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EFFECT OF TREATMENT OF SEVERE MALOCCLUSION AND RELATED FACTORS ON ORAL HEALTH-RELATED QUALITY OF LIFE
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EFFECT OF TREATMENT OF SEVERE MALOCCLUSION AND RELATED FACTORS ON ORAL HEALTH-RELATED QUALITY OF LIFE

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Malocclusions and dentofacial deformities associate with physical, psychological and social functioning, which are included in the concept of oral health-related quality of life (OHRQoL). It is not clear, however, how different aspects related to malocclusion are associated with OHRQoL and how the possible associations interrelate during treatment. The aim of this study was to investigate the effect of treatment of severe malocclusion and related functional and esthetic changes on OHRQoL in adult patients who undergo orthodontic or orthodontic-surgical treatment.

The study group comprised ninety-four adults (34 men and 60 women, age range 18–64 years) with severe malocclusion and considerable functional problem who were referred for orthodontic or orthodontic-surgical treatment in the Oral and Maxillofacial Department at Oulu University Hospital. Data were collected using questionnaires, dental casts, dental photographs and clinical examinations before and after treatment. OHRQoL (OHIP-14), facial pain and satisfaction with dental esthetics were measured with questionnaires. The methods to measure malocclusion, temporomandibular disorders (TMD) and dental esthetics were the Peer Assessment Rating (PAR) index, the Helkimo index and the Aesthetic Component (AC) of the IOTN.

Before treatment, associations between severity of malocclusion, TMD, facial pain and OHRQoL differed between genders. OHRQoL, malocclusion, signs and symptoms of TMD, facial pain and satisfaction with dental esthetics improved significantly during the follow-up. The greatest improvement was seen in the OHRQoL dimensions psychological discomfort, physical pain and psychological disability. Improvement in satisfaction with dental esthetics and decreased facial pain associated with improved OHRQoL.

In conclusion, treatment of severe malocclusion considerably improves OHRQoL. Especially satisfaction with dental esthetics and facial pain seem to be aspects that contribute to patients’ OHRQoL. Thus, the importance of dental esthetics and facial pain for patients should not be underestimated when making treatment decisions and assessing outcome.

Keywords: adult, dental esthetics, facial pain, malocclusion, orthodontics, orthognathic surgery, quality of life, temporomandibular disorders
Tiivistelmä

Purentavirheet sekä hampaiston ja kasvojen poikkeavuudet ovat yhteydessä fyysisen, psyykkisen ja sosiaaliseen toimintaan. Suunterveyteen liittyvä elämänlaatu on käsite, joka sisältää nämä fyysiset, psyykkiset ja sosiaaliset osa-alueet. On kuitenkin epäselvää, miten purentavirheen liittyvät eri näkökohdat ja niiden muutokset ovat yhteydessä suunterveeten liittyvään elämänlaatuaan ja sen muutoksiin hoidon aikana. Tutkimuksen tavoitteena oli tutkia vaikean purentavirheen hoidon ja siihen liittyvien toiminnallisten ja esteettisten muutosten vaikutusta elämänlaatuun aikuispotilailla, joille tehtiin oikomishoido tai oikomishoido yhdistettynä leukakirurgiseen hoitoon.

Tutkimusryhmän muodostivat 94 aikuista (34 miestä ja 60 naista, ikäjakauma 18–64 vuotta), joilla oli vaikea purentavirhe ja siihen liittyvä huomattava toiminnallinen haitta, ja jotka oli lähetetty ortodontiseen tai ortodontis-kirurgiseen hoitoon Oulun yliopistollisen sairaalan hammas- ja suusairauksien klinikalle. Tiedot kerättiin kyseisien makkeiden, kipsimallien, suuvalokuvien ja kliinisten tutkimusten avulla ennen hoitoa ja sen jälkeen. Suunterveeten liittyvää elämänlaatua (OHIP-14), kasvokipua ja hampaiden ulkonäköön liittyvää tyytyväisyyttä mitattiin kyselyvakkeella. Purentavirheen, purentaelimistön toimintahäiriöiden ja hampaiden ulkonäön mittaukseen käytettiin PAR-indeksiä, Helkimo-indeksiä ja IOTN:n ulkonäköosiota.


Vaikean purentavirheen hoito paransi merkittävästi suunterveeten liittyvää elämänlaatua. Mitatut muuttujista etenkin tyytyväisyys hampaiden ulkonäköön ja kasvokipu näyttävät olevan merkillisiä potilaan suunterveeten liittyvän elämänlaadun kannalta. Tästä syystä hampaiden ulkonäön ja kasvokivun merkitystä potilaille ei tulisi aliarviooida hoitopäätöstohtaisesti tehtäessä ja hoitotulosta arvioitaessa.

Asiasanat: aikuinen, elämänlaatu, hampaiden ulkonäkö, kasvokipu, leukakirurgia, oikomishoido, purentaelimistön toimintahäiriöt, purentavirhe
To my family
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20th October, 2014

Anna-Sofia Silvola
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>AC</td>
<td>Aesthetic Component of the Index of Orthodontic Treatment Need</td>
</tr>
<tr>
<td>Ai</td>
<td>Helkimo's anamnestic dysfunction index</td>
</tr>
<tr>
<td>AI</td>
<td>Angle Class I</td>
</tr>
<tr>
<td>AI</td>
<td>Angle Class II</td>
</tr>
<tr>
<td>AI III</td>
<td>Angle Class III</td>
</tr>
<tr>
<td>CFI</td>
<td>Comparative fit index</td>
</tr>
<tr>
<td>Di</td>
<td>Helkimo's clinical dysfunction index</td>
</tr>
<tr>
<td>DC/TMD</td>
<td>Diagnostic Criteria for Temporomandibular Disorders</td>
</tr>
<tr>
<td>DHC</td>
<td>Dental Health Component of the Index of Orthodontic Treatment Need</td>
</tr>
<tr>
<td>FoVo</td>
<td>OHIP items reported fairly often or very often</td>
</tr>
<tr>
<td>GLM</td>
<td>General linear modeling</td>
</tr>
<tr>
<td>NFI</td>
<td>Normed fit index</td>
</tr>
<tr>
<td>OHIP</td>
<td>Oral Health Impact Profile</td>
</tr>
<tr>
<td>OHIP-14</td>
<td>14-item Oral Health Impact Profile</td>
</tr>
<tr>
<td>OHRQoL</td>
<td>Oral health-related quality of life</td>
</tr>
<tr>
<td>PA</td>
<td>Path analysis</td>
</tr>
<tr>
<td>PAR</td>
<td>Peer Assessment Rating Index</td>
</tr>
<tr>
<td>QoL</td>
<td>Quality of life</td>
</tr>
<tr>
<td>RDC/TMD</td>
<td>Research diagnostic criteria for temporomandibular disorders</td>
</tr>
<tr>
<td>RMSEA</td>
<td>Root mean square error of approximation</td>
</tr>
<tr>
<td>SRO</td>
<td>Sagittal ramus osteotomy</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>TMJ</td>
<td>Temporomandibular joint</td>
</tr>
<tr>
<td>TMD</td>
<td>Temporomandibular disorders</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual Analogue Scale</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
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**List of original articles**

This thesis is based on the following publications, which are referred to throughout the text by their Roman numerals:


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1 Introduction

Occlusal and dentofacial characteristics affect the physiological functions of the masticatory system, such as chewing, biting and speaking, as well as the dental and facial appearance of a human. Therefore, dentofacial deformities and deviations from normal occlusal relationship can cause severe problems for individuals, including difficulties in mastication, speech problems, gingival traumas, pain, temporomandibular disorders, and diminished self-esteem and self-confidence due to perceived poor appearance.

The number of adults seeking orthodontic or orthodontic-surgical treatment is continually increasing, and orthodontists and general dentists face daily situations in practice when the need for orthodontic treatment is assessed. In these situations, a fundamental question is whether the patient will gain benefit from the treatment. When resources are limited, the professionals should have an understanding of which patients are likely to benefit the most from orthodontic care. In future, the health care funders are expected to demand increased evidence of cost-efficiency. The evidence of the benefits of treatment is particularly important in fields that may be perceived as ‘cosmetic’ treatment.

The severity of malocclusion and treatment outcome is usually assessed with occlusal and cephalometric measurements. Access to public orthodontic treatment is mainly based on occlusal indices, even though the measurements by clinicians may differ from patients’ reasons to seek treatment. According to Inglehart and Bagramian (2002), disease measured by professionals is not conceptually the same as illness and health assessed by patients, which emphasizes the importance of the patient’s perspective in decision-making.

The interest in patient-centered approach has led to a rapid development of research concerning the oral health-related quality of life (OHRQoL). It has been admitted that successful treatment outcome depends not only on improved occlusion and jaw repositioning, but also on how the patients perceive their oral health. Thus, in order to improve the quality and effectiveness of orthodontic care, it is essential to understand the impacts of malocclusion and its treatment from patients’ point of view. The present study was undertaken to investigate the effects of severe malocclusion and its treatment on OHRQoL.
2 Review of the literature

2.1 Occlusal factors

2.1.1 Definition and classifications of malocclusion

A normal dental occlusion was defined by Angle (1899) as a situation where “the sizes, forms, interdigitating surfaces, and positions of the teeth in the arches are such as to give to one another, singly and collectively, the greatest possible support in all directions”. Angle’s definition of normal occlusion has afterwards been considered to be more properly a picture of ideal occlusion, which is very rare in nature, whereas normal occlusion may contain minor deviations from the ideal dental relationships (Proffit 2013). In 1972, Andrews published a paper in which he presented six keys that should be proper in normal occlusion: correct molar relationship, correct crown angulation, correct crown inclination, no rotations, and flat occlusal plane, the description being still applicable (Andrews 1972).

Malocclusion can be defined as appreciable deviation from normal or ideal occlusion (Andrews 1972). Malocclusions are classified into two major groups: dental and skeletal malocclusions, depending on skeletal relationships. Severe malocclusions are frequently skeletal and often referred to as ‘dentofacial deformities’. Dentofacial deformities have been described as deviations from normal facial proportions and dental relationships severe enough to be handicapping (Proffit et al. 2003).

Malocclusions are classified into different malocclusion forms according to occlusal and skeletal characteristics in three planes of space. In 1899, Angle described three classes of malocclusion (Class I; neutroclusion, Class II; distocclusion, Class III; mesiocclusion), on the basis of sagittal relationships of the first molars. Angle’s classification is still a commonly used method for registration of malocclusion, and the terms for incisor relationship have been adapted into classification (Class II division 1 and 2). However, the limitation of Angle’s classification is that it takes into account only antero-posterior deviations. Methods where single traits of malocclusion are recorded are such as epidemiological registration of malocclusion developed by Björk et al. (1964). The method of Björk is based on an evaluation of individual morphological variables and has been the basis for further measures of occlusal traits.
In clinical examination, Angle’s classification and increased or reverse overjet indicate antero-posterior deviations in occlusion. Deep bite and open bite (anterior or posterior) show vertical deviations, and posterior cross-bite or scissors bite suggest transversal deviations from normal occlusal relationships. Crowding, spaces and irregularity of teeth describe the relationships between teeth and dental arches. Skeletally, Class II malocclusion can reflect maxillary prognathism and/or mandibular deficiency, and Class III maxillary deficiency and/or mandibular prognathism (Proffit et al. 2003). Furthermore, open bites are typical linked with vertical excess and asymmetry in occlusion can reflect skeletal asymmetric problems (Proffit et al. 2003). However, clinically assessed occlusal characteristics do not always indicate skeletal discrepancies. Therefore, diagnosis of malocclusion and dentofacial deformity is based, at minimum, on clinical examination, dental cast measurements, dental and facial photographs and radiologic analysis, all of which must be brought together when determining the overall diagnosis and treatment plan.

2.1.2 Occlusal measures

Occlusal characteristics are normally assessed in clinical examination by measuring single traits of occlusion, but diagnostic classifications do not provide a measure of the severity of malocclusion. Thus, various standardized indices have been developed in an attempt to measure occlusal disharmonies for research and clinical purposes.

The Index of Orthodontic Treatment Need (IOTN), developed by Brook and Shaw (1989), measures the orthodontic treatment need based on the severity of malocclusion. IOTN includes two elements: the Dental Health Component (DHC) and the Aesthetic component (AC). DHC classifies the orthodontic treatment need based on the worst single feature of malocclusion. AC includes a set of 10 standard photographs based on which a patient’s dental esthetics can be compared (Evans & Shaw 1987, Brook & Shaw 1989). The AC is used as an independent research variable in studies assessing normative and self-evaluated orthodontic treatment need or evaluating treatment success (Birkeland et al. 1997, Kerosuo et al. 2000, Liu et al. 2011). IOTN is a widely used index in prioritizing the treatment need and assessing the severity of malocclusion.

Another commonly used index is the Peer Assessment Rating (PAR) Index, which was developed in order to compare pre- and post-orthodontic treatment effectiveness and treatment outcome quantitatively (Richmond et al. 1992a). The PAR index includes five components (anterior segments, buccal occlusion, overjet,
overbite/open bite and centerline), which are scored from dental casts and summed to produce an overall total score. The features recorded for anterior segments are crowding, spacing and impacted teeth. For buccal occlusion the fit of the teeth in antero-posterior, vertical and transverse dimensions are recorded. The overjet is measured to score overjet of incisors, and anterior cross-bite and the overbite/open bite vertical relationship of incisors. Centerline records the difference between the upper and lower dental midlines. In British weightings, the overjet, overbite and centerline scores are multiplied by weighting factors of 6, 2 and 4, respectively (Richmond et al. 1992a).

