considered etiologic factors of TMD and that their role should not be overstated. (20, 30, 39, 40) In a systematic review by The Swedish Council on Health Technology Assessment (SBU) it was concluded that there is insufficient scientific evidence for an association between specific malocclusions and TMD. (12, 41)

**Orthognathic treatment and TMD**

Even though the occlusion does not seem to have a major role in the TMD aetiology, TMD are one of the main complaints among patients that are referred for orthognathic treatment. (15, 42) Can it be that individuals with dentofacial deformities are more susceptible to TMD than the population in general?

The frequency of TMD in patients with dentofacial deformities referred for orthognathic surgery, have been reported to vary between 43 and 73%. (13, 43-45) These existing studies are not population based and therefore, sound epidemiologic data on the prevalence of TMD in individuals with dentofacial deformities is limited.

It has been agreed that orthodontic treatment does not seem to have a negative impact on the frequency of TMD. (12, 33, 38, 46)

Several studies have investigated whether orthodontic treatment in combination with orthognathic surgery has an influence on TMD.
Some of these studies indicated that orthognathic treatment does not affect frequencies of TMD at all. (45, 47, 48) On the other hand, Pahkala et al (49) concluded that patients diagnosed with TMD of myogenous origin benefited more from treatment compared with those diagnosed with TMD of arthrogenous origin. This conclusion was based on the findings that TMJ clicking decreased whereas crepitations were found to increase. These findings were confirmed by Rodrigues-Garcia et al (50) who in Class II patients found a decrease in TMD pain and TMJ clicking, but an increase in TMJ crepitus after treatment. The finding of decreased TMD pain after treatment, especially when of myogenous origin, has been confirmed in other studies. (43, 44) There are also reports indicating an overall decrease in TMD after treatment. (13, 42, 51)

Taken together, the cited articles above show a broad spectrum of different study designs and results, reflecting the divergence of the available literature. Therefore no consensus can be reached at this point in time with regard to treatment outcomes of TMD after combined orthodontic and orthognathic treatment.

**Dentofacial deformities and mastication**

Mastication is one of the most important functions of the digestion process. During mastication the food particles are reduced in size, thereby increasing the surface area and facilitating enzymatic processing. Saliva is produced to moisten and lubricate the food for swallowing.

Mastication can be assessed as **masticatory ability** - an individual’s self-estimated masticatory capacity or as **masticatory performance** – the tested defragmentation of food after a certain number of chewing strokes.

The number of chewing cycles before swallowing depends on the volume (52, 53) and the characteristics of the food, such as consistency and the percentage content of water and fat. (54, 55) Swallowing thresholds for hard food products, like carrots, are further affected by the masticatory performance and maximum bite force. (54)

The number and size of the occlusal contacts have been proposed as one determinant of self estimated masticatory ability (56) and masticatory performance since the contacts between occluding
pair of teeth determine the area available for shearing and grinding the food. (57) Compared to individuals with a closer to “ideal” bite, individuals with malocclusions have fewer occlusal contacts. Malocclusions have also been found to negatively affect an individual’s masticatory performance and self estimated masticatory ability. (57, 58)

Masticatory performance has also been reported to be affected by the maximum bite force(54) Individuals with an open bite or a Class III occlusion have demonstrated less maximum isometric bite force compared with controls. (53, 59) One explanation for this, at least in patients with open bite, can be that they exhibit thinner masticatory muscles. (53)

It has also been shown that there are gender differences in both thickness and activities of the masticatory muscles, with men having thicker masseter muscles (60) and higher EMG activity (61) compared with women.

Masticatory ability, an individual’s own assessment of their mastication, is an important factor in oral-health related quality of life and general health. It may therefore possibly reflect the impact of mastication on food choice and enjoyment of meals.(56)
Orthognathic surgery and its effect on TMD and mastication have been examined in several studies. However, most of the existing studies were designed as case-series and diverging in both study-design and results. This means that based on previous literature it is difficult to evaluate and comprehend the treatment effects of orthognathic surgery. Therefore, a systematic literature review in an evidence-based manner could increase the understanding in this field of research.

The consequences for patients with impaired masticatory function and pain from the masticatory muscles or joints often include difficulties in speaking, chewing and swallowing. These types of problems can probably affect the individual in daily activities such as in the choice of food and even in the everyday social intercourse.

The indications for orthognathic treatment typically reflect the patient complaints. Besides symptoms of TMD and dissatisfaction with facial aesthetics, treatment is therefore primarily performed due to the need to correct functional problems like mastication. The available literature unfortunately does not bring clarity, neither to whether patients with TMD benefit from orthognathic treatment, nor if their mastication is improved. Since orthognathic treatment is arduous for the patient, not without complications, time consuming and expensive for the society and sometimes also for the individual, it is of outmost importance to evaluate if the treatment meets the expectations from the patients, the profession and the society.

This thesis is based on a series of studies, unique in the way that they in a prospective longitudinal design assess TMD and masticatory function, in patients with dentofacial deformities, before and after orthognathic treatment in comparison with a control group.
AIMS

Paper I
- To accomplish a systematic review of the present literature in order to evaluate whether orthognathic surgery affects the prevalence of signs and symptoms of TMD.

Paper II
- To evaluate whether TMD are more common in individuals referred for orthognathic surgery than in a control group.

Paper III
- To investigate whether correction of dentofacial deformities by orthognathic treatment alters the frequency of TMD.
- To compare and monitor the frequency of TMD in an untreated normal group over the same period of time.

Paper IV
- To evaluate the self estimated masticatory ability and masticatory performance in patients with dentofacial deformities before and after orthognathic treatment; in comparison to an age- and gender matched control group.
- To investigate possible factors that can have an impact on self estimated masticatory ability and masticatory performance.
HYPOTHESES

**Paper I**
- The scientific evidence based on currently available literature is insufficient to clarify if orthognathic treatment can affect the frequency of TMD.

**Paper II**
- Neither frequency of signs and symptoms of TMD or diagnosed TMD according to Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) would differ between the patient and control group.

**Paper III**
- Patients with dentofacial deformities benefit from treatment, in respect of TMD.
- Post-treatment, the frequency of TMD is similar to that in the control group.

**Paper IV**
- Patients with dentofacial deformities have impaired self-estimated masticatory ability and masticatory performance compared to a control group.
- For patients with dentofacial deformities the self estimated masticatory ability and masticatory performance is improved by orthognathic treatment.
MATERIALS AND METHODS

SUBJECTS
Paper II-IV
The treatment group comprised 121 consecutive patients (51 males and 70 females) with dentofacial deformities, referred to the Department of Oral Maxillofacial Surgery, Malmö University Hospital, Sweden for orthognathic treatment. The mean age at the start of the trial was 22.5±7.4 years. All patients with Class II, Class III, open bite or deep bite diagnoses were included and recruited during two periods, between 1992–1995 and 2000–2002. Patients with such severe dentofacial deformities are entitled to subsidized treatment under the Swedish National Health Service. The exclusion criteria were craniofacial syndromes, systemic arthritic and muscular diseases, and a dentition of fewer than 24 teeth. There were 98 patients that completed the follow-up examination (Paper III and IV, Figure 5); 38 males and 60 females, mean age 22.4 ± 7.5 years.

The control group comprised 56 subjects, 23 males and 33 females, mean age 23.4 ±7.4 years, age and gender matched with the subjects in the treatment group. They were recruited from general dental patients at the Faculty of Odontology, Malmö University, Sweden, and the Public Dental Health Clinic in Oxie, County Skane, Sweden. The inclusion criteria for the controls were normal occlusion, or minor malocclusions for which neither orthodontic treatment nor orthognathic surgery was indicated.

The same exclusion criteria applied to the control group as to the treatment group. Three years after the initial examination a follow-up questionnaire was sent to the individuals in the control group. They were contacted by telephone 2 to 3 weeks later, and asked to participate in the follow-up examination. Thirty-eight
of the 56 individuals (68 %) in the control group underwent the clinical follow-up examination in Paper III (Figure 5).

