Laura Krooks

MALOCCLUSIONS IN RELATION TO FACIAL SOFT TISSUE CHARACTERISTICS, FACIAL AESTHETICS AND TEMPOROMANDIBULAR DISORDERS IN THE NORTHERN FINLAND BIRTH COHORT 1966
LAURA KROOKS

MALOCCLUSIONS IN RELATION TO FACIAL SOFT TISSUE CHARACTERISTICS, FACIAL AESTHETICS AND TEMPOROMANDIBULAR DISORDERS IN THE NORTHERN FINLAND BIRTH COHORT 1966

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Abstract

Epidemiological studies on malocclusions in Finland have so far concentrated on children and adolescents. Regarding the Finnish adult population, there is scarce epidemiological knowledge available on malocclusions even though the number of adults seeking orthodontic treatment has increased during the last decades. Occlusion is an important factor in the function of the masticatory system, and its role in the aetiology of temporomandibular disorders (TMD) is one of the most disputed topics in dentistry. Malocclusions can affect the characteristics of the facial soft tissue profile.

The aim of the study was to investigate the prevalence of malocclusions and the role of occlusion in TMD as well as the association of facial characteristics with malocclusions and facial aesthetics. The study population consisted of subjects from the Northern Finland Birth Cohort 1966 (NFBC1966). Data were collected using questionnaires, standardized clinical examination and facial photos. The profile photographs were analysed using linear and angular soft tissue cephalometric measurements.

The most common malocclusion in the NFBC1966 subjects was lateral crossbite. This study showed a significant association between asymmetric malocclusions and TMD. TMD signs associated significantly with lateral crossbite, scissors bite, negative overjet, and the length and lateral deviation in slide between retracted contact position and intercuspal position (RCP-ICP). Soft tissue profile characteristics were highly correlated with negative overjet. The ANB-angle was significantly associated with the perception of facial attractiveness.

In conclusion, malocclusions were associated with signs and symptoms of TMD in the Finnish adult population. Overjet appeared to affect the facial profile more than overbite. Facial convexity seemed to be a more important determinant of facial aesthetics for orthodontists than for dentists and laypersons.

Keywords: aesthetics, cephalometry, cohort study, epidemiology, malocclusion, occlusion, orthodontics, soft tissue profile, temporomandibular disorders, TMDs
Suomalaiset epidemiologiset tutkimukset purennan poikkeamista ovat tähän asti keskittyneet tarkastelemaan lapsia ja nuoria. Tarkkaa epidemiologista tietoa suomalaisten aikuisväestön purennan poikkeamista on tällä hetkellä saatavilla vain niukasti, vaikka oikomishoitoon hakeutuvien aikuispotilaiden määrä on Suomessa viime vuosina lisääntynyt. Purennalla on tärkeä merkitys purentaelimistön toiminnassa ja sen rooli purentaelimistön toimintahäiriöiden (TMD) etiologiasa on yksi kiistanalaisimpia aiheita hammaslääketieteessä. Purennan poikkeamat voivat vaikuttaa myös kasvojen pehmytkudosprofiilin piirteisiin.


Tässä tutkimuksessa yleisin purennan poikkeama oli sivualueen ristipurenta. Asymmetriset purennan poikkeamat olivat merkittävästi yhteydessä TMD:hen; erityisesti sivualueen ristipurenta, sakspurenta, negatiivinen horisontaalinen ylipurenta sekä nivelaseman ja keskipurennan (RCP-ICP) välisen liu'un pituus ja sivuttainen deviaatio. Negatiivisen horisontaalisen ylipurennan todettiin vaikuttavan voimakkaasti kasvojen profiilin. ANB-kulma oli merkitsevästi yhteydessä kasvojen arvioitunut viehättävyyteen.


Asiasanat: epidemiologia, estetiikka, kelfalometria, kohorttitutkimus, oikomishoito, pehmytkudosprofiili, purennan poikkeama, purenta, purentaelimistön toimintahäiriöt, TMD
To my family
Acknowledgments