Besides IOTN and PAR index, occlusal indices such as the Treatment Priority Index (Grainger 1967), the Occlusal Index (Summers 1971), the Dental Aesthetic Index (WHO 1989) and the Index of Complexity, Outcome and need (Daniels & Richmond 2000) have been developed to determine the need or priority for orthodontic treatment or treatment outcome. In Finland, a 10-Grade Scale, based on the study of Heikinheimo (1989), is recommended to be used in public dental health in order to assist professionals to categorize the orthodontic treatment need. Standardized approaches enable harmonization in the evaluation of orthodontic treatment need, success and outcome, in terms of occlusal perspectives.

2.1.3 Malocclusions in adults

Malocclusions are highly prevalent in all age groups in most populations (Salonen et al. 1992, Brunelle et al. 1996, Buttke & Proffit 1999, Hägg et al. 2002, Thilander et al. 2001, Keski-Nisula et al. 2003, Pietilä & Nordblad 2008, Bock et al. 2011). For instance, according to the results of the third National Health and Nutrition Examination Survey (NHANES III), it has been estimated that approximately 50-70% of white adult population has at least moderate degrees of malocclusion (Proffit et al. 1998). Prevalence proportions of different characteristics have large ethnic variation: e.g. Class II malocclusion is frequent in white and blacks, whereas Class III has three times higher prevalence in Asians compared to blacks or whites (Proffit et al. 1998).

In the third National Health and Nutrition Examination Survey, the prevalence of severe Class II and Class III malocclusions (large overjet 7 mm or more, reverse overjet at least -3 mm) in white adult population was estimated to be about 4%, Class II being most prevalent (Proffit et al. 1998). Deep bite (overbite 5 mm or more) was found in 13% and severe open bite (negative overbite 2 mm or more) in less than 1% of the white adult population.
In a Finnish population-based survey, 31% of dentate adults had at least one feature of malocclusion that was severe enough to be an obvious risk for poor prognosis of occlusion (Pietilä & Nordblad 2008). The most commonly occurring malocclusion was cross-bite in 18% of the subjects. Scissors bite was found in 6%, large overjet (7 mm or more) in 7%, traumatic overbite in 4% and open bite in 2% of the population. Ten per cent of the adults had undergone orthodontic treatment.

Even though current practices favor treatment during the growth phase, many severe cases still require surgical treatment in adulthood. The occurrence of severe malocclusions in adult population is also explained by limited access to orthodontic treatment during growth. Some patients may also have refused or interrupted treatment in adolescence, but seek treatment later due to functional and/or esthetic disadvantages. Although children comprise the majority of orthodontic patients, it has been recognized that the number of adults seeking orthodontic and orthodontic-surgical treatment has continued to increase (Nattrass & Sandy 1995, Buttke & Proffit 1999, Proffit et al. 2013).

2.1.4 Treatment seeking and indications for treatment

Esthetic reasons, functional reasons, temporomandibular disorders (TMD), headache and reasons related to self-esteem and self-confidence have most commonly been reported as motivation factors to seek orthodontic/orthodontic-surgical treatment, but the percentages of reported motivation factors vary considerably between different studies (McKiernan et al. 1992, Hoppenreijs et al. 1999, Nurminen et al. 1999, Bailey et al. 2001, Zhou et al. 2001a, Siow et al. 2002, Pahkala & Kellokoski 2007, Espeland et al. 2008, Pabari et al. 2011, Trovik et al. 2012). Motivation and treatment seeking may also be influenced by psychosocial factors, cultural values, treatment costs, age, expected treatment outcomes and gender (Kiyak et al. 1981, Rivera et al. 2000). It has also been shown that patients’ own reasons for orthodontic-surgical treatment may differ from patient-perceived recommendations (Rivera et al. 2000). Furthermore, patients’ perception of the need of orthodontic treatment is not always in line with professional assessment (Hassan 2006).

Generally, women are more likely to seek treatment and, overall, experience more impairment related to malocclusion than men (Kiyak et al. 1981). A gender difference has been found in both functional and esthetic reasons for seeking treatment. It has been shown that men are less concerned about self-perceived
dental appearance and report a more favorable overall body image than women (Hoppenreijs et al. 1999, Lazaridou-Terzoudi et al. 2003). Furthermore, women are more likely to report improvement in self-confidence as one of the motivation factors for orthodontic-surgical treatment compared to men (Siow et al. 2002). Women also have higher prevalence of TMD and pain conditions, which increase treatment seeking (Rivera et al. 2000).

In Finland, orthodontic care is publicly funded by municipalities and provided free of charge for those children and adolescents whose malocclusions fill the criteria of orthodontic treatment need (Pietilä et al. 2004). For adults, publicly funded, partly subsidized orthodontic care is offered only for the most severe cases with consequential functional disorders. This orthodontic treatment for adults is provided as part of specialized medical care at hospitals (Forss 2009).

2.1.5 Treatment of severe malocclusions

After growth has ceased, treatment of severe malocclusion is possible by either orthodontic treatment or combined orthodontic-surgical treatment.

Orthodontic treatment is indicated for malocclusions that lead to functional problems, esthetic impairment or trauma. In young adults, occlusion based on harmonic skeletal relationships can be still achieved without surgery with functional appliances (e.g. the Herbst appliances). In cases with skeletal discrepancy without any growth potential left, occlusion can often be improved with camouflage treatment if the skeletal discrepancy is not severe or if the patient has refused the recommended surgical treatment. In these cases, however, compromises in appearance have to be accepted.

Orthodontic-surgical treatment is indicated when dentofacial problems are too severe to treat with orthodontics alone (Proffit & White 1990). The most frequently used surgical techniques are the sagittal ramus osteotomy (SRO) for the mandible and the LeFort I osteotomy for the maxilla (Proffit & White 1990, Zins et al. 2008). When the discrepancy between the maxilla and mandible is very large, bimaxillary surgery is indicated (Proffit & White 1990). Orthognathic surgery enables correcting sagittal, vertical and transversal skeletal discrepancies.

Adult patients generally have high treatment expectations compared to children (Nattrass & Sandy 1995). Nevertheless, studies have shown high satisfaction levels with combined orthodontic-surgical treatment; in most studies satisfaction rates have been more than 90 per cent (Cunningham et al. 1996, Nurminen et al. 1999, Siow et al. 2002, Espeland et al. 2008, Trovik et al. 2012).
2.2 Temporomandibular disorders (TMD) and facial pain

TMD is a collective term for a number of clinical problems that involve the masticatory muscles, temporomandibular joints (TMJs), and associated structures (de Leeuw 2008). The most important signs and symptoms of TMD include TMJ sounds, limited jaw opening capacity, deviations in mandibular movements, pain in masticatory muscles and TMJs and facial pain, (Okeson 2013). Malocclusion and dentofacial deformities can occur with signs and symptoms of TMD and facial pain (Panula et al. 2000, Abrahamsson et al. 2013), and they are thus common motivation factors for adults to seek treatment (Forssell et al. 1998, Alanko et al. 2010).

Several classification methods for TMD have been designed (Okeson 1997). Helkimo’s indices (Helkimo 1974) were developed for epidemiologic purposes in the diagnosis of TMD. Helkimo’s indices classify the severity of TMD based on the anamnestic index (Ai) and the clinical dysfunction index (Di). Ai denotes subjective symptoms of dysfunction: TMJ sounds (clicking and crepitation), feeling of stiffness or fatigue of the jaws, difficulties in wide opening the mouth, locking, luxations, pain on movement, and facial and jaw pain. Di is based on the evaluation of five clinical signs: impaired range of movement, impaired function of TMJ, muscle pain on palpation, TMJ pain on palpation, and pain on movement of the mandible. The total scores of the indices indicate the severity of TMD.

In 1990, the American Academy of Orofacial Pain (AAOP) established the first well-defined diagnostic classification for TMD, which was updated in 1996 (Okeson 1996). During the last 20 years, the most widely used classification method in TMD research has been the Research Diagnostic Criteria for TMD (RDC/TMD) (Dworkin & LeResche 1992). Unlike Helkimo’s indices, RDC/TMD is non-hierarchical, but it provides a dual diagnosis that recognizes both physical diagnoses (Axis I) and psychological factors (Axis II). RDC/TMD has further been developed into the Diagnostic Criteria for TMD (DC/TMD), which has been developed for both clinical and research purposes (Schiffman et al. 2014).

Mild TMD signs and symptoms (e.g. TMJ sounds) are common in normal population. For example, based on a large population-based survey, Health 2000, 38% of adult Finns were found to have at least one sign of TMD in (Rutkiewicz et al. 2006). In another large Finnish population-based survey, the Northern Finland Birth Cohort 1966 comprising Finnish young adults (in the year 1997), the prevalence of facial pain during one-year period was found to be 12.2% among men and 17.9% among women (Rauhala et al. 2000). However, only a small proportion of the
cases reporting TMD symptoms are severe enough to seek treatment. Namely, the treatment need for TMD was found to be only 6% among randomly selected Finnish subjects during a two-year follow-up (Kuttila et al. 1997).

According to studies, women are more likely than men to have TMD signs and symptoms and facial pain (LeResche 1997, Schmid-Schwap et al. 2013). Epidemiological studies disclose that TMD symptoms are most frequent in age groups between 20 and 40 years and twice as common among women as among men (Dworkin et al. 1990, LeResche 1997). The higher prevalence of orofacial pain, headache and pain tenderness on palpation of masticatory muscles among women has been found in clinical studies as well (Egermark et al. 2000, Sanders & Slade 2011, Schmid-Schwap et al. 2013).

The etiology of TMD is considered to be complex and multifactorial, with structures, occlusion, craniofacial morphology, function, joint hypermobility, trauma, stress and psychological factors as possible risk or contributing factors (Seligman & Pullinger 1991, Pullinger et al. 1993, Huang et al. 2002, Slade et al. 2007, Mladenovic et al. 2013). The significance of occlusion in TMD is still in debate. It has been suggested that occlusal condition may relate to TMD by two mechanisms: acute changes in occlusion can create a protective muscle co-contraction response, or occlusion can affect stability of the mandible as it loads against the cranium (Okeson 2013). However, in the case of malocclusion the results are controversial. In a review article Luther (1998) concluded that based on available evidence, it seems that neither the possession of a malocclusion nor orthodontic treatment can be said to cause or cure TMD. In a systematic review by Mohlin et al. (2007), the majority of the 58 reviewed articles failed to identify a significant or clinically important association between malocclusion and TMD. According to the study of Pullinger and Seligman (2000), occlusal characteristics are co-factors in the development of TMD in only a small proportion of patients, and the majority of the associated factors seem to be non-occlusal. In addition, some occlusal variations, such as anterior open bite in adults, may be a consequence rather than an etiologic factor for TMD (Pullinger & Seligman 1991, Pullinger et al. 1993).

Factors that have been found to be associated especially with facial pain are parafunctional activity, depression, health anxiety and chronic widespread pain (Aggarwal et al. 2010, Glaros & Williams 2012). Certain occlusal factors (occlusal interferences and tooth contact) have been suggested to have a role in the development of facial pain (Rauhala et al. 1999, Lambourne et al. 2007, Sonnesen & Svensson 2008, Glaros & Williams 2012).
Even though the current consensus suggests that there is no a causal link between TMD and occlusion, the prevalence of the signs and symptoms of TMD has been found to be higher in malocclusion patients compared to the normal population (Celic et al. 2002, Egermark et al. 2003, Miller et al. 2004, Abrahamsson et al. 2013). The malocclusion types which have been suspected to associate to some degree with TMD include mesial occlusion, cross-bite, anterior open bite, deep bite, Angle Class II/III occlusion and extreme maxillary overjet (Alamoudi 2000, Pullinger & Seligman 2000, Celic et al. 2002, Thilander et al. 2002, Sipila et al. 2006, Schmitter et al. 2007, Selaimen et al. 2007, Sonnesen & Svensson 2008, Barrera-Mora et al. 2012). In contrast, some authors have not found any association between occlusal features and TMD (John et al. 2002, Landi et al. 2004). John and co-workers (2002) carried out a large population-based study and failed to find any relationship between overbite, overjet and self-reported TMD symptoms.

According to current knowledge, orthodontic treatment does not increase the risk for or worsen pre-treatment TMD signs and symptoms, but there is also an agreement of the lack of evidence (Henrikson & Nilner 2000, Mohlin et al. 2007, Rey et al. 2008, Michelotti & Iodice 2010). The effects of orthodontic-surgical treatment for signs and symptoms of TMD in patients with preoperative TMD are individual and cannot always be predicted. Studies have reported improvement in TMD signs and symptoms after orthognathic surgery (Egermark et al. 2000). Even though the majority of patients with skeletal malocclusion and TMD benefit from the surgical treatment, some of the patients show deterioration (Hoppenreijs et al. 1999, Panula et al. 2000, Westermark et al. 2001). The largest variation in post-surgical results has been found in TMJ sounds; clicking is more likely to improve than deteriorate after surgery, but crepitus does not seem to be affected by surgery (Al-Riyami et al. 2009).