Analysis of those who withdrew from the treatment and control groups, (n = 23, 19 %, and n = 18, 32 %, respectively) showed no significant differences compared with the final samples with respect to age, gender, self-rated level of anxiety, pain in the jaws and related muscles, diagnosed TMD, self-estimated masticatory ability or performance reported at baseline. Thus, the participants who completed the study were considered to be representative of the initial study sample.

Ethical considerations
The study was approved by the Ethics Committee of Lund University, Sweden (Ref. No. LU-241-01), which follows the guidelines of the declaration of Helsinki.

Figure 5. Flow chart showing the participants in Paper III.
Search strategy
To identify all studies that examined orthognathic surgery and its effect on TMD in patients with severe malocclusions, a literature survey was performed using the PubMed (www.ncbi.nlm.nih.gov) and the Cochrane Library electronic databases (www.cochrane.org). The search covered the period from January 1966 to April 2006.

The terms used in the search were malocclusion (MeSH-term), retrognathia (MeSH-term), prognathia, open bite (MeSH term), and deep bite in various combinations with craniomandibular disorders (MeSH-term), temporomandibular disorders, temporomandibular dysfunction, temporomandibular joint dysfunction, temporomandibular joint pain, and orthognathic surgery (MeSH-term), surgical-orthodontic treatment, and surgery (MeSH-term).

Selection criteria
Controlled human studies published as full-length articles, comparing symptoms and signs of TMD before and after orthognathic surgery in patients with malocclusion, were included. Articles concerning treatment of syndromes, e.g. cleft lip and palate were not considered. Three reviewers independently assessed all the article abstracts that appeared to meet the inclusion criteria. The article abstracts were collected irrespectively of the language in which they were published, after that the retrieved articles were read in their entirety and independently by the three reviewers. The reference lists of the retrieved articles were also hand-searched for relevant studies not found in the database search. Any inter-examiner conflicts were resolved by discussion to reach a consensus.

Data collection and analysis
Data were extracted on the following items: author, year of publication, study design, sample size, gender and age, surgical treatment methods, follow-up time, methods to determine TMD, outcomes, and authors’ conclusions. In addition, to document the methodological soundness of each article, a quality evaluation modified by the methods described by Antczak et al (62) and Jadad et al (63) was performed with respect to pre-established characteristics. The following variables were evaluated:
1. Study design; RCT = 3 points, prospective study = 2 points, retrospective study = 1 point
2. Adequate sample size = 1 point,
3. Adequate selection description = 1 point
4. Valid measurement methods = 1 point
5. Use of method error analysis = 1 point
6. Adequate statistics provided = 1 point
7. Consequences of confounders discussed in analysis = 1 point

By summarizing the scores for these seven variables, a study could achieve a quality score ranging from zero to a maximum of 9. A study’s quality was then categorized as low (0 to 4 points), medium (5 to 7 points), or high (8 or 9 points). To increase the objectivity of the analysis, four evaluators independently assessed the data extraction and quality scoring from each article. For each article, any inter-examiner disagreements were resolved by discussion to reach a consensus.

**Supplemental search**

Paper I was supplemented with a new literature search extending from April 2006 to May 2013 in the PubMed database and the Cochrane Collaboration Library for reviews and clinical trials. The same search terms as previously were used, and with the addition of the MeSH term “dentofacial deformities” in combination with the original terms. The same selection criteria, data collection and analysis as described in Paper I were used, the only exception being that only three evaluators assessed the quality of the retrieved articles.

The grading and the final level evidence, based on the evaluated studies, were estimated according to the SBU (Tables 1 and 2). (38, 64-66)
Table 1. Criteria for grading of assessed studies.(66)

Grade A – High value of evidence
All criteria should be met:
• Randomized clinical study or a prospective study with a well-defined control group
• Defined diagnosis and endpoints
• Diagnostic reliability test and reproducibility tests described
• Blinded outcome assessment

Grade B – Moderate value of evidence
All criteria should be met:
• Prospective or retrospective study with defined controlled or reference group
• Defined diagnosis and endpoints
• Diagnostic reliability tests and reproducibility tests described

Grade C – Low value of evidence
One or more of the conditions below:
• Large attrition
• Unclear diagnosis and endpoints
• Poorly defined patient material

Table 2. Definitions of the evidence levels.(66)

<table>
<thead>
<tr>
<th>Level</th>
<th>Evidence</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strong</td>
<td>At least two studies assessed as grade A.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>One grade “A” study and at least two grade “B” studies.</td>
</tr>
<tr>
<td>3</td>
<td>Limited</td>
<td>At least two grade “B” studies.</td>
</tr>
<tr>
<td>4</td>
<td>Insufficient</td>
<td>Fewer that two grade “B” studies</td>
</tr>
</tbody>
</table>
Paper II-IV

**Questionnaire**

In the questionnaire, the individuals reported:

- Reasons for seeking treatment (impaired chewing capacity, symptoms from the masticatory muscles, TMJs, headaches, and aesthetic reasons)
- State of general health
- Use of painkillers for headaches and TMD (yes/no)
- Awareness of oral parafunctions as tooth grinding (yes/no), or tooth clenching (yes/no)
- Frequency of TMD pain, jaw fatigue, TMJ clicking, and headache (never/once or twice a month/once a week/once or twice a week/daily)
- Pain at rest (yes/no) and during mandibular movements (yes/no) and reported TMJ clicking (yes/no)
- Ability to masticate different kinds of food; meat (yes/no), carrots (yes/no), toffee (yes/no), French loaf (yes/no) or cold cuts of ham, cheese and cucumber (yes/no).

A visual analogue scale (VAS) (67) 0-100 mm, was used to register severity of overall symptoms of TMD (Paper II) with the endpoints none = 0 and severe = 100 and on a verbal scale as follows: 0 = no or minimal discomfort, 1 = slight discomfort, 2 = moderate discomfort, 3 = severe discomfort, 4 = very severe discomfort (Paper III, IV). The VAS was also used for registration of the individuals self-estimated ability to masticate food with the end points “good” = 0 mm and “bad” =100 mm and the level of anxiousness with the endpoints “calm” = 0 and “nervous/anxious” = 100.

The follow-up questionnaire in Paper III included questions about treatment satisfaction, including whether the pre treatment information had been adequate (yes/no), whether treatment met expectations (yes/no) and whether, post-treatment, the subjects had perceived any alterations in masticatory capacity, aesthetics and TMD symptoms (better, unchanged, worse).

**Clinical examination**

Before the orthognathic treatment was started, two calibrated specialists in stomatognathic physiology conducted the clinical
examination at the Department of Stomatognathic Physiology at Malmö University. The extraoral examination preceded the intraoral examination.

The examination included measurement of mandibular movements, pain during non-guided mandibular movements, registration of TMJ sounds (clicking and crepitation), and tenderness of the TMJs and related muscles. The clinical registrations were improved by calibrating the examination techniques of the two examiners before the start of the study. The calibration was performed by examining 8 patients, not included in the study, and was achieved after discussion. The 8 subjects were also examined regarding occlusal interferences with an observer error that was found to be acceptable. (33) The specialists conducting the examinations were not informed whether the subject belonged to the treatment or control group at the follow-up.

The functional occlusion was assessed by methods previously described and investigated for observer error. (68) Mediotrusion interferences within a lateral excursion of 3 mm, laterotrusion interferences, protrusion interferences, and the distance and the direction of the slide between retruded contact position (RCP) and the intercuspal contact position (ICP) were registered.

Sub-diagnoses of TMD
Diagnoses according to RDC/TMD (19) are divided into three groups (Paper II):

- Muscle disorders: (a) myofascial pain, (b) myofascial pain with limited opening
- Disc displacements: (a) disc displacement with reduction; (b) disc displacement without reduction, with limited opening; (c) disc displacement without reduction, without limited opening
- Arthralgia, arthritis, arthrosis: (a) arthralgia, (b) osteo-arthritis of the TMJ, (c) osteoarthrosis of the TMJ

In Paper III the criteria for diagnosis of disc displacement were modified:

Disc displacement was diagnosed if, upon opening and closing from maximum intercuspation, a click was noted audible or by palpation. Osteoarthritis was diagnosed as registered crepitations by palpation of the TMJ.
Sub-diagnoses of dentofacial deformities
Morphologic occlusion according to Björk et al (69) was registered by intraoral examination. For the patient group, further data were obtained from dental study casts, lateral cephalograms, and a cephalometric analysis. (70) An open bite was classified as an NSL/ML angle of ≥40° and a deep bite as an NSL/ML angle of ≤26°. A Class II skeletal relationship between the dental arches was classified as an ANB angle of ≥6° and a Class III skeletal relationship as an ANB angle of ≤0°. Consequently, the diagnoses in the treatment group were separated into sagittal and vertical discrepancies (Table 4).

Paper III-IV
In the treatment group, TMD and masticatory function was assessed by means of a questionnaire and a clinical examination before (baseline) and 18 months after surgery. The interval between the two examinations was approximately 3 years depending on the length of the orthodontic treatment. The questionnaire and the clinical examination were performed after treatment planning. The control group was similarly assessed, on two occasions, at an interval of at least 3 years.

Treatment methods
All subjects in the treatment group underwent pre- and postsurgical orthodontic treatment with fixed orthodontic appliances in both arches. Ten specialists carried out the orthodontic treatment; the duration varied between 18 and 24 months.

Four maxillofacial surgeons at the Department of Oral Maxillofacial Surgery, Malmö University Hospital, Sweden, performed the orthognathic surgery. Vertical deformities was corrected in the maxilla with a one piece Le Fort I osteotomy or a segmental maxillary osteotomy (Table 4). (71) Sagittal adjustments were made either by sagittal split osteotomy, to advance the mandible (72) or by intraoral vertical ramus osteotomy, to correct mandibular prognathism (Table 4). (71) When bimaxillary surgery was indicated, maxillary osteotomies were combined with either sagittal split or vertical ramus osteotomies (Table 4). Maxillo-mandibular fixation was used for 4 weeks after intraoral vertical ramus osteotomies. In all other cases, rigid intra jaw fixation was used.
**Paper IV**

*Self-estimated masticatory ability*

Assessed by a questionnaire, as described previously (p. 42).

**Masticatory performance test**

For assessment of the masticatory performance (73), the individuals were instructed to chew round tablets of silicon impression material (Optosil®, Bayer, Germany) with a standardized weight (Figure 6). The test involves chewing of 5 separate tablets for 20 strokes. The chewed sample was expectorated into a plastic cup. The mouth was then rinsed with water until all particles were removed from the mouth. The rinse water was also collected in the cup and then filtered. The chewed material from each of the tablets was fractionated in a system of sieves with coarse, medium and fine meshes (Figure 6). Essentially, the more efficient the mastication was, the greater the quantity of material that passed through the finest sieve. The quantity of material was estimated by weight.

A masticatory performance value, by proportion of weight, was calculated for each test portion, and the mean of the best four values out of five was used as the masticatory performance index (MPI). (73) The index ranges from 0 to 100 - the highest number corresponds to the highest performance value. Data of the MPI test was lost from 1 patient at baseline and another 6 patients at follow-up in the treatment group. In the control group the MPI test was only performed at baseline.

**Figure 6. Showing the Optosil® tablet and the sievesystem.**
Tooth contacts
The number of tooth contacts was recorded in habitual intercuspal position during maximal isometric biting force. The indication of contacts was registered in the maxilla by means of a thin double folded plastic-foil (GHM occlusion foil® 8 μm, Hanel –Ghm Dental, Germany). The markings by the foil were registered as follows: single dot = one contact; line = two contacts; region of several small markings = three contacts (Figure 7). The evaluation of the methodological error for measuring the number of occlusal contacts has been described earlier and was found to be low. (58)

Figure 7. Registration of tooth contacts. 1) Single dot – one contact, 2) Line – two contacts, 3) Region of several small markings – three contacts.

Statistical analyses
All statistical analyses were performed using the Statistical Package for the Social Scenes (SPSS) versions 13-20 for Windows (IBM). The criterion for significance (alpha) was set at .05. The tests were 2-tailed, which means that an effect in either direction was recognized. When necessary, statistical consultations were made with a statistician at the Department of statistics, Lund University, Sweden.
Sample size calculation (Paper II-IV)
With the proposed sample size of 35 in the treatment and control groups, the study had a power of 89.8% to yield a statistically significant result. This computation assumed that the difference in proportions was 0.30 (specifically, 0.05 versus 0.35) in the prevalence of TMD pain. This difference was selected as the smallest effect that would be important to detect, in that any smaller effect would not be of clinical or substantive significance.

Descriptives
Mean and standard deviations were calculated for all continuous, numerical variables (Paper II-IV) and medians and percentiles (Q) for continuous, ordinal variables (Paper II-IV).

Differences between groups
Pearson’s chi-square test with Yate’s correction for continuity was used when 2 x 2 cross tabulations were applicable. When the expected cell value was less than 5, Fisher’s exact test was used (Paper II-IV).

Mann-Whitney rank sum test was used to compute the difference between ranks and groups with ordinal data (Paper II-IV).

Two-sample t-statistics was used when comparing means of numerical variables (Paper II-IV).

Analysis of variances (ANOVA) was used when comparing means between sub groups of sagittal and vertical discrepancies (Paper IV).

Differences within groups (Paper III-IV)
McNemar exact test was used to analyse dichotomous data before and after treatment.

Wilcoxon signed ranks test was used to analyse ordinal data before and after treatment.

Paired t-test was used to compare the means of maximum mandibular opening capacity.
Multivariate analysis
Linear regression analysis, with the enter method, adjusted for age and group belonging, was used for multivariate analysis of masticatory ability and MPI (Paper IV).

Bivariate analysis

Bivariate correlation with Pearson correlation coefficient was performed on numerical variables (thesis).
RESULTS

Systematic review – Paper I
The search strategy resulted in 467 articles. After analysis according to the inclusion/exclusion criteria, three articles (43-45) were included for further analysis. All of the included studies were controlled, prospective and longitudinal.

An agreement of more than 90 % was found between the reviewers in assessing the data extraction and decisions of quality scores of the included articles.

Dentofacial deformities and frequency of TMD
When comparing signs and symptoms of TMD before treatment, none of the included studies (43-45) found any significant differences between patients and control groups or between different kinds of malocclusion.

The effect of orthognathic surgery on TMD
The reported findings after orthognathic treatment were contradictory. Two of the studies(43, 44) found a statistically significant decrease in muscle palpation tenderness after surgery, whereas in one study, (45) no such change was found. (Table 3) One study(43) also reported a significant decrease in TMJ palpation tenderness (Table 3). Consequently the authors’ conclusions for the studies also diverged with two of the studies(43, 44) declaring that both signs and symptoms related to TMD had improved significantly, whereas one study, (45) reported that TMD symptoms did not always show improvement after surgical correction, and for some patients, the symptoms even changed for the worse.
Quality analysis
According to the quality assessment of the included articles there were two studies (44, 45) of medium and one (43) of low quality. All of the studies used valid and well-known methods for measurements and provided adequate statistics. The general shortcomings were inadequate selection description, no method error analysis and no discussion of consequences of confounders. One study was also found to have an inadequately small control sample. (43) It is also notable that no study (43-45) reported a prior estimate of the sample size.