It has been found that both self-reported facial pain and clinically assessed pain on masticatory muscle palpation tend to decrease after orthognathic surgery (Al-Riyami et al. 2009). The possible positive effect may be due to balanced occlusion, corrected asymmetry, corrected facial height or reduced emotional stress.

Studies have found a substantial influence of TMD and facial pain on OHRQoL in TMD patients but there is lack of evidence of these associations in malocclusion patients (Murray et al. 1996, John et al. 2007, Hunter 2011, Miettinen et al. 2012). Dahlström and Carlsson (2010) conducted a systematic review of 12 articles and concluded that subjective TMD symptoms had a greater impact on OHRQoL than did clinical findings of TMD, and that the more painful and severe the TMDs were, the greater the impact was.
2.3 Esthetic considerations

The severity of malocclusion is related to the degree of dental and facial esthetic impairment (Kiekens et al. 2006, Badran 2010). Typical malocclusion-related dental esthetic problems are crowding, spacing, rotations, increased/reverse overjet, increased overbite and open bite. Occlusal characteristics in anterior segments, such as spacing and incisal irregularity, have been found to have the most negative influence on self-perceived dental appearance (Bernabe & Flores-Mir 2007). The severity of malocclusion has been found to be associated with dental esthetics according to both self-perceived and examiner’s evaluation (Abu Alhaija & Al-Khateeb 2005, de Paula Junior et al. 2009, Badran 2010, Feu et al. 2010, Claudino & Traebert 2013). For instance, among Brazilian young males, subjects with severe malocclusion showed 88% higher prevalence of poorer esthetic self-perception when compared to those with minor malocclusion (Claudino & Traebert 2013).

Self-perceived dental esthetics usually correlates with professionals’ evaluation, although the correlation has been found to be weak or modest at best (Badran 2010, Alanko et al. 2014). It has also been found that the profession, gender and age of the rater affect the esthetic evaluation (Soh et al. 2006, Abu Alhaija et al. 2011, Olsen and Inglehart 2011, Pithon et al. 2012). Orthodontists are found to be more critical than general dentists or laypersons when assessing esthetics (Kokich et al. 2006). Moreover, orthodontists have also been reported to consider an attractive smile more important compared to general dentists or laypersons (Abu Alhaija et al. 2011).

Although the severity of malocclusion generally associates with self-perceived esthetics, some patients with severe malocclusions may be satisfied or indifferent with their appearance even with deviations while others are very concerned about minor irregularities (Hassan 2006). In addition to individual differences, women are usually found to be more critical in their perceptions of dental appearance and more critical of the impacts related to dental esthetics (Klages et al. 2004, de Paula Junior et al. 2009, Johnston et al. 2010).

Physical attractiveness is an important factor affecting social relationships. A compromised dental appearance due to malocclusion is associated with a greater risk of developing psychological problems, including unfavorable social response, negative stereotyping, and lower self-concept (Shaw et al. 1980, de Paula Junior et al. 2009, Badran 2010). Badran (2010) examined randomly selected adolescents and found that dissatisfaction with dental esthetics was associated with self-perceived unattractiveness and that dissatisfaction with dental appearance had a strong
predictive effect on self-esteem. Alanko et al. (2014) studied orthodontic-surgical patients before treatment and found that self-perceived dental appearance was more important to body image than dental appearance assessed by an orthodontist. Klages et al. (2006) investigated a group of young males and suggested that self-perceived dental irregularity and negative impact of dental esthetics might affect general dental health (plaque, sulcus bleeding and decayed/missing teeth), whereas previous extensive orthodontic treatment may have favorable effects by improving dental health compliance.

Previous qualitative research has indicated that adults with poor dental appearance may handle their situation in different ways: avoiding showing their teeth, underplaying the importance of appearance or seeking orthodontic treatment (Josefsson et al. 2010).

Studies concerning motivation for orthodontic and orthodontic-surgical treatment have found that almost all patients list appearance as one of the rationales for treatment (Siow et al. 2002, Williams et al. 2005, Pabari et al. 2011). Skeletal malocclusion influences facial appearance, which is one of the main motivation and satisfaction factors for patients undergoing orthodontic-surgical treatment (Zhou et al. 2001a, Zhou et al. 2001b). However, in a longitudinal study with a large sample of orthodontic-surgical patients, improvement of dental appearance was an even more important motivation factor for the patients than improvement of facial appearance (Espeland et al. 2008).

2.4 Oral health-related quality of life (OHRQoL) and malocclusion

2.4.1 The concepts of quality of life and OHRQoL

The concept of ‘quality of life’ (QoL) has been defined by the World Health Organization (WHO) as ‘individuals’ perceptions of their position in life in the context of culture and value systems in which they live, and in relation to their goals, expectations, standards, and concerns. It is a broad ranging concept affected in a complex way by the person’s physical health, psychological state, level of independence, social relationships, and their relationships to salient features of their environment’ (WHO study protocol 1993). In health-related quality of life (HRQoL), the focus is on those QoL components that are impacted by the disease (Guyatt et al. 1993). The interest in HRQoL has emerged from recognition that patient-oriented instruments are needed to complement clinical measurements.
The growing emphasis on HRQoL reflects the fact that improved subjective well-being is now regarded as one of the main goals of treatment, sometimes even more important than elimination of the disease or prolonging life.

Locker and Allen (2007) have defined OHRQoL as ‘a multidimensional concept that includes subjective evaluation of the perceived physical, psychological and social aspects of oral health’ and further as ‘the impact of oral disorders on aspects of everyday life that are important to patients and persons, with those impacts being of sufficient magnitude, whether in terms of severity, frequency or duration, to affect an individual’s perception of their life overall’. A remarkable influence of OHRQoL research has been the work of Locker. In 1988, Locker published a conceptual model to explain the biological, behavioral and psychological consequences of oral health. Thereafter, several indices based to the model have developed to measure OHRQoL (Locker & Allen 2007).

Locker’s conceptual model is based on the WHO’s first classification of impairment, disability and handicap (Fig. 1). The model links clinical conditions and their personal and social outcomes. The concepts in Locker’s framework include disease, impairment, death, functional limitations, discomfort, disability (physical, psychological and social well-being) and handicap. Although the original model included ‘death’, death rates are not useful indicators for common dental and oral disorders and hence the model has afterwards been presented without the dimension of ‘death’.
Fig 1. Locker’s conceptual model of oral health (Locker 1988).

Nuttall et al. (2006) tested Locker’s model in a large population sample of adults. Based on population responses, they created an empirically derived model that removed the pathways between the dimensions ‘impairment’ and ‘handicap’, ‘functional limitation’ with ‘disability’, and ‘functional limitation’ and ‘handicap’. The pathways were added between ‘impairment’ and ‘disability’, ‘functional limitation’ and ‘pain/discomfort’, and ‘pain/discomfort’ and ‘handicap’ (Fig. 2).
Fig 2. The empirically derived model of Nuttall et al. (2006). The original conceptual model was modified by removing pathways representing 0.1% or fewer of response combinations and by adding pathways that fitted more than 0.1% of response combinations (black arrows).

In the empirically derived model, the oral impacts were measured by using the 14-item Oral Health Impact Profile (OHIP-14), which is a widely used instrument in OHRQoL research. The OHIP was developed by Slade and Spencer (1994) and originally it consisted of 49 questions. The original 49-item OHIP was shortened to reduce respondent burden and facilitate research in practice (Slade 1997). Both the original 49-item OHIP and OHIP-14 have been shown to have good reliability, validity and precision (Slade 1997). The OHIP measures capture seven dimensions based on Locker’s conceptual model of oral health but does not measure the dimensions ‘disease’ and ‘impairment’. The OHIP-14 was originally tested on adults over 60 years, but the measure has subsequently been suggested to have at least equal relevance in people under 60 years old (Nuttall et al. 2006). OHIP-14 has been translated into multiple languages and experience with OHIP has been

Numerous other instruments have been drawn up in order to measure general HRQoL and OHRQoL (Locker & Allen 2007). Examples of generic HRQoL instruments are the Short-Form 36-item Health Survey (SF-36) (Ware & Sherbourne, 1992) and the Sickness Impact Profile (SIP) (Bergner et al. 1981). However, the majority of the SF-36 and SIP domains are not sensitive to changes in oral health. In addition to OHIP-14, other frequently used OHRQoL instruments are, among others, the Oral Impacts on Daily Performance (OIDP) (Adulyanon & Sheiham 1997) and Psychosocial Impact of Dental Aesthetics Questionnaire (PIDAQ) (Klages et al. 2006). Some indicators, such as the Orthognathic Quality of Life Questionnaire (OQLQ) (Cunningham et al. 2000, Cunningham et al. 2002), have been developed specifically for orthodontic-surgical patients. OQLQ has been designed to evaluate orthodontic-surgical patients only, which limits its use in orthodontic patients. Typically the OHRQoL indicators focus on problems in oral health, while few indicators have been designed to measure the positive effect of oral health. When comparing generic and disease-specific indicators, disease-specific indicators have been shown to have better discriminatory ability in relation to patients with dentofacial deformities (Lee et al. 2007, Lee et al. 2008).

2.4.2 Association between malocclusion and OHRQoL

Adults with malocclusion and dentofacial deformities generally have poorer OHRQoL than people with normal occlusion (Lee et al. 2007, Tajima et al. 2007, Hassan & Amin 2010, Rusanen et al. 2010, Liu et al. 2011a, Frejman et al. 2013). Furthermore, the severity of malocclusion reportedly associates with OHRQoL (Traebert & Peres 2005, Feu et al. 2010, Hassan & Amin 2010). Liu et al. (2009) concluded in a systematic review that malocclusion and orthodontic treatment need are associated with quality of life, but the strength of the association could at best be described as modest. However, the majority of studies included in the review concerned children or adolescents.

Although studies have shown that patients seeking orthodontic care have poorer OHRQoL compared to normal population, the association between malocclusion and OHRQoL among adults not seeking orthodontic treatment is still unclear. In a cohort study of Arrow et al. (2011), the occlusal status appeared to have limited
association with QoL and psychosocial factors. Heravi et al. (2011) studied randomly selected young males and found that malocclusion was significantly associated with poorer OHRQoL, but only with the oral symptoms dimension of OHRQoL, and not with functional limitations, emotional well-being or social well-being.

Studies among adolescents have indicated that girls are likely to report more oral impacts related to malocclusion than boys (de Oliveira & Sheiham 2004, Feu et al. 2010), but most researchers have not found this gender difference among adults (Al-Bitar et al. 2009, Hassan & Amin 2010, Masood et al. 2013).

Based on the literature, self-perceived dental and facial attractiveness seems to play an integral role in perceived OHRQoL. Klages et al. (Klages 2004) showed a direct link between self-perceived dental esthetics and psychosocial well-being among university students, the effect being more significant in subjects with high self-consciousness. Feu et al. (2010) studied adolescents who were seeking orthodontic treatment and found that self-perceived esthetics was more useful in identifying differences in OHRQoL than dental esthetics evaluated by the examiner. They also suggested that severely compromised esthetics is a better predictor for worse OHRQoL than treatment seeking. Furthermore, Traebert and Peres (2005) conducted a study among randomly selected young males and found that incisal crowding, anterior maxillary irregularity and large overjet had an impact on QoL, especially in terms of satisfaction with appearance, while the molar relationship did not have an impact.

In a review of Kiyak (2008), the author concluded that patients focus primary on esthetic and social aspects of OHRQoL as a motive for seeking orthodontic treatment. The type of malocclusion did not affect patients’ OHRQoL as much as its severity or visibility.

2.4.3 Impact of treatment of malocclusion on OHRQoL

Treatment of malocclusion has been shown to be associated with improved OHRQoL (Choi et al. 2010, Palomares et al. 2012). The majority of studies have concerned orthodontic-surgical treatment, and the effect on conventional orthodontic treatment on OHRQoL has mostly been studied in children and adolescents (Cunningham & Hunt 2001, Liu et al. 2009, Zhang et al. 2006, Zhou et al. 2014).
Impact of conventional orthodontic treatment on OHRQoL

In a large study of Brazilian adolescents, those participants who had completed orthodontic treatment reported fewer oral impacts (OHIP-14) compared to adolescents who were currently undergoing treatment and those who had never had treatment (de Oliveira & Sheiham 2004). Also in a study among Brazilian adolescents, orthodontic treatment with fixed appliances showed significantly improved OHRQoL, particularly in terms of psychological discomfort and psychological disability (Feu et al. 2013). It is notable that malocclusion has generally been found to be associated with psychosocial discomfort but not with oral symptoms or functional limitations in children or adolescents (Kiyak 2008).

To date, only little data exist on the effect of conventional orthodontic treatment on OHRQoL in adults. Liu and co-workers (2011b) investigated changes in OHRQoL during fixed orthodontic appliance treatment and found a deterioration in OHRQoL measured by OHIP-14, particularly in the early phase of treatment, but they did not report a post-treatment outcome of OHRQoL. Gazit-Rappaport et al. (2010) reported a significant improvement on OHRQoL after orthodontic treatment among patients with milder dental malocclusion. The improvement was found especially in dental self-confidence, and psychological and social aspects of oral health. Also, in a cross-sectional study among young Brazilian adults, patients who had completed orthodontic treatment had significantly better OHRQoL than did patients who were waiting for treatment (Palomares et al. 2012). In contrast to most of the studies in this field, Arrow et al. (2011) found that the need of orthodontic treatment in adolescents was not associated with OHRQoL in adulthood, but appeared to be negatively associated with self-esteem and satisfaction with life. Zhou et al. (2014) concluded in a review that the strength of the association between orthodontic treatment and OHRQoL could at best be described as modest.