New literature search
The complementary literature search of studies published April 2006-May 2013 resulted in 234 articles. Only one study met the inclusion criteria. (74) The reasons for exclusion and number of excluded articles were:

- Studies not concerning the objectives of this review (analysis of surgery technique, treatment of arthritis and osteoarthritis, treatment of syndromes as cleft lip or palate treatment) 218
- Case reports, case series 10
- Review articles 5

Total 233

Treatment effects
The only included study in the new search was a prospective, longitudinal and controlled trial (Paper III in this thesis). (74) The findings revealed a decrease of both myofascial pain, arthralgia and disc displacements. The results also indicated an increase in osteoarthritis (Table 3). The conclusions from the study were that for patients with dentofacial deformities orthognathic surgery has a positive treatment outcome in respect of TMD pain. After treatment the frequency of TMD was lower and comparable to that of a control group. (74)
Quality Analysis
The research quality/methodological soundness for the included study was estimated as high. (74) Adequate sample size, in advance calculated by a power analysis, and selection description was provided. The study used a valid and well-known measurement method, method error analysis and adequate statistics. Confounders were discussed in the analysis. The only, but major, shortcoming was that the study design was not a RCT.

Evidence for differences in frequency of TMD before and after orthognathic treatment
Only one study used RDC/TMD as a diagnostic tool when assessing frequencies of TMD. (74) Therefore, according to the definitions of evidence level by SBU (61) there is insufficient evidence for an effect on diagnosed TMD from orthognathic treatment.

The majority of the included studies in the systematic review, instead assessed signs and symptoms of TMD. The result from Paper I and the complementary search revealed that there is limited evidence for a decrease in pain on palpation in the masticatory muscles after orthognathic treatment. (44, 74)

There was insufficient scientific evidence, partly due to contradictory results, (44, 45, 74) to support an effect on TMJ sounds and TMJ pain on palpation from orthognathic treatment.
Table 3. Results of the quality analysis and the treatment outcome of the studies included in Paper I and the new literature search.

<table>
<thead>
<tr>
<th>Study</th>
<th>Quality</th>
<th>Score</th>
<th>Number of patients</th>
<th>Type of dentofacial deformity</th>
<th>Follow-up after surgery</th>
<th>Subdiagnoses of TMD</th>
<th>Pain on palpation of the masticatory muscles and TMJs</th>
<th>TMJ sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onizawa et al, 1995</td>
<td>Moderate</td>
<td>5</td>
<td>30</td>
<td>Various</td>
<td>6 months</td>
<td>no</td>
<td>Unchanged</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Panula et al, 2000</td>
<td>Low</td>
<td>4</td>
<td>60</td>
<td>Various</td>
<td>29 months</td>
<td>no</td>
<td>Decrease in both muscle and joint pain on palpation</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Dervis et al, 2002</td>
<td>Moderate</td>
<td>5</td>
<td>50</td>
<td>Various</td>
<td>24 months</td>
<td>no</td>
<td>Decrease in muscle pain on palpation, joint pain on palpation unchanged</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Abrahamsson et al 2013</td>
<td>High</td>
<td>8</td>
<td>121</td>
<td>Various</td>
<td>18 months</td>
<td>yes (RDC/TMD) Decrease in myofascial pain, arthralgia and disc displacement</td>
<td>Decrease in both muscle and joint pain on palpation</td>
<td>Joint clicking decreased, crepitations increased</td>
</tr>
</tbody>
</table>
Paper II
Anamnestic findings
The self-rated level of anxiousness was similar in the treatment and control groups, with median VAS scores of 19.5 (Q1 = 7, Q3 = 47) and 19.0 (Q1 = 6, Q3 = 43), respectively. Furthermore, there were no differences between the groups with regard to reported weekly headaches or awareness of para-functional habits such as tooth clenching and tooth grinding. No subject in either of the two groups reported heart or joint disease. No significant differences were found between the groups regarding frequencies of allergies, stomach and dermatologic diseases.

The severity of the overall symptoms of TMD was rated higher on a verbal scale in the treatment group compared with the control group (P = .001).

The reasons for seeking treatment reported by the patients were (more than one answer was possible):

- impaired mastication (75 %)
- symptoms from masticatory muscles, TMJs, and headaches (72 %)
- aesthetic reasons (66 %)

TMD diagnoses
The treatment group had a significantly higher frequency of myofascial pain, disc displacement with reduction (DDR), and arthralgia compared with the control group (Figure 8). The frequency of myofascial pain with limited opening, osteoarthritis, and osteoarthritis was low, with no differences found between the two groups.

There were no significant differences in the frequency of diagnosed TMD between the different malocclusion traits, shown in Table 4.
Figure 8. Percentage distribution of TMD diagnoses according to RDC/TMD in the treatment group (n =121) and the control group (n = 56) before treatment.

Table 4. Distribution of different kinds of malocclusions and performed surgery in the treatment group.

<table>
<thead>
<tr>
<th>Dentofacial Deformities</th>
<th>Maxillary osteotomy</th>
<th>Bilateral Sagittal Split Osteotomy (BSSO)</th>
<th>Intraoral Vertical Ramus Osteotomy (IVRO)</th>
<th>LeFort I and BSSO</th>
<th>LeFort I and IVRO</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class II</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Class III</td>
<td>6</td>
<td>6</td>
<td>29</td>
<td>0</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td>Open bite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in combination with orthognathic jaws</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>in combination with Class II</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>in combination with Class III</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Deep bite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in combination with Class II</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>in combination with Class III</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Paper III
TMD diagnoses
After treatment, the frequencies of myofascial pain, disc displacement and arthralgia were significantly reduced in the treatment group, but at the same time, there was a significant increase in osteoarthritis (Figure 9). At baseline, significantly more patients in the treatment group had myofascial pain and arthralgia compared with the control group, whereas there was no difference post-treatment...
(Figure 10). For the treatment group the number of patients with at least one TMD pain diagnosis had decreased with 42 %.

The only TMD diagnosis, in the treatment group, with a significant gender difference was myofascial pain. Before treatment (P = .015); it was more common in women (32%) than in men (12%), but at follow-up, no gender-related differences were found for this or any other of the TMD diagnoses.

TMD diagnoses in relation to different kinds of dentofacial deformities

After treatment, there were significantly decreased frequencies of myofascial pain (P = .022) and arthralgia (P = .031) in Class III patients (with a normal vertical jaw relationship). None of the other subgroups showed significant differences in TMD diagnoses between baseline and follow-up.

**Figure 9. Percentage distribution of TMD diagnoses in the treatment group (n=98) before and after treatment.**
Figure 10. Percentage distribution of TMD diagnoses in the treatment group (n=98) and control group (n=56) after treatment.

Symptoms of TMD
In the treatment group, both self-evaluated severity of overall symptoms of TMD and pain from the masticatory muscles and TMJs, decreased significantly from baseline to follow-up (P < .001). No such difference was found in the control group (Figures 11-13).

Figure 11. Self-evaluated overall symptoms of TMD, in the treatment group (n=97), at baseline and follow-up (P < .001). For one patient no answer was registered.
Figure 12. Self-evaluated overall symptoms of TMD, in the control group, at baseline and follow-up (P = NS).

Figure 13. Reported pain from the masticatory muscles and TMJs during rest, wide opening and/or mastication, in the treatment (n=97) and control group (n=38), before and after treatment. For one patient in the treatment group no answer was registered.

Mandibular movement capacity
At both baseline and follow-up, the maximum mandibular opening capacity in the treatment group was lower than in the control group (P = .005, P < .001 respectively). The opening capacity in the treatment group had decreased at follow-up, from 50 ± 8 mm to 48 ± 7 mm (P = .009). For the control group, no significant changes in mandibular opening capacity were recorded from baseline to follow-up examinations (mean 54±5 mm and 53±6 mm, respectively).
Occlusal interferences
At baseline, the treatment group had significantly more interferences (P < .05) than the control group, except for lateral deviation between RCP and ICP. At follow-up, the number of subjects in the treatment group with interferences had decreased significantly (P < .05) and no inter-group differences were disclosed.