Impact of orthodontic-surgical treatment on OHRQoL

The positive effect of combined orthodontic-surgical treatment on OHRQoL has been documented in several longitudinal studies in different skeletal malocclusion types like Class II and Class III malocclusions (Hatch et al. 1998, Motegi et al. 2003, Lee et al. 2008, Nicodemo et al. 2008). However, the results obtained by Schmidt et al. (2013) indicate that skeletal malocclusion patients have lower OHRQoL after orthodontic-surgical treatment compared to general population.
There are some studies that have used both generic and disease-specific instruments to study the effects of orthodontic-surgical treatment. While a significant improvement on OHRQoL has been found in these studies, there is controversy regarding the treatment effect on generic HRQoL. Some authors have reported improvement in both OHRQoL and generic HRQoL after surgical correction (Hatch et al. 1998, Motegi et al. 2003) while others have only found an improvement in OHRQoL (Azuma et al. 2008, Lee et al. 2008).

Orthognathic surgery is a demanding procedure with a recovery period lasting weeks to months, and thus improvement in OHRQoL is not seen immediately. A deterioration in aspects related to general well-being has been noted in the early postoperative period, but a significant reduction in oral impacts has already been reported 6 months postoperatively (Lee et al. 2008, Choi et al. 2010). In a study with a long follow-up period, the improvement of OHRQoL remained stable between 2 and 5 years, suggesting that improvement after treatment is permanent (Motegi et al. 2003).

Orthodontic-surgical treatment has been found to improve psychological and social functioning more than physical functioning of OHRQoL (Motegi et al. 2003, Lee et al. 2008). Factors that have been found to correlate with higher OHRQoL scores are satisfaction with treatment outcome, improvement in social interactions and improvement of orofacial pain (Schmidt et al. 2013).

Although findings of recent research support the association between malocclusion and oral impacts, the longitudinal studies to date have tended to focus on orthodontic-surgical patients. Moreover, only few studies have been focused on associations between malocclusion-related factors and OHRQoL. Consequently, greater understanding of these associations is needed in order to improve the quality of orthodontic and combined orthodontic-surgical treatment, particularly when assessing treatment indication and treatment outcome.
3 Aims of the study

The aim of this study was to determine the association between severe malocclusion and oral health-related quality of life (OHRQoL) in adult patients who undergo combined orthodontic-surgical or orthodontic treatment.

The specific research objectives were:

1. To investigate the pathways between the signs of TMD, severity of malocclusion, facial pain and OHRQoL (I).
2. To investigate the associations of changes in OHRQoL with the changes in the severity of malocclusion, facial pain, and signs and symptoms of TMD during treatment (II, III).
3. To study the association between satisfaction with dental esthetics and OHRQoL, and satisfaction with dental esthetics in relation to esthetic evaluations of three panel groups before and after treatment (IV).
4 Subjects and methods

4.1 Subjects

One hundred and sixty-nine adults were screened for the investigation. All the patients were referred for orthodontic treatment to the Oral and Maxillofacial Department at Oulu University Hospital, Finland, during the years 2001-2004. The inclusion criteria were severe malocclusion with considerable functional problems. The original study group comprised 99 adult patients, all of whom had severe skeletal malocclusion, diagnosed by cephalometry, with considerable functional problems like pain or difficulty in mastication or traumatic occlusion. Five participants were excluded from the study for missing values (missing OHIP items 3 or more). Distribution of the patients according to their malocclusion is described in Table 1. All the patients were diagnosed to have one or more type of malocclusion.

Table 1. Distribution of the patients according to their malocclusion (n=94). All the patients had one or more type of malocclusion.

<table>
<thead>
<tr>
<th>Malocclusion type</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class II malocclusion</td>
<td>48</td>
<td>51</td>
</tr>
<tr>
<td>Class III malocclusion</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Deep bite (&gt; 4 mm)</td>
<td>49</td>
<td>52</td>
</tr>
<tr>
<td>Anterior open bite</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Lateral cross-bite</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>Scissor-bite</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Lateral open bite</td>
<td>23</td>
<td>24</td>
</tr>
</tbody>
</table>
4.1.1 Panel groups

In substudy IV, three panel groups evaluated series of oral pretreatment and follow-up photographs. Three panel groups comprised ten orthodontists (2 males, 8 females, mean age 46.1 years, range 36–56 years), a convenience sample of 30 laypersons (16 males, 14 females, mean age 34.7 years, range 21–62 years) and 30 fourth-year dental students from the University of Oulu, Finland (9 males, 21 females, mean age 25.5 years, range 22–32 years). The socio-economic background of the non-dental judges varied greatly, but they were not connected to dentistry.

4.2 Methods

The patients underwent orthodontic or combined orthodontic-surgical treatment during the years 2002-2006. The surgical techniques used were SRO (sagittal ramus osteotomy) and/or LeFort I osteotomy. Mean active treatment time was 2.0 years (range 1.3–3.7 years).

Only the patients with adequate data were included in the further analysis. The patients with more than 2 missing OHIP items were excluded as were the patients with edentulous maxilla or mandible in substudies II and IV and with regard to occlusal measurements in substudy I (Table 2). The demographic characteristics in studies I-IV of patients are described in detail in Table 3. The flow chart of the subjects through each stage of study is presented in Figure 3. Analysis of the loss of the subjects were conducted for Study II, which has the largest loss, but no statistically significant differences were found in gender, age, oral impacts or PAR scores between follow-up subjects and the subjects who declined to participate in the study.

Standardized self-completed questionnaires were collected and clinical examination performed before treatment and an average of three years after treatment. Dental casts were collected before treatment and on average 1.5 years after treatment. The questionnaire included the social-economic background and questions concerning OHRQoL, satisfaction with esthetics, facial pain and symptoms of TMD. Standardized oral photographs were taken of the patients before treatment and on average of three years after active treatment. All the photographs were taken in frontal view, with the teeth in intercuspal position using lip retractors. A summary of the study procedures and timelines of the substudies is shown in Figure 4.
Table 2. Inclusion and exclusion criteria in the substudies I-IV.

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe malocclusion with related functional problems</td>
<td>I-IV Missing OHIP items ≥ 3</td>
</tr>
<tr>
<td>Age ≥ 18 years</td>
<td>I (in PAR measurements):</td>
</tr>
<tr>
<td></td>
<td>Inadequate dental casts</td>
</tr>
<tr>
<td></td>
<td>Edentulous maxilla or mandible</td>
</tr>
<tr>
<td></td>
<td>II Inadequate dental casts</td>
</tr>
<tr>
<td></td>
<td>Edentulous maxilla or mandible</td>
</tr>
<tr>
<td></td>
<td>IV Edentulous maxilla or mandible</td>
</tr>
</tbody>
</table>

Table 3. Demographic characteristics of the study groups.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Study I</th>
<th>Study II</th>
<th>Study III</th>
<th>Study IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients (n)</td>
<td>94</td>
<td>51</td>
<td>64</td>
<td>52</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>60</td>
<td>35</td>
<td>46</td>
<td>36</td>
</tr>
<tr>
<td>Males</td>
<td>34</td>
<td>16</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Age (y)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>38</td>
<td>37</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>Range</td>
<td>18-64</td>
<td>18-61</td>
<td>18-64</td>
<td>18-61</td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthodontic-surgical</td>
<td>36</td>
<td>44</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Orthodontic</td>
<td>15</td>
<td>20</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>
Fig 3. Flow chart of the subjects through each stage of the study. Inclusion criteria were severe malocclusion with considerable functional problem.
Fig 4. Timeline showing the average timings of the questionnaires, dental impressions, oral photographs, and the clinical examinations performed before treatment and after active treatment in the substudies I-IV.
4.2.1 Questionnaire (I–IV)

OHRQoL (I–IV)

The oral health-related quality of life was measured using a Finnish translation of the 14-item Oral Health Impact Profile (OHIP-14), which has been used earlier in a nationally representative survey to get population estimates for prevalence, extent and severity (Lahti et al. 2008). OHIP-14 includes seven conceptual dimensions of OHRQoL (Slade & Spencer 1994) (Table 4).

The frequency of each impact was asked during the preceding month on an ordinal five-point scale. Responses were coded as follows: 0 = ‘never’, 1 = ‘hardly ever’, 2 = ‘occasionally’, 3 = ‘fairly often’ and 4 = ‘very often’. The OHIP-14 severity score (potential range 0–56) was calculated by summing ordinal values for 14 items (I–IV). Item-specific responses were categorized by using two cut-off points: FoVo (‘fairly often’, ‘very often’) and OFoVo (‘occasionally’, ‘fairly often’, ‘very often’). The extent and prevalence scores were calculated using both cut-off points (II, III). The extent score is the number of items reported (potential range 0–14). The prevalence is the percentage of people reporting one or more items. Higher OHIP scores indicate worse and lower scores indicate better OHRQoL. For cases with one or two missing OHIP items, values were imputed using the item’s sample mean.
Table 4. The questions of the Oral Health Impact Profile (OHIP-14).

<table>
<thead>
<tr>
<th>OHIP dimension</th>
<th>OHIP item</th>
<th>Description</th>
</tr>
</thead>
</table>
|                | How often have you had problems with your teeth, mouth or dentures during the previous month? 0=“never”, 1=“hardly ever”, 2=“occasionally”, 3=“fairly often” and 4=“very often”.
| Functional limitation | 1 | Have you had trouble pronouncing any words because of problems with your teeth, mouth or dentures? |
| | 2 | Have you felt that your sense of taste has worsened because of problems with your teeth, mouth or dentures? |
| Physical pain | 3 | Have you had painful aching in your mouth? |
| | 4 | Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures? |
| Psychological discomfort | 5 | Have you felt self-conscious because of problems with your teeth, mouth or dentures? |
| | 6 | Have you felt tense because of problems with your teeth, mouth or dentures? |
| Physical disability | 7 | Has your diet been unsatisfactory because of problems with your teeth, mouth or dentures? |
| | 8 | Have you had to interrupt meals because of problems with your teeth, mouth or dentures? |
| Psychological disability | 9 | Have you found it difficult to relax because of problems with your teeth, mouth or dentures? |
| | 10 | Have you been a bit embarrassed because of problems with your teeth, mouth or dentures? |
| Social disability | 11 | Have you been a bit irritable with other people because of problems with your teeth, mouth or dentures? |
| | 12 | Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures? |
| Handicap | 13 | Have you felt that life in general was less satisfying because of problems with your teeth, mouth or dentures? |
| | 14 | Have you been totally unable to function because of problems with your teeth, mouth or dentures? |

Facial pain symptoms (I, III)

Prevalence of facial pain was asked in the pre-treatment questionnaire with the following question: “Have you had pain in the face during the last 12 months?” with response options no/now and then/fairly often/often or continuously. If the patient reported facial pain, the patient was asked to assess the intensity of facial pain with a Visual Analogue Scale (VAS) with the following instruction:
“Mark the intensity of facial pain at the moment on the pain line. If you do not have any pain at the moment, think about the pain during the last 12 months”. The VAS had anchor points at the left- (no pain) and right-hand (worst pain imaginable) ends of a 100-mm horizontal line. If the patient reported having no facial pain, the VAS value was coded as 0.

In the post-treatment questionnaires, prevalence of facial pain was asked as follows: “Have you had pain in the face during the last week” with the same response options as previously. If the patient reported facial pain, the patient was asked to assess the intensity of facial pain with VAS scale with the instruction “Mark the intensity of facial pain at the moment on the pain line. If you do not have any pain at the moment, think about the pain during the last week”. The anchor points were similar with the pre-treatment questionnaire.

**Symptoms of TMD (I, III)**

The severity of TMD symptoms was measured with Helkimo’s anamnestic dysfunction index (Ai) and classified according to anamnestic dysfunction index as 0 (no symptoms), I (mild symptoms: joint noises or a feeling of tiredness or stiffness of jaws) and II (severe symptoms: pain in masticatory muscles or TMJ, difficulties in opening mouth, locking, or luxation of jaws) (Helkimo 1974).

**Satisfaction with dental esthetics (IV)**

Self-rated satisfaction with dental esthetics was measured by using the 100-mm VAS scale by the question: “How satisfied are you with your current dental appearance?” A response of 0 mm meant “very satisfied” and a response of 100 mm meant “very unsatisfied”.

**4.2.2 Clinical examination (I, III)**

The clinical examinations were conducted by three dentists trained by one dentist specialized in stomatognathic physiology. The degree of TMD was assessed using the total score of Helkimo’s clinical dysfunction index (Di) (Helkimo 1974). The Di is based on the evaluation of five clinical signs: impaired range of movement, impaired function of TMJ, muscle pain, TMJ pain, and pain on movement of the mandible. The signs of TMD were classified with the standardized classification of Helkimo: Di 0 (0 points, no signs and symptoms), Di I (1–4 points, mild TMD), Di II (5–9 points, moderate TMD) and Di III (10–25 points, severe TMD).
4.2.3 Dental cast measurements (I, II)

The severity of malocclusion was assessed using the Peer Assessment Rating (PAR) index (Richmond et al. 1992a). The PAR index consists of five components: an anterior segment, buccal segments, overjet, overbite and midline. The individual scores of the components were weighted according to British weightings and summed to the weighted PAR score (Richmond et al. 1992a). Higher scores indicated increased levels of irregularity and malocclusion. In cases with an individual missing a tooth, a space of more than 4 mm was not recorded if the patient was to receive a prosthetic replacement. One examiner (AS), trained and calibrated for the use of the PAR index, scored the dental casts.

4.2.4 Esthetic evaluation (IV)

A series of oral photographs comprising the study group’s pre-treatment and follow-up photographs were set in random order and numbered.

The panel groups (orthodontists, dental students and laypersons) rated the photographs using the Aesthetic Component (AC) of the Index of Orthodontic Treatment Need (IOTN) (Howells & Shaw 1985, Brook & Shaw 1989). The AC consists of ten dental color photographs illustrating attractiveness of occlusion, grade 1 being the most attractive and grade 10 the least attractive. Before judging the series of photographs, the tables with 10 reference photographs of AC were shared to the raters. The following instructions were presented to the panel groups:

“Assess dental esthetics of the photographs. Do not pay any attention to possible plaque, staining, retention arches, prosthesis etc.” Each photograph was shown for ten seconds during the slide show.

4.3 Ethical approval

The study was approved by the Ethics Committee of the Northern Ostrobothnia Hospital District, Finland, and informed consent was obtained from all patients.

4.4 Statistical analysis

The means and medians were calculated of the OHIP-14 severity, extent and prevalence scores in the substudies (I–IV). The percentage reductions of the pre- and post-treatment OHIP-14 scores were calculated. Changes occurring during follow-
up were normally distributed, thus statistical significances were evaluated using the paired samples t-tests (II–IV). The mean scores for the seven dimensions of OHIP-14 before and after treatment as well as the mean change scores were evaluated. The means of the OHIP-14 scores were calculated separately for both genders and both treatment groups (orthodontic-surgical treatment versus orthodontic treatment). Differences in OHIP scores between genders and treatment groups were evaluated using Mann Whitney U test (OHIP-14 severity and extent) and $\chi^2$-test (OHIP-14 prevalence) before and after treatment. The statistical significance of changes in OHIP scores during the follow-up was evaluated for genders and treatment groups using the Wilcoxon signed-rank test.

In Study I, the mean values and 95% confidence intervals were calculated for OHIP-14 severity, Di, PAR and facial pain measured with VAS. The mean values were calculated separately for men and women, and statistical significance of the differences was evaluated with $t$-test. A hypothetical model of the interrelationships between TMD signs, severity of malocclusion, facial pain and OHRQoL was constructed based on Locker’s conceptual model of oral health (Locker 1988) (Fig. 5). Path analysis (PA) was conducted to test if the hypothetical model fits the data. Since a gender difference was found in Di and facial pain measured with VAS, further gender-specific analyses were conducted. Models were modified for best fitting by weighting non-significant paths to 0 (i.e., no effect). Standardized estimates were calculated.

**Fig 5. Hypothetical model of associations between temporomandibular disorders, occlusal characteristics, facial pain, and oral health-related quality of life (OHRQoL).**
For Studies I and II, the intra-observer error of the PAR measurements was evaluated by rescoring twenty randomly selected dental casts. The repeated measurements were compared using intraclass correlation (ICC). The correlation was 0.99 in weighted PAR scores.

In Study II, the post-treatment PAR and OHIP-14 scores were asymmetrically distributed, therefore, non-parametric methods were used. Pre-treatment PAR and OHIP-14 scores and the changes in PAR and OHIP scores were normally distributed, hence, parametric tests were used when studying those. The means and medians of the PAR scores were calculated and the statistical significances were evaluated using the paired samples t-test. Differences in PAR scores between treatment groups (orthodontic-surgical treatment vs. orthodontic treatment) were evaluated using t-tests and Mann-Whitney U-test. The reduction and the percentage reduction of the pre- and post-treatment weighted PAR scores were calculated. The correlation between PAR total scores and OHIP-14 severity scores was assessed before and after treatment, and between the changes during the follow-up period, using Pearson’s and Spearman’s correlation coefficients. The cases were also divided into categories based on the change in PAR: ‘Worse/No different’, ‘Improved’ and ‘Greatly improved’. In order for a case to be ‘Improved’, the PAR score had to be reduced by at least 30 per cent. For a case to be ‘Greatly improved’, the score had to be reduced by at least 22 PAR points (Richmond et al. 1992b). The mean scores for OHIP-14 severity, extent and prevalence were calculated for ‘Improved’ and ‘Greatly improved’ groups, and the statistical difference was evaluated using the paired samples t-tests. The groups were compared according to the changes in OHIP, and the independent samples t-test was used to test the statistical significance.

In Study III, changes in OHIP-14, facial pain (VAS) scores and Helkimo’s clinical dysfunction index were asymmetrically distributed, and therefore non-parametric methods were used in the analysis. Statistical significances of differences in facial pain VAS scores between male and female, and orthodontic-surgical and orthodontic patients at different time points were evaluated using Mann-Whitney U test. Statistical significances of differences in prevalence of pain in the face, Di and Ai between male and female, and orthodontic-surgical and orthodontic patients at different time points were evaluated using \( \chi^2 \)-test. Statistical significance of the changes occurring during the study was evaluated using Wilcoxon signed-rank test for facial pain (VAS), Di and Ai scores. McNemar’s test was used for OHIP-14 and facial pain prevalence scores. Associations between changes in OHIP-14 severity, facial pain, clinical dysfunction index and anamnestic dysfunction index scores were evaluated using Spearman’s correlation coefficients.
In Study IV, the mean values and their changes were calculated for patients’ aesthetic satisfaction, OHIP-14 severity and its dimensions and AC evaluated by laypersons, dental students and orthodontists before and after treatment, separately for both treatment groups and genders. Because changes occurring during the follow-up were normally distributed, statistical significances of the changes were evaluated with paired samples t-tests. Since no statistically significant differences were found between the orthodontic and orthodontic-surgical groups or genders in OHIP-14 severity scores, mean values for different dimensions or esthetic satisfaction before treatment, after follow-up or in the changes during the follow-up, further analyses were done for the entire study population. To investigate the relationship between esthetic satisfaction and OHRQoL, the study group was divided into subgroups according to esthetic satisfaction quartiles before and after treatment, and between these groups, OHIP-14 scores were evaluated using univariate GLM. Associations between changes in OHIP-14 scores and patients’ esthetic satisfaction and esthetic components evaluated by laypersons, dental students and orthodontists were evaluated with Pearson’s correlation coefficients.

The Statistical Package for Social Sciences version 16.0, 19.0 and 20.0 (SPSS Inc., Chicago, Illinois, USA), and AMOS version 16.0 (I) were used in statistical analysis. To handle missing data, AMOS uses Full Information Maximum Likelihood (FIML) procedure, which is an approach to the estimation of simultaneous equations (Graham et al., 2003).
5 Results

A synthesis of the results is reported without following the order of the original articles. Roman numerals refer to the original articles.

5.1 OHRQoL (I-IV)

The improvement in all OHIP variables (severity, extent, prevalence) and all dimensions was statistically significant during the follow-up period (p<0.001) (Table 5). The mean scores for the seven OHIP dimensions at both time points and the mean scores for change during the follow-up period are presented in Figure 6. Of the dimensions, physical pain was the most often reported impact before treatment. The greatest improvement was seen in psychological discomfort, followed by physical pain and psychological disability. After follow-up, physical pain was most often reported by the patients.
Table 5. Mean values of the scores of the Oral Health Impact Profile (OHIP-14) before orthodontic/orthodontic-surgical treatment (T1) and after the follow-up period (T2) (p-values of the t-tests). The Roman numerals indicate the original publications.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time point</th>
<th>Change %</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>OHIP-14 severity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>18.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>17.6</td>
<td>4.1</td>
<td>76.7</td>
</tr>
<tr>
<td>III</td>
<td>18.1</td>
<td>4.5</td>
<td>75.1</td>
</tr>
<tr>
<td>IV</td>
<td>18.4</td>
<td>4.7</td>
<td>74.5</td>
</tr>
<tr>
<td>Extent (Fovo)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>2.6</td>
<td>0.1</td>
<td>96</td>
</tr>
<tr>
<td>III</td>
<td>2.8</td>
<td>0.2</td>
<td>93</td>
</tr>
<tr>
<td>Extent (OFoVo)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>5.8</td>
<td>1.2</td>
<td>79</td>
</tr>
<tr>
<td>III</td>
<td>5.9</td>
<td>1.3</td>
<td>79</td>
</tr>
<tr>
<td>Prevalence (FoVo)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>71</td>
<td>10</td>
<td>86</td>
</tr>
<tr>
<td>III</td>
<td>71</td>
<td>11</td>
<td>85</td>
</tr>
<tr>
<td>Prevalence (OFoVo)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>94</td>
<td>49</td>
<td>48</td>
</tr>
<tr>
<td>III</td>
<td>94</td>
<td>52</td>
<td>45</td>
</tr>
</tbody>
</table>

Severity, sum of OHIP impacts (potential range 0-56); extent, number of items reported ‘fairly often’ or ‘very often’ (FoVo) or ‘occasionally’, ‘fairly often’ or ‘very often’ (OFoVo) (potential range 0-14); prevalence, the percentage of subjects reporting at least one OHIP impact.
As compared to men, women reported more oral impacts before treatment, but the gender difference in OHIP severity was not statistically significant. There were no statistically significant differences between the genders or orthodontic and orthodontic-surgical treatment groups in any of the OHIP scores (severity, extent, prevalence) before or after treatment (Table 6).
Table 6. Gender and treatment-specific mean values of the Oral Health Impact Profile (OHIP-14) scores before treatment (T1) and at follow-up (T2) (III).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time</th>
<th>All n=64</th>
<th>Gender</th>
<th>Treatment</th>
<th>Orthodontic-surgical n=44</th>
<th>Orthodontic n=20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n=18</td>
<td>Female</td>
<td>Orthodontic-surgical n=44</td>
<td>Orthodontic n=20</td>
<td></td>
</tr>
<tr>
<td>Severity mean</td>
<td>T1</td>
<td>18.1</td>
<td>16.2</td>
<td>18.8</td>
<td>18.3</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>4.5</td>
<td>4.2</td>
<td>4.6</td>
<td>4.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Prevalence (%)</td>
<td>T1</td>
<td>71</td>
<td>65</td>
<td>73</td>
<td>74</td>
<td>63</td>
</tr>
<tr>
<td>FoVo cut-off</td>
<td>T1</td>
<td>94</td>
<td>88</td>
<td>96</td>
<td>93</td>
<td>95</td>
</tr>
<tr>
<td>Prevalence (%)</td>
<td>T2</td>
<td>52</td>
<td>50</td>
<td>52</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>OFoVo cut-off</td>
<td>T1</td>
<td>2.8</td>
<td>2.2</td>
<td>3.0</td>
<td>2.8</td>
<td>2.6</td>
</tr>
<tr>
<td>FoVo cut-off</td>
<td>T2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Extent mean, FoVo cut-off</td>
<td>T1</td>
<td>5.9</td>
<td>5.2</td>
<td>6.2</td>
<td>6.0</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>1.3</td>
<td>1.0</td>
<td>1.3</td>
<td>1.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Severity, sum of OHIP impacts (potential range 0-56); prevalence, the percentage of subjects reporting at least one OHIP impact; extent, number of items reported ‘fairly often’ or ‘very often’ (FoVo) or ‘occasionally, fairly often’ or ‘very often’ (OFoVo) (potential range 0–14). All the changes between time points T1 and T2 were statistically significant (P<0.05, Wilcoxon test).

5.2 Pathways between TMD, pain, severity of malocclusion and OHRQoL (I)

A hypothetical model of the interrelationship between dysfunction index, facial pain (VAS), PAR total score, and OHIP severity score was tested. The constructed hypothesized model did not fit well for either gender, and the model was modified for women and men separately to fit the data. The modified models resulted in a very good fit and are shown in Figure 7. A gender difference was found in severity of malocclusion, which was directly associated with OHRQoL in men but not in women. In women, severity of malocclusion was associated with OHRQoL indirectly via facial pain.
Fig 7. Standardized estimates for females’ (F) and males’ (M) final modified path model of associations between TMD (as assessed using Helkimo’s clinical dysfunction index), severity of malocclusion (PAR), facial pain (as assessed using Visual Analogue Scale, VAS), and the severity score of the Oral Health Impact Profile (OHIP-14).

5.3 Association between changes in severity of malocclusion and OHRQoL (II)

The total PAR decreased on average by 78%, and the change was statistically significant in all PAR components ($P<0.001$) (Table 7). The pre-treatment PAR scores were significantly lower in the orthodontic group compared to the surgical treatment group, the mean values being 25.5 and 34.5, respectively ($P=0.005$), but no statistically significant difference was found in PAR scores between the groups after treatment. The improvement was greater in the surgery group than in the orthodontic group, mean values being 27.3 and 19.4, respectively ($P=0.007$).
Table 7. The components and the weighted total score of the Peer Assessment Rating (PAR) index before treatment (T1) and after an average of 1.5 years after active treatment (T2)(n=51).