Patients’ satisfaction with treatment
When asked about their satisfaction with the treatment, 82% of the patients in the treatment group reported improved aesthetics, 80% reported improved masticatory comfort and 61% reported fewer symptoms of TMD after treatment. Ninety-two percent were satisfied with the information received before treatment. Sixty-eight percent reported their experience of treatment to be as they had expected, or less burdensome than expected. There were no gender differences with regard to treatment satisfaction.

Level of anxiety
The median self-evaluated level of anxiety registered on a VAS decreased from 19 to 11 after treatment (P = .001). The corresponding figures for the control group were 20 at baseline and 25 at follow-up examination (P = .871).

Paper IV
Self estimated masticatory ability
At baseline, the patients rated their masticatory ability significantly lower (mean = 52.2 ± 29.5) than the control group (mean = 85.7 ± 17.4, P < .001). They also found it more difficult to chew meat (P < .001), raw carrots (P = .019), toffee (P = .002), French loaf (P < .001) and cold cuts of ham, cheese and cucumber (P < .001). At follow-up, the masticatory ability had significantly improved in the treatment group (mean = 83.9 ± 19.2, P < .001) and reached a level similar to that of the control group with no significant difference between the groups.

Factors influencing the self estimated masticatory ability
The only factors significantly associated with the masticatory ability in the treatment group were the number of occlusal contacts during
maximum biting pressure and self-estimated overall symptoms of TMD. When the treatment group and control group were merged a significant association between TMD pain and masticatory ability was found (Table 5).

In a linear regression analysis adjusted for age, factors like number of occlusal contacts during maximal biting pressure, severity of overall symptoms of TMD and study group belonging explained 45% of the total variation of the masticatory ability. Fewer occlusal contacts during maximal biting pressure, a higher severity of the overall symptoms of TMD and belonging to the treatment group all had a negative association with the masticatory ability. When subgroups of dentofacial deformities were assessed it was found that patients with a Class II relation (n = 27) rated their masticatory ability higher (mean = 68.7, ± 25.9) compared with patients with Class III and normal sagittal relations (n = 71, mean = 46.5, ±28.7, P = .002, 95% CI 8.4-35.9). No significant differences were found between separate vertical jaw relations.

Masticatory performance
There were large individual variations of the masticatory performance index (MPI), within the groups. At baseline, the treatment group had a lower MPI than the control group (mean 10.4± -10.4 versus mean 37.3±-16.8). For the treatment group, the MPI increased at follow-up (mean 21.0±19.2) but was still low compared with the baseline level in the control group (P < .001).

After stratifying the material into sagittal and vertical deformities it was found that the MPI improved after treatment in patients with:
- Class III malocclusion (normal vertical relation)
  - Mean: 12.8 ± 11.0 to 23.7 ±18.5 (P < .001)
- Open bite (normal sagittal relation)
  - Mean 6.3 ± 6.0 to 19.9 ± 19.9 (P = .038)
- Class III combined with open bite
  - Mean 7.9 ± 8.4 to 24.7 ± 20.6 (P = .003)

No significant differences after treatment were found in patients with deep bite or Class II malocclusion.
Factors influencing MPI
When the treatment group and control group were analysed altogether the variables gender; number of occlusal contacts during maximal biting pressure; self reported severity of overall symptoms of TMD and TMD pain diagnoses were all found to significantly have an influence on the MPI at baseline, (Table 6). When the treatment group and control group were analysed separately only gender and occlusal contacts had an influence on the MPI in the treatment group whereas gender and a TMD pain diagnosis influenced the MPI in the control group. No association was found between age and MPI for any of the groups (Table 6).

A linear regression analysis, adjusted for age and group belonging, explained 37 % of the total variation of MPI. The number of occlusal contacts during maximal biting pressure was the factor that had the highest influence on MPI, with increased MPI with a higher number of contacts. Open bite was the only kind of dentofacial deformity with a significant influence on MPI, showing a negative effect on MPI.

Patients with an open bite (n = 41) were also found to have an impaired masticatory performance (mean = 6.7, SD 6.8) compared with patients with deep bite or a normal vertical relation (n = 57, mean = 13.2, SD 11.8, P = 001, 95 % CI 2.7-10.2). No significant differences were found between separate sagittal relations.

Correlations
Before treatment, significant correlations were found between:

- Self-estimated masticatory ability and masticatory performance (0.483, P < .001).
- Self-estimated masticatory ability and number of occlusal contacts during maximum biting pressure (0.428, P < .001).
- Masticatory performance and number of occlusal contacts during maximum biting pressure (0.509, P < .001).
Occlusion
Before treatment, there were no significant differences in number of teeth between the treatment (mean = 28 ± 1.9) and the control group (mean = 29 ± 2.0). During treatment teeth were extracted in some of the patients and at follow-up there were significant differences between the two groups (mean = 27 ± 2.1 and 29 ± 2.0 respectively, P = .002).

The treatment group had significantly fewer occlusal contacts during maximum biting pressure than the control group (mean = 13 ± 6.4 versus 18 ± 5.5, (P < .001). After treatment the number of contacts increased (Mean = 16 ± 6.1, P < .001) and did not significantly differ from the control group.

When subgroups of sagittal and vertical discrepancies were assessed before treatment, the 41 patients with open bite had significantly fewer occlusal contacts during maximum biting pressure compared with the 48 patients with normal vertical relation (mean = 14 ± 5.8, P = .014) and the the 9 patients with deep bite (mean =10 ± 5.0 versus 19 ±9.5, P < .001) and the 48 patients with normal vertical relation (mean=14 ± 5.8, P = .014). No significant differences between sagittal discrepancies were found before treatment. After treatment there were no significant differences between any of the subgroups.
Table 5. Statistically significant differences of the Mean self-evaluated masticatory ability by levels of Occlusal factors and TMD in the whole study group (Both Treatment and Control group) \( n = 153 \) and the two groups separately. Twelve patients were not asked for their masticatory ability before treatment.

<table>
<thead>
<tr>
<th>Influencing binary parameters</th>
<th>Patient group</th>
<th>Control Group</th>
<th>Both groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n )</td>
<td>MPI</td>
<td>SD</td>
</tr>
<tr>
<td>Female</td>
<td>50</td>
<td>57.1</td>
<td>31.5</td>
</tr>
<tr>
<td>Male</td>
<td>36</td>
<td>45.4</td>
<td>25.4</td>
</tr>
<tr>
<td>Number of occlusal contacts during maximal biting pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 10</td>
<td>28</td>
<td>38.7</td>
<td>25.5</td>
</tr>
<tr>
<td>( \geq 10 )</td>
<td>58</td>
<td>58.7</td>
<td>29.3</td>
</tr>
<tr>
<td>One diagnose of TMD pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>59</td>
<td>56.4</td>
<td>28.4</td>
</tr>
<tr>
<td>Yes</td>
<td>27</td>
<td>43.1</td>
<td>30.4</td>
</tr>
<tr>
<td>Severity of overall symptoms of TMD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insignificant/ light</td>
<td>60</td>
<td>60.1</td>
<td>26.8</td>
</tr>
<tr>
<td>Moderate-very severe</td>
<td>36</td>
<td>41.2</td>
<td>29.9</td>
</tr>
</tbody>
</table>
Table 6. Statistically significant differences of the mean Masticatory Performance Index (MPI) by levels of Occlusal factors and TMD in the whole study group (Both Treatment and Control group) n = 153 and the two groups separately.