<table>
<thead>
<tr>
<th>PAR</th>
<th>T1 Mean</th>
<th>Med</th>
<th>T2 Mean</th>
<th>Med</th>
<th>Change %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior segments</td>
<td>6.1</td>
<td>6</td>
<td>0.4</td>
<td>0</td>
<td>93%³</td>
</tr>
<tr>
<td>Buccal segments</td>
<td>4.5</td>
<td>4</td>
<td>2.7</td>
<td>3</td>
<td>40%³</td>
</tr>
<tr>
<td>Overbite</td>
<td>2.6</td>
<td>3</td>
<td>0.5</td>
<td>0</td>
<td>81%³</td>
</tr>
<tr>
<td>Overjet</td>
<td>1.5</td>
<td>1</td>
<td>0.2</td>
<td>0</td>
<td>87%³</td>
</tr>
<tr>
<td>Centerline</td>
<td>0.6</td>
<td>1</td>
<td>0.2</td>
<td>0</td>
<td>67%³</td>
</tr>
<tr>
<td>PAR weighted total</td>
<td>31.8</td>
<td>34</td>
<td>6.9</td>
<td>4</td>
<td>78%³</td>
</tr>
</tbody>
</table>

³ \( P<0.001 \)

The correlation between PAR total scores and OHIP severity scores was assessed before and after treatment, and between the changes during the follow-up period. A statistically significant correlation 0.307 \((P=0.028)\) was found after the follow-up. Those with higher PAR scores reported higher levels of oral impacts.

When the results were expressed in terms of treatment outcome, all the subjects were classified as ‘Improved’ (57%) or ‘Greatly improved’ (43%). No statistically significant differences were found in the changes in OHIP scores between the ‘Improved’ and ‘Greatly improved’ groups (Table 8).

Table 8. Changes in the Oral Health Impact Profile (OHIP-14) variables in relation to the ‘Improved’ (n=29) and ‘Greatly improved’ (n=22) occlusal outcome groups (n=51).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Improved Mean</th>
<th>Greatly improved Mean</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity change</td>
<td>12.4</td>
<td>14.3</td>
<td>0.530</td>
</tr>
<tr>
<td>Prevalence change (FoVo)</td>
<td>0.5</td>
<td>0.7</td>
<td>0.211</td>
</tr>
<tr>
<td>Prevalence change (OFoVo)</td>
<td>0.6</td>
<td>0.3</td>
<td>0.108</td>
</tr>
<tr>
<td>Extent change (FoVo)</td>
<td>2.2</td>
<td>2.7</td>
<td>0.494</td>
</tr>
<tr>
<td>Extent change (OFoVo)</td>
<td>4.5</td>
<td>4.7</td>
<td>0.854</td>
</tr>
</tbody>
</table>

Improved = more than 30% improvement in the total weighted PAR score. Greatly improved = more than 22 points reduction in the total weighted PAR score. No statistically significant differences were found between the ‘Improved’ and ‘Greatly improved’ groups.
5.4 Relationships between changes in facial pain, TMD and OHRQoL (III)

Of the examined patients in Study III, 62% had experienced facial pain during a one-year period before treatment. Women reported facial pain significantly more often at baseline than men ($P=0.040$, Mann-Whitney test and $\chi^2$-test). The values were 70% for women and 41% for men. There were no statistically significant differences at follow-up between genders or between treatment groups (Table 9).

Table 9. Reported pain in the face and intensity of facial pain (as assessed using Visual Analogue Scale, VAS) before treatment (T1) and at follow-up (T2) (n=64).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time</th>
<th>All n=64</th>
<th>Gender</th>
<th>Treatment</th>
<th>Orthodontic-surgical n=44</th>
<th>Orthodontic n=20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported pain in face (%)</td>
<td>T1</td>
<td>62%</td>
<td>41%</td>
<td>70%</td>
<td>66%</td>
<td>53%</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>20%</td>
<td>17%</td>
<td>22%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Facial pain mean (VAS)</td>
<td>T1</td>
<td>3.1</td>
<td>2.2</td>
<td>3.5</td>
<td>3.2</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>0.9</td>
<td>0.4</td>
<td>1.1</td>
<td>0.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Distributions of Helkimo’s dysfunction indices are shown in Figures 8 and 9. Ninety percent of the patients reported TMD symptoms (Helkimo’s Ai I or Ai II) before treatment, compared to 60% after the follow-up. Before treatment, 84% of the patients were classified as having moderate or severe TMD (Di II, Di III) while the corresponding level after treatment was 29%. In Study III, the differences between genders or between treatment groups at the time points were not statistically significant ($\chi^2$-test). The positive changes in Ai and Di occurring between the time points were statistically significant ($P<0.05$, Wilcoxon test) among all patients and among all subgroups, except that among men the improvement in Ai was not statistically significant.
Fig 8. Distributions of Helkimo’s anamnestic dysfunction index (Ai) before treatment (T1) and at follow-up (T2) among men and among women. Ai 0 refers to no symptoms, Ai I to mild symptoms, and Ai II to severe symptoms.

Fig 9. Distributions of Helkimo’s clinical dysfunction index (Di) before treatment (T1) and at follow-up (T2) among men and among women. Di 0 refers to no signs and symptoms, Di I to mild TMD, Di II to moderate TMD, and Di III to severe TMD.
The changes in OHIP severity scores and facial pain intensity were positively correlated among patients ($r=0.296$, $P=0.019$) (Table 10). Those whose facial pain decreased also reported better OHRQoL. The changes in Helkimo indices were not associated with changes in OHIP severity or facial pain intensity. A statistically significant positive correlation was found between changes in the clinical and anamnestic dysfunction indices ($r=0.387$, $P=0.005$).

The correlations between the changes in OHIP dimensions and facial pain are shown in Table 11. The change in facial pain was correlated with the changes in physical pain, physical disability and social disability ($P<0.05$); the patients whose facial pain had decreased had an improvement in these OHRQoL dimensions.

**Table 10. Correlations between changes in the Oral Health Impact Profile (OHIP-14) severity score, intensity of facial pain (VAS), Helkimo clinical dysfunction index (Di) and anamnestic dysfunction index (Ai) during follow-up (n=64).**

<table>
<thead>
<tr>
<th>Variable</th>
<th>OHIP-14 severity</th>
<th>Facial pain (VAS)</th>
<th>Di</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r^*$</td>
<td>$r^*$</td>
<td>$r^*$</td>
</tr>
<tr>
<td>Facial pain (VAS)</td>
<td>0.296$^1$</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Di</td>
<td>0.165</td>
<td>0.009</td>
<td>1</td>
</tr>
<tr>
<td>Ai</td>
<td>0.196</td>
<td>0.189</td>
<td>0.387$^2$</td>
</tr>
</tbody>
</table>

$r^*$, Spearman’s correlation coefficient for association between changes, $^1 P<0.05$, $^2 P<0.01$

**Table 11. Mean scores before treatment (T1) and after follow-up (T2) and changes during follow-up (T1-T2) for the Oral Health Impact Profile (OHIP-14) dimensions, and correlations between changes in dimensions and change in facial pain intensity (VAS).**

<table>
<thead>
<tr>
<th>OHIP-14 dimension</th>
<th>Mean T1</th>
<th>Mean T2</th>
<th>Change</th>
<th>Facial pain (VAS) $r^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional limitation</td>
<td>1.8</td>
<td>0.7</td>
<td>-1.1</td>
<td>0.165</td>
</tr>
<tr>
<td>Physical pain</td>
<td>4.3</td>
<td>1.8</td>
<td>-2.5</td>
<td>0.253$^1$</td>
</tr>
<tr>
<td>Psychological discomfort</td>
<td>3.9</td>
<td>0.9</td>
<td>-3.0</td>
<td>0.239</td>
</tr>
<tr>
<td>Physical disability</td>
<td>1.6</td>
<td>0.2</td>
<td>-1.4</td>
<td>0.263$^1$</td>
</tr>
<tr>
<td>Psychological disability</td>
<td>2.8</td>
<td>0.4</td>
<td>-2.4</td>
<td>0.210</td>
</tr>
<tr>
<td>Social disability</td>
<td>1.9</td>
<td>0.2</td>
<td>-1.7</td>
<td>0.281$^1$</td>
</tr>
<tr>
<td>Handicap</td>
<td>1.8</td>
<td>0.3</td>
<td>-1.5</td>
<td>0.185</td>
</tr>
</tbody>
</table>

$r^*$, Spearman’s correlation coefficient for association between changes in OHIP dimensions and facial pain (VAS), $^1 P<0.05$
5.5 Associations between esthetic satisfaction, dental esthetics and OHRQoL (IV)

Self-reported satisfaction with dental esthetics improved significantly after treatment \((P<0.001)\) (Table 12, Table 13). All panel groups evaluated patients’ dental esthetics as being statistically significantly better after treatment than before treatment \((P<0.001)\). Orthodontist graded the dental esthetics as worse and the outcome as better than laypersons; the scores evaluated by dental students fell between the two groups, the differences being statistically significant \((P<0.05,\) paired samples \(t\)-test)

Table 12. Mean values of satisfaction with dental esthetics (as assessed with Visual Analogue Scale, VAS, scale 0-100, 0 being the most satisfied) and Aesthetic Components (AC) of the panel groups before and after treatment according to gender.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=16)</th>
<th>Female (n=36)</th>
<th>All (n=52)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
<td>Change</td>
</tr>
<tr>
<td>Esthetic satisfaction</td>
<td>57.7</td>
<td>21.3</td>
<td>-36.4(^1)</td>
</tr>
<tr>
<td>AC laypersons</td>
<td>5.9</td>
<td>3.4</td>
<td>-2.5(^1)</td>
</tr>
<tr>
<td>AC dental students</td>
<td>5.9</td>
<td>2.9</td>
<td>-3.0(^1)</td>
</tr>
<tr>
<td>AC orthodontists</td>
<td>6.6</td>
<td>2.7</td>
<td>-3.9(^1)</td>
</tr>
</tbody>
</table>

\(^1 P<0.05, \) \(^2 P<0.001\) (paired samples \(t\)-test)

Table 13. Mean values of satisfaction with dental esthetics (as assessed with Visual Analogue Scale, VAS, scale 0-100, 0 being the most satisfied) and Aesthetic Components (AC) of the panel groups before and after treatment according to treatment type.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Orthodontic (n=14)</th>
<th>Orthodontic-surgical (n=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td>Esthetic satisfaction</td>
<td>71.9</td>
<td>19.8</td>
</tr>
<tr>
<td>AC laypersons</td>
<td>5.4</td>
<td>3.5</td>
</tr>
<tr>
<td>AC dental students</td>
<td>5.6</td>
<td>2.8</td>
</tr>
<tr>
<td>AC orthodontists</td>
<td>5.6</td>
<td>2.3</td>
</tr>
</tbody>
</table>

\(^1 P<0.05\) (paired samples \(t\)-test)

Mean values of OHIP-14 and AC for quartiles according to esthetic satisfaction are presented in Table 14. The most unsatisfied patients reported poorer OHRQoL both before and after treatment, but most of these differences were not statistically significant. At baseline, orthodontists evaluated dental esthetics of the most
unsatisfied patients as worse than esthetics of the most satisfied patients, the difference being statistically significant \((P<0.05)\). The trend was similar but not statistically significant after follow-up and among other panel groups.

Table 14. Mean values of the Oral Health Impact Profile (OHIP-14) severity and dimensions and Aesthetic Component (AC) according to self-reported esthetic satisfaction (VAS) quartiles before treatment (T1) and at follow-up (T2) \((n=52)\).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Esthetic satisfaction T1</th>
<th>Esthetic satisfaction T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
<td>Q2,Q3</td>
</tr>
<tr>
<td>OHIP-14 severity</td>
<td>15.92(^1)</td>
<td>16.27(^1)</td>
</tr>
<tr>
<td>Functional limitation</td>
<td>1.77</td>
<td>1.69</td>
</tr>
<tr>
<td>Physical pain</td>
<td>4.23</td>
<td>4.73</td>
</tr>
<tr>
<td>Psychological discomfort</td>
<td>2.85(^1)</td>
<td>3.46(^1)</td>
</tr>
<tr>
<td>Physical disability</td>
<td>1.77</td>
<td>1.50</td>
</tr>
<tr>
<td>Psychological disability</td>
<td>1.85(^1)</td>
<td>2.12(^1)</td>
</tr>
<tr>
<td>Social disability</td>
<td>1.85</td>
<td>1.54</td>
</tr>
<tr>
<td>Handicap</td>
<td>1.62</td>
<td>1.23</td>
</tr>
<tr>
<td>AC laypersons</td>
<td>4.87</td>
<td>5.70</td>
</tr>
<tr>
<td>AC dental students</td>
<td>5.02</td>
<td>5.90</td>
</tr>
<tr>
<td>AC orthodontists</td>
<td>4.94(^1)</td>
<td>6.24(^1)</td>
</tr>
</tbody>
</table>

\(^1\) \(P<0.05\), statistically significant differences between esthetic satisfaction quartiles (Univariate GLM).

The lower quartiles (Q1) represent the 25% of the patients who were the most satisfied with their dental esthetics and the upper quartiles (Q4) represent the 25% of the patients who were the most unsatisfied with their dental esthetics. Q3: \(n=13\); Q2, Q3: \(n=26\); Q4: \(n=13\).