<table>
<thead>
<tr>
<th>Influencing binary parameters</th>
<th>Patient group</th>
<th>Control Group</th>
<th>Both groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>MPI</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>95 % CI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of occlusal contacts during maximal biting pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>8.2</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>1.3 - 10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>5.6</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>3.8 – 11.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One diagnose of TMD pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>11.6</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>11.5 – 30.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>8.2</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>11.5 - 30.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity of overall symptoms of TMD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insignificant-light</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>11.5</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>11.5 - 30.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate-very severe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>9.0</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>8.9 – 18.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


This thesis is based on a series of studies evaluating TMD and masticatory function in patients with dentofacial deformities referred for orthognathic surgery. The first part of the thesis (Paper I) reviewed previous literature to determine whether there was evidence for a positive or negative outcome with respect to TMD after orthognathic treatment. The clinical studies (Paper II-IV) were unique as they provided a longitudinal comparison of a patient group with a control group that had no or minor malocclusions. Studies with a controlled and longitudinal study design are scarce in this field of research.

The main finding of the initial systematic review (Paper I) was that there are very few controlled studies that longitudinally assess TMD in patients treated with orthognathic surgery. Thus, it was very difficult to draw any conclusions regarding treatment outcomes. This lack of studies may reflect the difficulties in performing these kind of clinical trials.

The main findings of the clinical studies (Paper II-IV) were that patients with dentofacial deformities and referred for orthognathic surgery had more TMD than a normal population. These patients also estimated their masticatory ability lower and was tested having lower masticatory performance than the control group. After treatment the frequency of TMD had been reduced in the treatment group and were similar to the levels found in the control group. Also the masticatory ability and the masticatory performance had improved, although the masticatory performance was still lower compared to the control group.
Systematic review
In 1992 Davidoff et al(75) estimated that dedicated health care professionals would have to read and critically review about 17 original articles every day to keep up to date with the recent published science. Today the figures are probably even higher, and consequently this task is obviously impossible to implement for most clinicians, making systematic reviews valuable.

In a systematic review a well-formulated question is addressed by analysing all available evidence. It includes an objective search of the literature, critically appraising what is found to be relevant. Then data is extracted, synthesized and summarized. The process is aimed at minimizing bias in order to have a more reliable basis for clinical decision-making. (76, 77) There is also the view that systematic reviews should always precede new research projects in order to improve study designs, and consequently to produce new trials with a higher impact. (78)

In the present systematic review the formulated question was “Does orthognathic surgery affect the prevalence of signs and symptoms of TMDs?” and the inclusion criteria were:

- Studies comparing signs and symptoms of TMD before and after orthognathic surgery in patients with malocclusion.
- Randomized controlled trials (RCTs) or controlled, prospective or retrospective studies.

The result of the literature search in the initial and the complementary review revealed a limited number of studies that corresponded to the inclusion criteria. (43-45, 79) Furthermore, neither of these studies were RCTs. In research, a well-designed and properly executed RCT, is claimed to provide the highest level of evidence on the efficacy of health care interventions and is therefore considered the gold standard(80-82). Unfortunately, often due to ethical reasons, it is not possible to perform randomised trials, instead leaving observational studies like cohort or case-control studies as the only choice. Considering patients with dentofacial deformities, scheduled for orthognathic surgery, it can be considered unethical to randomize one group of patients for treatment and postpone treatment for another group of patients for one or two years. With this in mind, it was even more surprising that there were so few
observational studies with a well-defined control group as it is well known that studies without a control group only provide low scientific evidence.

The methodology for data extraction and the quality assessment used in the present systematic review was partly adopted from Antczak et al (62) and partly from SBU. (64)

It can be discussed whether the scoring criteria were too ambitious since RCT can be difficult to implement in this type of research. Even so, one study (Paper III in this thesis) was judged as high value of evidence, confirming that well-designed observational studies can reach as high level of evidence equivalent to RCTs. (64, 81)

When grading studies as high, medium or low value of evidence, there is always the possibility of subjective impact on the assessment. All of the retrieved articles in Paper I was therefore independently analysed by all four authors. Consensus was then reached through discussion.

The systematic review, complemented with the new literature survey, found limited scientific evidence for a decrease in pain on palpation of the masticatory muscles and insufficient evidence for alterations of TMJ pain and sounds after treatment. Only one study (74) used TMD diagnoses according to RDC/TMD(19) when assessing treatment outcomes, consequently the evidence for alterations of TMD after orthognathic treatment was insufficient. One more study estimated as high, or two studies estimated as moderate value of evidence (66), confirming the results of Paper III in this thesis, are needed for implementation in clinical decision-making.

**Methodological aspects**

**Paper II-III**

RCTs are, as discussed earlier, the golden standard in evidence-based research. In the present study, due to ethical reasons, an observational design in the form of a case-control study was the preferred choice. It has been argued that observational studies can exaggerate treatment results but there are also reports showing no differences in the treatment outcome between RCTs and observational studies. (81) Because of the case-control design the present study cannot present epidemiologic figures with regard to the prevalence of TMD in individuals with dentofacial deformities in the population, since these types of trials should be population-based.
The number of patients included in our study, exceeded the power-calculations, with the intention to have the possibility to subgroup the material for different kinds of dentofacial deformities. Obviously, some of the subgroups, most notably deep bite, became too small and could not be statistically calculated with any significance. What could have been done differently in this regard? The size of the subgroups could conceivably have been set before the collection of patients started. However, the data collection was carried out during two time periods 1992-1995 and 2000-2002, a period of totally 7 years. It would have taken many more years to get sufficient subgroups, especially for the deep bite diagnoses.

Another methodological issue was the choice of definitions for the subgroups. In both Paper II and III it was decided to subgroup the different dentofacial deformities as a combination of vertical and sagittal discrepancies resulting in relatively well defined but small groups. Another possibility for classification, which was used in Paper IV, was to separate the dentofacial deformities in vertical and sagittal discrepancies. This meant that the treatment outcome was related to sagittal discrepancies and to vertical discrepancies independently. Every patient had both a sagittal and a vertical diagnosis. This alternative created larger subgroups but implies a higher risk of biases, in form of overlap between different kinds of malocclusion.

In the early 1990’s, when this study was initiated, the RDC/TMD (19) had recently been introduced and accepted in TMD research but not yet been established as a diagnostic tool worldwide. Therefore, the individuals in this study were assessed for signs and symptoms of TMD according to an examination form used at the time in the clinic, at the department of Stomatognathic Physiology in Malmö. The RDC/TMD diagnoses for myofascial pain disorders and arthritic disorders were thereafter implicated. Since the measurements of reciprocal clicking had not been assessed exactly as prescribed in the RDC/TMD it was, in Paper III, deliberately chosen, not to use RDC/TMD diagnoses for disc displacements with reduction. The RDC/TMD has been found to demonstrate sufficiently high reliability for the most common TMD diagnoses, supporting its use in clinical research and decision-making.(83)The validity of the RDC/TMD has in a review(84)been estimated to range from poor to extremely
good, depending on the diagnosis to be tested. Myofascial pain (limited opening included) was found to have acceptable sensitivity and extremely good specificity. The authors concluded that individuals where unlikely to be over-diagnosed when using the RDC/TMD. (84) Recently there has been a revision of the RDC/TMD and a new index, the diagnostic criteria for TMD (DC/TMD), (85) is claimed to be more suitable for routine clinical implementation, since psychological and biological data are better integrated. (84)

When assessing frequencies of TMD, it could be argued that the results of the present study are biased, since patients are prone to highlight physical disorders, like TMD to gain attention in the financially subsidized health care system. In order to avoid this phenomenon, the stomatognathic examination was performed at a separate occasion and in a department separate from the one in which the orthognathic treatment was performed in. Furthermore the specialists that performed the examinations were not involved in the decision-making regarding the orthognathic treatment of the patients.

Some of the participants in the initial sample withdrew at follow-up (Paper III and IV). In spite of this, both the treatment and control group included a sufficient number of participants according to the initial power calculation. An analysis of the drop-outs revealed no significant differences with respect to age, gender, self-reported anxiety, pain in the jaws and related muscles, diagnosed TMD or masticatory ability and performance compared to the remaining participants. Therefore, both the treatment and control group were considered having sufficient participants to ensure reliability between the baseline and follow-up examinations.

The strength of the studies was that the patients were consecutively included, with the size of the study groups calculated beforehand by a power analysis, and a low-rate of dropouts. A control group was included, with the aim to, as far as possible, reflect a normal population. The specialists conducting the stomatognathic examinations were calibrated and blinded to the extent that was possible; as to they were not informed whether the individual belonged to the treatment or the control group. Despite this, there were obviously for some of the patients before treatment, anatomical features that could be detectable.
Before the analysis of the results in Paper III, the sub-diagnoses of different kinds of dentofacial deformities were rechecked with the surgery protocols. There were three patients diagnosed with “open bite and normal vertical relation” in Paper II and one patient diagnosed with “open bite and Class II relation” that were re-diagnosed as “open bite with a Class III relationship”. When frequencies of TMD were analysed with the correct diagnosis of dentofacial deformity no significant differences could be found compared with the results in Paper I.

Furthermore, the sub-diagnoses of TMD were rechecked between Paper II and Paper III, and one patient was found to have osteoarthrosis at baseline, which had not been registered for Paper II.

**Paper IV**

The self-estimated masticatory ability in Paper IV was assessed by a questionnaire. A shortcoming was that the questions involving masticatory ability were limited. Since the present study was initiated in 1992, a Jaw Function Limitation Scale (JFLS) has been developed. (86) This scale has been shown to exhibit good reliability and validity in assessing limitations in mastication, jaw mobility and verbal and emotional expression (86). Since, the questionnaire in Paper IV focused solely on mastication, it would have been interesting to extend it according to the JFLS to have the possibility to assess also if patients with dentofacial deformities are limited in their daily life when talking, swallowing, making facial expressions etc.

In the present study it was chosen to test the masticatory performance by methods developed by Edlund and Lamm.(73) The advantages of using Optosil® tablets were the standardization of size and texture of the tablets, together with the water and age resistance. (73) Unfortunately, the weight composition of the Optosil® material was changed by the manufacturer over the years, and therefore it was decided for the control group not to perform the masticatory performance test at the follow-up examination. The follow-up tests for the treatment group were performed using the former variant of the Optosil® tablets, and the collected data were checked for inconsistencies.
**Anamnestic findings**

The questionnaire in Paper II revealed no anamnestic differences between the treatment and control group. Neither were there any differences for self-estimated level of anxiety, reported on a VAS. The VAS is a rough instrument for assessing psychological variables but the result still gave an indication that the treatment group did not differ from the control group in respect of self-perception.

For the patients with dentofacial deformities, impaired masticatory function, symptoms from the masticatory muscles, TMJs and headaches followed by aesthetics were the most common reasons for seeking treatment, which is in line with other studies (15, 87-89). However, in our study (Paper II) the aesthetic reasons were rated relatively low compared with earlier studies reporting that facial appearance was the most important reason for seeking treatment. (90, 91) Cultural differences and financial aspects probably explain this divergence in results. (15, 87) Facial appearance has been suggested to be one of four dimensions in Oral-Health-related quality of life (92) and a new scale, the Oral Esthetical Scale (OES) has been developed, which has shown satisfying reliability and validity. (93) The use of such a scale would have been beneficial to assess the perception of aesthetics of the patients and individuals in this thesis.

**Frequency of TMD**

In Paper II the most common diagnoses of TMD were myofascial pain, disc displacement and arthralgia. These results are in accordance with other studies. (19, 28, 83) These diagnoses were also significantly more common in the treatment group compared with the control group. Consequently, the hypothesis of Paper II, that there are no differences in the frequency of TMD between patients with dentofacial deformities and a normal control group, was rejected. This finding is diverging from previous controlled studies (43-45) that did not find any differences in frequency of TMD between the treatment groups and control groups at the baseline examination. Probable causes for the diverging results between these studies and the present study are differences in measurement methods and the sizes of the control groups. It is well accepted that signs and symptoms of TMD are common in a population and therefore sub
diagnoses of TMD according to RDC/TMD are more suitable when assessing TMD. (19)

After treatment; myofascial pain, disc displacement and arthralgia was significantly reduced in the treatment group, while osteoarthrosis increased. Taken together, despite the increase in frequency of osteoarthrosis, the present study clearly revealed a positive treatment outcome considering TMD pain and disc displacements and thereby the first hypothesis of Paper III was confirmed.

The second hypothesis yielded that there would be no differences between the treatment group and the control group after treatment and since no significant differences were found also this hypothesis was confirmed.

The increase of osteoarthrosis in the TMJs after orthognathic treatment has also been observed in studies by Rodrigues-Garcia et al (50) and Pahkala et al(94) and has been suggested to be a result of post-surgical changes of the condylar position in the glenoid fossa. (95) The results may also have been affected by the uncertainty in differentiating a specific joint sound (i.e. crepitus) from clicking or even from soft tissue sounds during digital palpation. Only marginal validity is reported for these signs due to low sensitivity and high specificity for crepitus. (84)

The present study also investigated the maximum mandibular opening capacity, which was significantly lower in the treatment group, compared with the control group, and also decreased after treatment. A reduction in opening capacity has also been noted in other studies. (47, 96) However, the posttreatment decrease of 2 mm in the present study was not considered clinically important. In a recent review (97) it was proposed that the opening capacity will increase gradually during the first years after orthognathic surgery. There was also a general understanding that the impaired lateral excursions that most patients experience after surgery improves over time and that most patients regain the full range of motion two years after surgery.(97)

The present study did not find any subgroup of dentofacial deformities that, separately, was significantly associated with TMD before treatment. Anyhow, it should be remembered, that most of the subgroups were too small to detect any statistical significance, as indicated by the power analysis. An interesting finding was that
patients with Class III bite in combination with normal vertical relation showed less myofascial pain and arthralgia after treatment. All of the Class III patients had intraoral vertical ramus osteotomy (IVRO) for setback of the mandible. A positive treatment outcome for patients with TMD has been an argument for using IVRO, instead of bilateral sagittal split osteotomy (BSSO), for correction of a protrusive mandible. (6, 14)

**Masticatory ability and performance**

The results of Paper IV supported the hypothesis that patients with dentofacial deformities has an impaired self estimated masticatory ability and masticatory performance in comparison with a control group without dentofacial deformities before treatment, which is in consistency with other controlled studies. (57, 58)

The masticatory ability improved after orthognathic treatment and at follow-up no differences were found between the treatment and the control group. However, there seems to be an overestimation of the masticatory ability, which was rated high compared with the tested masticatory performance, which also improved but not as much as the masticatory ability. This was particularly evident in Class II patients who reported significant higher levels of masticatory ability, compared with patients with other dentofacial deformities, properties that were not confirmed in the masticatory performance test. In a study by Henrikson et al, (58) involving 11-15 year old girls with Class II malocclusions, the same overestimation of the masticatory ability was found. (58)

The reason for the modest improvement in masticatory performance in the present study may be the relatively short follow-up period (18 months). It has been suggested that a follow-up period of 5 years is more appropriate and beneficial for the masticatory performance, since the musculature needs a relatively long time to readapt before regaining full strength. (98, 99)

The factors that were found to have an association with the masticatory ability and the masticatory performance differed slightly between the treatment and control groups. The number of occlusal contacts during maximal biting pressure affected both the masticatory ability and performance in the treatment group, but had no association with mastication in the control group. This result is
strengthened by the finding that patients with an open bite, the only type of dentofacial deformity associated with masticatory performance, had fewer occlusal contacts compared with patients with deep bite and normal vertical relations.

The masticatory performance was found to be significantly higher in men than in women. This result can be explained by the fact that men have a higher EMG activity of the masticatory muscles together with a higher muscle thickness, especially for the masseter muscle. (60, 61)

**Patient satisfaction**

The patients were in general satisfied with the treatment. The variables most frequently reported as improved were masticatory function and aesthetics, followed by symptoms of TMD. In a study by Öland et al (89) it was shown that the pre-treatment motives correlated with the satisfaction after treatment. They also found that patients that, at baseline, rated oral function highest also expressed the lowest degree of treatment satisfaction, which is contradictory to our results (Paper III). In a study by Trovik et al (88) it was noticed that peer comments about appearance after treatment affected both self-esteem and quality of life.