The change in esthetic satisfaction correlated positively with the changes in OHIP-14 severity and four dimensions. Of the dimensions, the strongest positive correlations with the change in esthetic satisfaction were found in the changes in psychological discomfort and psychological disability \((r=0.482, r=461\), respectively, \(P<0.01\)). The changes in esthetic evaluations of the panel groups correlated very strongly with each other, but had only weak or moderate correlation with patients’ esthetic satisfaction or OHRQoL (Table 15).
Table 15. Correlations between changes in ‘severity’ and impacts of the Oral Health Impact Profile (OHIP-14) severity, esthetic satisfaction (Visual Analogue Scale) and Aesthetic Component (AC) during the follow-up period (n=52).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Esthetic satisfaction</th>
<th>Functional limitation</th>
<th>Physical pain</th>
<th>Psychol. discomfort</th>
<th>Physical disability</th>
<th>Psychol. disability</th>
<th>Social disability</th>
<th>Handicap</th>
<th>AC laypersons</th>
<th>AC dental students</th>
<th>AC orthodontists</th>
</tr>
</thead>
<tbody>
<tr>
<td>OHIP-14 severity</td>
<td>0.427$^2$</td>
<td>0.544$^2$</td>
<td>0.690$^2$</td>
<td>0.814$^2$</td>
<td>0.801$^2$</td>
<td>0.815$^2$</td>
<td>0.776$^2$</td>
<td>0.747$^2$</td>
<td>0.246</td>
<td>0.235</td>
<td>0.257</td>
</tr>
<tr>
<td>Functional limitation</td>
<td>0.142</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical pain</td>
<td>0.278$^1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychol. discomfort</td>
<td>0.482$^2$</td>
<td>0.396$^2$</td>
<td>0.371$^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiol. Disability</td>
<td>0.234</td>
<td>0.484$^2$</td>
<td>0.622$^2$</td>
<td>0.516$^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical disability</td>
<td>0.461$^2$</td>
<td>0.289$^2$</td>
<td>0.323$^1$</td>
<td>0.778$^2$</td>
<td>0.472$^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social disability</td>
<td>0.325$^1$</td>
<td>0.346$^1$</td>
<td>0.436$^2$</td>
<td>0.554$^2$</td>
<td>0.481$^2$</td>
<td>0.626$^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handicap</td>
<td>0.212</td>
<td>0.231</td>
<td>0.558$^2$</td>
<td>0.472$^2$</td>
<td>0.587$^2$</td>
<td>0.599$^2$</td>
<td>0.602$^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC laypersons</td>
<td>0.328$^1$</td>
<td>0.220</td>
<td>0.107</td>
<td>0.134</td>
<td>0.103</td>
<td>0.274$^1$</td>
<td>0.330$^1$</td>
<td>0.083</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC dental students</td>
<td>0.176</td>
<td>0.110</td>
<td>0.153</td>
<td>0.063</td>
<td>0.174</td>
<td>0.234</td>
<td>0.258</td>
<td>0.106</td>
<td>0.832$^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC orthodontists</td>
<td>0.278$^1$</td>
<td>0.195</td>
<td>0.142</td>
<td>0.124</td>
<td>0.103</td>
<td>0.207</td>
<td>0.289$^1$</td>
<td>0.080</td>
<td>0.797$^2$</td>
<td>0.786$^2$</td>
<td></td>
</tr>
</tbody>
</table>

$^1$ P<0.05, $^2$ P<0.01, Pearson's correlation coefficient
6 Discussion

6.1 Methodological considerations

The strength of the present study was that the mean follow-up period was long compared to most of the previous studies (Hatch et al. 1998, Azuma et al. 2008, Lee et al. 2008, Nicodemo et al. 2008, Choi et al. 2010). It can be assumed that with the long follow-up, patients had time to become familiar with their new occlusion and appearance, providing a more reliable impression of treatment outcome. The long follow-up, however, was partly the reason for loss of subjects, for example due to migration. Nevertheless, the study group and the lost subjects did not differ regarding gender, age, pre-treatment PAR status or pre-treatment OHIP status in the drop-out analysis.

In the study group, on average two-thirds of the subjects were women. A similar gender distribution is common among orthodontic adult patients as women are more likely to experience impairment in esthetics, report more pain and are more motivated to seek treatment, and generally utilize medical services more than men (Green & Pope 1999, Bailey et al. 2001, Siow et al. 2002).

The age range of the subjects was wide in this study. This can be considered as a limitation as well as a strength. In general population, age has been reported to be associated with OHRQoL; older adults are more likely to have tooth loss and removable dentures and are thus more likely to report oral impacts (Steele et al. 2004, Lahti et al. 2008). However, when the influence of tooth loss and status of dentures has been controlled, the influence of age has been found to be almost negligible (John et al. 2004) or even opposite (Steele et al. 2004). On the other hand, earlier investigations have typically focused on young adults and there is very little information about the treatment effects in middle-aged or older patients. Because the age of patients seeking orthodontic or orthodontic-surgical treatment has large variation, no upper age limit was set in the present study.

For ethical reasons, it was not possible to obtain an untreated control group with the same level of malocclusion and symptoms. However, the results of OHRQoL can be compared to the results of the National Health 2000 survey among normal Finnish adult population (Lahti et al. 2008). Studies have shown that OHRQoL is associated with clinical oral status (tooth loss, untreated caries, periodontal disease) and low socioeconomic status (Steele et al. 2004, Locker 2009, Locker & Quinonez 2011, Al Habashneh et al. 2012, Anweigi et al. 2013). In
the present study, all patients had undergone basic dental care before being referred to orthodontic treatment.

Due to practical reasons, the post-treatment dental casts were collected on average 1.5 years after active treatment, whereas other post-treatment data was collected on average 3 years after treatment. Based on the literature, it can be assumed that relapse is fastest immediately after treatment and diminishes after the first year (Proffit et al. 2003).

The instruments used to measure OHRQoL, occlusion and dental esthetics have been tested to be reliable and valid (Howells & Shaw 1985, Richmond et al. 1992a, Slade 1997b, Allen et al. 1999, Lahti et al. 2008).

OHIP-14 was chosen for OHRQoL measures for the reasons that it is a widely used instrument, has a validated Finnish translation, and is comparable with existing normal Finnish control material (Lahti et al. 2008). The changes in OHIP scores during the follow-up showed that it is sensitive for measuring also changes related to orthodontic and orthodontic-surgical treatment. Lee et al. (2007) compared OHIP-14 with a generic HRQL measure (SF-36) and a condition-specific measure (OQLQ), and stated that OHIP-14 has the ability to discriminate between individuals with and without dentofacial deformity.

The PAR index has been found to have excellent validity and reliability for measuring severity of malocclusion, treatment outcome and improvement when analyzed on dental casts, and it has also been found to be suitable for assessing the clinical outcome of orthodontic-surgical treatment (Richmond et al. 1992a, Richmond et al. 1992b, DeGuzman et al. 1995, Templeton et al. 2006). Compared to another widely used occlusal index, DHC of IOTN, the PAR index has higher sensitivity. Secondly, PAR has specifically been developed for the measurement of treatment outcome, whereas DHC has been designed as an indicator of treatment need, not outcome. The analysis of repeated PAR measurements showed very high reproducibility.

Helkimo’s dysfunction index was chosen to measure the severity of TMD, because it allows numerical scoring, in contrast to RDC/TMD (Dworkin & LeResche 1992). Although RDC/TMD is currently most commonly used for research purposes and provides diagnosis of TMD divided into specific sub-classifications, Helkimo’s index enables evaluating the severity of TMD, meaning that it is cumulative and therefore more suitable for pathway analysis.

The questions for measuring the prevalence and the intensity of pain had different time periods before and after treatment. The shorter reference period in the post-treatment questionnaire concerning facial pain intensity was chosen to exclude
pain due to treatment. In a previous study, the reference period (1 month vs. 1 year) did not have a statistically nor clinically significant effect on reported oral impacts (Sutinen et al. 2007). A re-analysis of the same data on four single-item questions was conducted, showing the agreement to be substantial for three items: OHIP-pain item, facial pain and jaw pain (Sipilä et al. 2014). The re-analysis showed moderate agreement for the fourth item, dental pain, which is commonly acute compared to facial pain, which is more often chronic. Nevertheless, the amount of improvement in facial pain during follow-up should be interpreted with caution.

As regards the indices designed to measure dental esthetics, AC of IOTN was chosen for esthetic evaluation, as it is widely used in similar studies with non-professional panel groups (Stenvik et al. 1997, Hunt et al. 2002, Livas & Delli 2013). A limitation of AC is that it represents dental appearance of 12-year-old children. Nonetheless, it has frequently been used also in adults (Hassan 2006, Johnston et al. 2010, Kolawole et al. 2012). The photographs in the AC do not include cases with anterior open bite and reverse overjet, but the sensitivity of AC in cases with these malocclusion forms has been later demonstrated in a clinical study by Abu Alhaija and Al-Khateeb (2005).

Associations between severity of malocclusion, facial pain and TMD signs before treatment were studied with path analysis. In path analysis, model χ² should be non-significant indicating failure to reject the hypothetical model. NFI assesses the relative improvement in fit of the hypothesized model. NFI has shown a tendency to underestimate fit in small samples, so it was revised to CFI, which takes sample size into account. For NFI and CFI values over 0.95 indicate superior fit. RMSEA is a parsimony-adjusted index including correction for model complexity. Of two models with similar fit, it favors the simpler model. Values RMSEA < 0.05 indicate a very good fit (Byrne 2001, Kline, 2005).

6.2 OHRQoL

The results of this study showed that treatment of severe malocclusion had an extensive influence on OHRQoL. When comparing reported oral impacts with the results of average Finnish adult population, the prevalence of patients reporting one or more items ‘fairly often’ or ‘very often’ were 7-fold higher before treatment and declined to the level of general population after treatment (Lahti et al. 2008). Similarly, the severity of reported impacts declined after treatment to the level of general population. When ‘occasionally’ reported impacts were taken into account in the prevalence score, the prevalence was higher among treated patients
compared to normal populations (49–52% vs. 35%). These results illustrate that occasional impacts are common after treatment, while only a minority of patients suffer frequently occurring impacts.

It is interesting that no statistically significant differences were found in OHRQoL between the orthodontic and orthodontic-surgical groups in this study. This suggests that milder skeletal deformities may be as harmful for the patient as more severe skeletal disharmonies. However, it has to be remembered that the patients in this study were a selected group, and they all had significant complaints related to malocclusion before accessing treatment. To investigate the independent association between malocclusion and OHRQoL, the study should be based on a population-based sample.

The prevalence of reported oral impacts at baseline was at the same level with some other studies among patients with dentofacial deformities (Lee et al. 2008, Frejman et al. 2013). The results of improvement in OHRQoL are in agreement with other longitudinal studies concerning orthognathic surgery (Hatch et al. 1998, Motegi et al. 2003, Lee et al. 2008, Choi et al. 2010). The improvement in OHIP values in this study was greater compared to the study of Lee et al. (2008), which can be explained by shorter follow-up periods in that study. Only little data exist of OHRQoL in relation to conventional orthodontic treatment among adult patients. In a cross-sectional study of Palomares et al. (2012), the OHIP severity scores of young adults waiting for orthodontic treatment were 5.3 times higher than of treated subjects, the scores being close to the findings of the present study. Overall, the remarkable improvement in OHRQoL in this study indicates that the quality of treatment was good.

In the current study, statistically significant improvement was found in all seven OHIP items. Similar findings have been seen in previous longitudinal studies among orthodontic-surgical patients (Lee et al. 2008, Choi et al. 2010). However, this result differs from the cross-sectional study of Lee et al. (2007), who did not find significant differences in physical pain, physical disability or social disability between subjects with dentofacial deformity and controls without dentofacial deformity. This is probably related to the differences in patient material between the studies or the cross-sectional study design of that study.

The most marked improvement was seen in psychological discomfort, followed by physical pain and psychological disability. The results are in line with another longitudinal study where changes in psychological discomfort, more specifically in ‘self-conscious’, correlated to most of the other items after orthognathic treatment (Rustemeyer & Gregersen 2012). It can be suggested that psychological discomfort
is the most sensitive indicator for improvement in OHRQoL after treatment of severe malocclusion. The remarkable changes in psychological discomfort of OHIP-14 also emerged in a systematic review of Soh and Narayanan (2013) in which the effect of orthognathic surgery on OHRQoL was evaluated.

The smallest improvement was seen in functional limitations. When considering this, it must be recognized that functional limitation in the OHIP-14 questionnaire measures trouble in pronouncing words and worsened taste. Particularly the latter is not a common malocclusion-related impact. Hence, the small effect of malocclusion and its treatment on functional limitation was expected.

In a longitudinal study of Rustemeyer and Gregersen (2012), three orthognathic-specific questions were added to OHIP-14. They did not find any significant change between pre- and post-surgical evaluation in physical limitation, pain and chewing function, but the psychological factors and aesthetic results were more in the focus of the patients than functional outcomes. Motegi et al. (2003) studied Class II malocclusion patients and found greater improvement in psychosocial functioning than in physical functioning. The findings in the present study and previous research emphasize the importance of psychosocial aspects in treatment outcome.