A positive finding was that a great majority of the patients (92 %) were satisfied with the information that they had received before the treatment. It should be remembered though, that 32 % of the patients experienced the treatment as more difficult than they had expected, which should be taken into consideration when presurgical information is given.

**Future research**

The results of this thesis showed that frequencies of TMD decreased after orthognathic treatment. However, as indicated by the systematic review (Paper I) and the supplementary literature survey further research is required. A stronger evidence base to be able to evaluate whether orthognathic treatment alters frequencies of TMD would require one more study of high, or two more studies of medium value of evidence, assessing alterations of sub-diagnoses of TMD according to RDC/TMD.
It should also be noted that in the present study we found an increase in the number of patients with osteoarthrosis 18 months post treatment. As it is well known that TMD fluctuates over time it would be valuable to carry out a 5 years follow-up to assess how the treatment outcome of TMD persists in the long run.

Moreover, since oral-health-related quality of life has been associated with both TMD and masticatory function in previous studies (56, 92, 100) it would be of interest to investigate how the psychosocial well-being is affected after orthognathic treatment by using the Swedish version of the Oral Health Impact Profile (OHIP-S). (100) Such a study is planned and will be presented in the future.
The systematic review, including the supplementary literature search, led to the following conclusions:

- There is insufficient evidence for a decrease in TMD subdiagnoses after orthognathic treatment.
- There is low scientific evidence for an improvement of masticatory muscle pain on palpation after orthognathic treatment.
- There is insufficient evidence considering alterations of TMJ pain on palpation and TMJ sounds after orthognathic surgery.
- Further controlled, well-designed studies assessing TMD before and after orthognathic treatment are needed to secure strong evidence considering treatment outcomes.

In the cross-sectional, case-control study comparing frequencies of TMD in patients referred for orthognathic treatment with a control group it was concluded that:

- Patients with dentofacial deformities have higher frequencies of signs and symptoms of TMD and diagnosed TMD compared with a normal group.

In the controlled, longitudinal, follow-up study comparing frequencies of TMD before and after orthognathic treatment, it was concluded that in patients with dentofacial deformities:

- Frequencies of TMD decrease after orthognathic treatment.
- Frequencies of TMD were after orthognathic treatment comparable in the patient group and control group.
In the controlled, longitudinal, follow-up study before and after orthognathic treatment of patients with dentofacial deformities, it was concluded that:

- Masticatory ability and masticatory performance increased after orthognathic treatment.
- The number of occlusal contacts and severity of overall symptoms of TMD influenced both the masticatory ability and performance.
- Open bite had a negative effect on masticatory performance.

**Key conclusions and clinical implications:**
Patients with dentofacial deformities diagnosed with TMD do in most cases benefit from orthognathic treatment. In addition, masticatory ability and performance, which is impaired in patients with dentofacial deformities, improve after treatment. Thus, patients with dentofacial deformities that are to be treated with orthodontics in combination with orthognathic surgery can be recommended the treatment in order to relieve symptoms of TMD and impaired mastication.
ACKNOWLEDGEMENTS

The work with this project has taken many years to accomplish. It started already in the 1990s when one of my supervisors, Thor Henrikson was curious and enthusiastic enough to gather specialists from different disciplines of odontology to formulate a research programme in a field that at the time was not studied by many. About a decade later I gratefully got the opportunity to be a part of that research group and to complete the project.

During the years many individuals have been involved in the project and first of all I wish to humbly thank:

All the patients and the individuals in the control group who participated in the studies.

Associate Professor Ewa Carin Ekberg, my main supervisor, co-author and friend for your never failing support and for always having time for me, for helping me find my research self-esteem when I needed it and for guiding me through hard times. Thank you for your enthusiastic participation in the clinical examinations in the project and for your invaluable advice during my doctoral education!

Professor Lars Bondemark, my assistant supervisor, and main supervisor during the first part of the project, co-author and friend for sharing your enormous knowledge and wisdom in research, for tirelessly being there with the pencil when needed and for your generous
support during a turbulent time of my life. Thank you for always having time for me!

Associate Professor Thor Henrikson, my assistant supervisor and co-author for first of all generously letting me into the project. In the beginning patiently guiding me through how to sieve silicon tablets, how to do a power-point presentation, register variables in the statistic programme and so on. Later on, pushing the project forward by sharing your knowledge and wisdom through fruitful discussions. It has been a privilege to work with you!

Associate Professor Bo Sunzel, my co-author of Papers II and III, for stimulating discussions, for generously sharing your knowledge about orthognathic surgery, for enthusiastic help with collecting data and for performing the orthognathic treatment for part of the patient group.

Professor Maria Nilner, my co-author of Papers II and III, for sharing your wisdom in research, for constructive criticism of the manuscripts and for your enthusiastic participation in the clinical examinations.

My colleagues, co-workers and friends at the Department of Orthodontics and the Department of Paediatric Dentistry, Faculty of Odontology, Malmö for encouragement and support over the years. Especially I want to thank Ingrid Carlin for assistance with the tablets used in the masticatory performance test, Hans Herrlander for scanning of the radiographs and Stella Giuseppin for secretarial assistance.

Staff members at the Department of Stomatognathic Physiology, Faculty of Odontolgy, Malmö for assistance with the clinical examinations.

Staff members at the Department of Oral and Maxillofacial surgery, Lund University Hospital and especially Ingela Nilsson for patiently gathering data about the patients in the studies.
Staff members at the dental clinic of Oxie, for assistance during the clinical examinations of the individuals in the control group.

*Associate professor Eva Lilja-Karlander,* for friendship and support during the research education and for creating the fantastic illustrations at the front page.

*Drs Liselotte Björnsson and Sofia Petrén,* my colleagues and friends, for your encouragement and support, for lovely moments with our families, for answering my never ending questions about research. We have a lot of congresses left to visit and a lot of shopping left to do!

*Dr Diana Girdo,* my roommate, colleague and friend for cheering me up with relieving laughters, for patiently listening to my frustrated sighs, for being the perfect travel mate and for sharing my newly awakened passion for macarons.

*Associate Professor Krister Bjerklin,* for friendship, for generously sharing your wisdom in orthodontic science and for invaluable advices during the revision of Paper III.

*Per Egevad,* for invaluable and enthusiastic help in a desperate crisis situation with a new computer and a non-working reference tool.

*Per-Erik Isberg,* for invaluable help with the statistical analysis.

*Dr Birgitta Häggman Henrikson,* for excellent revision of the English text.

*Annika Österlind Hansen,* my dear, dear sister and best friend for your love and support and for endless talks and relaxing runs during hard times.

*My parents Gerd and Bo Österlind,* for your endless love and for always being there for me when I need you. And in particular I thank my mother for patiently listening to me day as night when
I’m feeling low and for cheering us up with home baked cookies and other little things that makes life a little more easy.

And most of all my soul mate and beloved husband Jonas, for your love, faith and understanding. With you by my side I am invincible! And to our fabulous children for bringing joy and happiness to life.

Klara - my lovely riding mate, for giving me daily laughter with your crazy and disarming jokes.

Alva – my sweet shopping companion, for always insuring me of your love.

Henrik – my cool football player, for always wanting to do your best and for your brilliant 6 year-old wisdom.

-I Love You!

The following financial support is gratefully acknowledged: TePe Scholarship Ltd, Sweden; Swedish Dental Society; Faculty of Odontology, Malmö University, Sweden.
REFERENCES


76. The Cochrane Library.


CECILIA ABRAHAMSSON

Masticatory Function and Temporomandibular Disorders in Patients with Dentofacial Deformities

Studies before and after orthodontic and orthognathic treatment

ISSN 0348-6672