Although this study confirmed the positive effect of orthodontic and orthodontic-surgical treatment on OHRQoL, some patients always gain less benefit from the treatment. What is not seen in follow-up studies is OHRQoL of non-responding patients who have been lost without a known reason (e.g. lack of time, migration or death). It is possible that there are more patients among these patients whose treatment time has been prolonged, who have become tired of treatment, who have had complications such as numbness in the lips or jaws, or whose expectations have not been fulfilled.

6.3 Associations between severity of malocclusion, facial pain, TMD and OHRQoL before treatment

The path analysis showed that severity of malocclusion, TMD and facial pain were associated with OHRQoL before treatment in both genders, but the association of malocclusion was different in females and males.

In both genders, TMD was associated with OHRQoL directly and via facial pain. The association between TMD and OHRQoL has mainly been studied in TMD patients (Dahlström & Carlsson 2010). While these studies have shown that OHRQoL was markedly impaired in TMD patients, the association was weak in the present study.
In this study, women reported significantly more intense facial pain than men, which is a general finding in TMD patient populations (Dao & LeResche 2000, Blanco-Hungria et al. 2012, Sanders & Slade 2011, Schmid-Schwap et al. 2013). In addition, the association between facial pain and OHRQoL was stronger among women than among men. The negative impact of orofacial pain on OHRQoL is in line with studies in subjects with TMD (Barros Vde et al. 2009, Murray et al. 1996). It is noteworthy, that, in contrast to our study, the gender differences in associations between facial pain and OHRQoL have been small or insignificant in TMD patients (Barros Vde et al. 2009). Interestingly, occlusal characteristics were associated directly with OHRQoL but not with facial pain among men. Among women, on the other hand, occlusal characteristics were associated with OHRQoL indirectly via facial pain. This may be partly explained by the gender differences in treatment seeking. On the basis of this study, it seems that women may suffer more from pain conditions while men experience more harm from poor occlusal relationships.

Another gender difference in pathways was found between severity of malocclusion and TMD, the association being negative among women and positive among men. This may also be explained by the treatment seeking and the specificity of the group of patients. Patients with malocclusion and TMD-related problems may have been more easily referred to treatment, leading to a situation where patients with less severe malocclusion may have had relatively more TMD signs and symptoms in the study group and vice versa. Regardless of the associations of severity of malocclusion with TMD and facial pain, occlusal characteristics had a relatively low association with OHRQoL in the study.

6.4 Associations between the changes in occlusion, facial pain, TMD and OHRQoL after treatment

The changes in occlusion measured using PAR index and changes in OHRQoL were not correlated in this study, suggesting that improvement in OHRQoL does not necessarily correlate with clinical measurements of malocclusion. Nurminen et al. (1999) found that orthodontic patients whose PAR index was ‘Greatly improved’ were the most satisfied with the treatment. In the present study, no statistically significant difference was found in OHRQoL between the ‘Improved’ and ‘Greatly improved’ groups, although the trend was that OHRQoL improved slightly more among patients in the latter group.

An association between occlusion and OHRQoL was noted after treatment, with patients with a more compromised occlusal outcome reporting poorer OHRQoL.
The highest scores in PAR components after treatment were seen in buccal segments suggesting difficulty of achieving good interdigitation with orthodontic/orthodontic-surgical treatment when many of the patients had severe sagittal malocclusion at baseline. Because compromised interdigitation is associated with reduced occlusal contact area, it may affect masticatory performance (Magalhães et al. 2010). Occlusion with compromised buccal relationship may also cause a feeling of unstable occlusion and increase parafunctional activity (Celic et al. 2002) and thus affect well-being.

A decreased intensity of facial pain was associated with improved OHRQoL. The OHP dimensions particularly associated with decreased facial pain were physical pain, physical disability and social disability. It was expected that facial pain would correlate with physical pain, but the association with physical disability and especially with social disability was interesting, because social disability concerns irritability and difficulty in doing usual jobs.

There was only limited evidence for an association between TMD and OHRQoL. Even though TMD was associated with OHRQoL at baseline, no association was found in the changes of the parameters. It seems that TMD does not have a direct association with OHRQoL in malocclusion patients.

The results of this study indicate that decreased facial pain is directly associated with improved OHRQoL, while the impact of the changes in occlusion and TMD was not verified. These findings reflect similar hierarchy as seen in the empirically derived model of Nuttall et al. (2006). If the severity of malocclusion is set as ‘disease’ and facial pain is in ‘discomfort/physical pain’, malocclusion may affect OHRQoL via impairment whereas pain is contained in OHRQoL. In the empirically derived model, physical pain is linked with all other OHRQoL dimensions. Therefore, the association of the changes in facial pain with physical and social disability supports the model.

If TMD were set in the model of oral health, it could partly be ‘disease’ but also ‘impairment’, ‘functional limitation’ or in more severe cases, ‘physical pain’ or ‘physical disability’. This may be one reason why the changes in signs and symptoms of TMD were not correlated with OHRQoL even though many studies in TMD patients have shown a strong association between these factors (Murray et al. 1996, Barros Vde et al. 2009, Miettinen et al. 2012, Rener-Sitar et al. 2013). In TMD patients who seek treatment for TMD, the disease has led to impairment and pain in a majority of patients. In this study, on the other hand, the patients may have had signs or symptoms (i.e., clicking) that were not experienced as harmful or that had not improved during the treatment (Dworkin et al. 1990). Additionally, the
majority of OHRQoL studies in TMD patients have used RDC/TMD as diagnostic
criteria, which includes psychosocial aspects of TMD.

In the literature, no data were found on the association between TMD, facial
pain and OHRQoL in malocclusion patients. The relationships between PAR, TMD
(measured with modified Helkimo’s indices) and facial pain, and satisfaction with
orthognathic treatment outcome have previously been investigated in a retrospective
study of Pahkala and Kellokoski (2007). They found a positive correlation between
patient’s satisfaction and the reduction in PAR score and changes in subjective
TMD and facial pain after treatment. Neither changes in PAR nor TMD were
associated with high satisfaction when ‘very satisfied’ and ‘rather satisfied’ were
compared. Instead, the changes in chewing ability and self-confidence correlated
with high satisfaction. Although OHRQoL was not included in the study of Pahkala
and Kellokoski, there are some similarities between the findings of their study and
the present study, suggesting that patients generally experience benefit from the
improved anatomic occlusion, but the impact seems to be indirect.

6.5 Role of dental esthetics on OHRQoL

In this study, improved satisfaction with dental esthetics was associated with
improved OHRQoL, especially with psychological discomfort and psychological
disability. The finding is in line with previous studies that have found an association
between negative OHRQoL and self-perceived esthetic impairment (Khan & Fida
2008, Feu et al. 2010).

The trend was that females reported slightly more dissatisfaction with dental
esthetics before treatment and were more satisfied with the esthetic outcome
compared to males (although not significantly). A similar gender difference has
previously been reported (Egermark et al. 2000, Klages et al. 2004).

In previous Finnish studies, the proportions of patients reporting esthetic
reasons as motives for treatment have been notably low (Nurminen et al. 1999,
Pahkala & Kellokoski 2007) compared to the majority of studies in other countries
(Alanko et al. 2010). The differences between countries can be sociocultural or
influenced by factors such as organization of health care in general and access to
treatment. In Finnish publicly funded orthodontic care, esthetic impairment only
is not a sufficient reason for general dentists or orthodontists to refer patients to
orthodontic care, and that may result in emphasizing functional reasons. It has
been suggested that patients may believe that they are more easily accepted for
treatment if they have a functional rather than an esthetic problem (Panula 2003).
However, the findings of the current study do not support the previous research among Finnish malocclusion patients suggesting that functional aspects would be more important for patients than esthetic ones (Nurminen et al. 1999).

Because self-perceived esthetics may differ from other people’s opinion, there was also interest in investigating whether evaluated dental esthetics is associated with OHRQoL and esthetic satisfaction. Three panel groups, orthodontists, dental students and laypersons, were chosen to represent different forums of how dental appearance is evaluated. All panel groups evaluated the dental esthetics of the least satisfied patients as worse than the esthetics of the most satisfied patients both before and after treatment.

The change in self-perceived esthetic satisfaction correlated with the changes in grading of the laypersons and orthodontists, but not with the change in grading of the dental students. It can be suggested that patients’ satisfaction with dental esthetics is generally in line with the opinion of laypersons and professionals. The finding that changes in the students’ grading and esthetic satisfaction were not associated may be explained by the emphasis of functional aspects in dental studies. Therefore, the students may pay more attention to occlusal traits that may lead to functional problems (e.g. posterior cross-bite). The study of Hunt et al. (2001) found that general dentists attributed more oral health and functional benefits to orthodontic treatment than specialists, who focused on the psychosocial benefits of treatment.

The changes in evaluation of laypersons and orthodontists were also associated with the change in the OHIP dimension of social disability, and in the case of laypersons, also with the change in psychological disability. This indicates that examiner-assessment of dental esthetics is associated with both esthetic satisfaction and OHRQoL. The results are in line with a cross-sectional study among Brazilian adolescents, where subjects seeking orthodontic treatment reported higher OHIP values and had greater examiner-perceived esthetic impairment (Feu et al. 2010). Trovik et al. (2012) reported in a retrospective study that orthodontic-surgical patients whose friends and families had noticed a change in the patients’ appearance were more satisfied and reported better OHRQoL after 10 to 14 years of follow-up.

The finding that orthodontists were more critical than laypersons in assessing pre-treatment dental photographs is in agreement with earlier studies (Shaw et al. 1980, Abu Alhaija & Al-Khateeb 2005, Kokich et al. 2006). It has also been found in a recent study of Alanko et al. (2014) that self-perceived dental appearance was a better predictor for poor orthognathic QoL than orthodontist’s assessment among patients waiting for orthognathic-surgery.
When examining patients in quartiles according to the esthetic satisfaction, the most unsatisfied patients reported poorer OHRQoL than more satisfied patients. A similar trend was seen in the panel groups’ gradings, but the differences between the middle quartile and the most unsatisfied were relatively small. This may reflect the fact that although self-perceived esthetics is usually in line with other people’s evaluations, some patients may be unsatisfied regardless of a relatively good esthetic outcome. The post-treatment dissatisfaction may be related to unrealistic expectations. Since the esthetic satisfaction contributes to OHRQoL, it is essential that professionals make sure that the patient has realistic expectations of treatment outcome. Consequently, more an interactive relationship between professionals and the patient during the treatment process may improve the esthetic satisfaction.

6.6 Clinical implications and future perspectives

The results of this study emphasize the importance of focusing on patients’ perceptions of malocclusion-related impacts when referring patients to treatment, making treatment decisions and estimating treatment outcome. Cunningham and Hunt (2001) have stated that change in quality of life is the ideal measure of outcome and that it should be a patient-derived measure of change. They also argued that we must be able to show that benefits are derived from the treatment. The results of the present study showed a great benefit from the treatment, suggesting that the indications for treatment have been appropriate.

Of the measured aspects, it seems that dental esthetics and facial pain are one of the key factors in improved OHRQoL during treatment of malocclusion. Also, the occlusion was associated with post-treatment OHRQoL, indicating the importance of good occlusal outcome. It is noteworthy that there were no statistically significant differences in OHRQoL between the treatment groups. The orthodontic-surgical patients had more severe malocclusion measured with PAR index and greater change in occlusion after treatment. The trend was that the orthodontic patients were more dissatisfied with dental esthetics, although the difference was not statistically significant.

The gender differences in OHRQoL were clinically unimportant, but facial pain came up especially among women as an important aspect influencing self-perceived oral health. Although clinical assessment and measurements by professionals are crucial, anatomic occlusion and clinical signs of TMD did not play the major role from the perspective of OHRQoL in this study. Therefore, it is an important
challenge to find a balance between clinical and patient-centered aspects when making treatment decisions and comparing optional treatment approaches.

The number of papers describing OHRQoL in malocclusion patients is increasing rapidly, and an understanding of this relationship is required not only for clinical purposes, but also when resource allocation is considered. In the future, more studies concerning associations between different malocclusion-related aspects, such as facial features, and OHRQoL are needed in order to assemble the whole puzzle. Finally, an important goal in the future is to consider how patient-centered measures could be used in clinical practice in order to provide the best care using available resources.
7 Conclusions

This study establishes that treatment of severe malocclusion with related functional problems considerably improves oral health-related quality of life (OHRQoL) regardless of patients’ gender or type of treatment.

1. Patients with severe malocclusion who also had TMD signs and facial pain often had impaired OHRQoL. Before treatment, TMD was associated with OHRQoL directly and indirectly via facial pain. The association of the severity of malocclusion with OHRQoL differed between genders at baseline; among men, severity of malocclusion was directly associated with OHRQoL, whereas among women an indirect association via facial pain was found.

2. Improvement in OHRQoL was found to be positively associated with decreased facial pain, but not with changes in TMD or occlusion. Patients with compromised occlusal outcome were more likely to report oral impacts than those with better occlusal outcome, emphasizing the importance of delivering a high standard of orthodontic care.

3. The patients who were most unsatisfied with their dental appearance reported worse OHRQoL before and after treatment. The changes in dental esthetics evaluated by orthodontist and laypersons associated with patients’ perceived esthetic satisfaction and social disability, and among laypersons also with psychological disability.
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