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9th September, 2018

Laura Krooks
Abbreviations

2D Two-dimensional
3D Three-dimensional
ANB-angle The magnitude of discrepancy between the jaws, comprised
    of soft tissue A-point, nasion and B-point
A-point Deepest point of the curvature between subnasale and the
    most prominent point of the upper lip (also known as soft
    tissue A-point)
B-point Deepest point of the curvature between pogonion and the
    most prominent point of the lower lip (also known as soft
    tissue B-point)
CI Confidence interval
DC/TMD Diagnostic Criteria for Temporomandibular Disorders
E-line Rickett’s aesthetic line
E-plane Rickett’s aesthetic plane
f Aperture
FA Facial Axis
FA-point of the lower lip The most prominent point of the lower lip
FA-point of the upper lip The most prominent point of the upper lip
H-angle Holdaway’s H-angle
H-line Harmony line
ICC Intra-class correlation
ICP Intercuspal position
ISO International Organization of Standardization
LAFH Lower anterior facial height
LTR Laterotrusion
μ Mean of a population
N Population size
NFBC Northern Finland Birth Cohort
OR Odds ratio
P Probability value
Pog Soft tissue pogonion
PTR Protrusion
R² Coefficient of determination
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP</td>
<td>Retruded contact position</td>
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<tr>
<td>RDC/TMD</td>
<td>Research Diagnostic Criteria for Temporomandibular Disorders</td>
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<td>SD</td>
<td>Standard deviation</td>
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<tr>
<td>SI</td>
<td>Sublabiale</td>
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<tr>
<td>Sn</td>
<td>Subnasale</td>
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<tr>
<td>Sn-N-Sl</td>
<td>Subnasale-nasion-sublabiale; cutaneous analogue of ANB-angle</td>
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<tr>
<td>TMDs</td>
<td>Temporomandibular disorders</td>
</tr>
<tr>
<td>TMJ</td>
<td>Temporomandibular joint</td>
</tr>
<tr>
<td>Tr-Na</td>
<td>The line between tragus and nasion</td>
</tr>
<tr>
<td>Tragus line</td>
<td>A vertical reference line at 70 degrees to the line connecting tragus and nasion</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual Analogue Scale</td>
</tr>
<tr>
<td>$X^2$</td>
<td>Chi-Square</td>
</tr>
<tr>
<td>Z-angle</td>
<td>Merrifield’s Z-angle</td>
</tr>
</tbody>
</table>
List of original publications

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


*The authors contributed equally to the study.
# Contents

Abstract
Tiivistelmä
Acknowledgments 9
Abbreviations 11
List of original publications 13
Contents 15
1 Introduction 17
2 Review of the literature 19
   2.1 Malocclusion.................................................................................................. 19
      2.1.1 Definition and classifications of malocclusion........................................ 19
      2.1.2 Prevalence of malocclusion................................................................. 21
      2.1.3 Orthodontic treatment........................................................................ 25
   2.2 Temporomandibular disorders and occlusion.............................................. 25
      2.2.1 Definition of temporomandibular disorders.......................................... 25
      2.2.2 Aetiology of TMD.............................................................................. 26
      2.2.3 Association of malocclusions with signs and symptoms of TMD.............. 28
      2.2.4 The role of orthodontic treatment in TMD......................................... 29
   2.3 Facial soft tissue characteristics.................................................................... 31
      2.3.1 Cephalometric analysis........................................................................ 31
      2.3.2 Linear and angular facial measurements............................................. 32
      2.3.3 Facial aesthetics................................................................................... 33
      2.3.4 Facial soft tissue profile and malocclusion.......................................... 34
3 Aims of the study 37
4 Subjects and methods 39
   4.1 Subjects........................................................................................................ 39
      4.1.1 Study design......................................................................................... 39
   4.2 Methods.......................................................................................................... 40
      4.2.1 Questionnaires (I, II)............................................................................ 40
      4.2.2 Clinical examination (I-IV)................................................................... 41
      4.2.3 Facial soft tissue measurements (III, IV)............................................. 45
      4.2.4 Evaluation of facial aesthetics (IV)....................................................... 47
   4.3 Statistics........................................................................................................... 48
   4.4 Error of the method........................................................................................ 49
      4.4.1 Error of the method in the clinical examination (I, II, III)................. 49
      4.4.2 Error of the method in facial soft tissue measurements (III, IV)........... 50
4.4.3 Error of the method in aesthetic evaluation (IV) ........................................ 52
4.5 Ethical considerations ................................................................................... 52

5 Results
5.1 Prevalence of malocclusion traits (I) .......................................................... 53
5.2 Prevalence of previous orthodontic treatment (I) .................................... 56
5.3 Association between signs and diagnoses of TMD and occlusal variables (II) ................................................................. 57
5.4 Distribution of TMD signs and diagnoses in subjects having had orthodontic treatment (II) ......................................................... 59
5.5 Distribution of occlusal interferences according to orthodontic treatment in subjects with TMD (II) ......................................................... 62
5.6 Gender differences in facial soft tissue profile (III) ................................. 62
5.7 Correlation between facial soft tissue profile, and overbite and overjet (III) ........................................................................ 64
5.7.1 Entire sample population ...................................................................... 64
5.7.2 Subgroup analysis .............................................................................. 66
5.8 Aesthetic evaluation (IV) ......................................................................... 67
5.8.1 Differences in perceived attractiveness between the panel groups ............................................................ 67
5.8.2 Comparisons between the study groups and the control group .............. 68
5.8.3 Association between facial attractiveness and facial characteristics ....................................................... 68

6 Discussion
6.1 The prevalence of malocclusion traits and orthodontic treatment ............ 73
6.2 Association of occlusion with TMD .......................................................... 76
6.3 TMD and orthodontic treatment ............................................................... 77
6.4 Occlusal interferences in TMD subjects with orthodontic treatment experience ............................................................... 79
6.5 Association between facial soft tissue profile and malocclusions ............. 79
6.6 Perception of facial aesthetics between the panel groups ......................... 81
6.7 Association between facial sagittal and vertical characteristics and facial attractiveness .................................................. 81
6.8 Strengths and weaknesses of the study ...................................................... 83
6.9 Clinical implications and future perspectives ........................................... 85

7 Conclusions
References
Appendix
Orginal articles
1 Introduction

Malocclusion is a complex term that covers all deviations of occlusion and jaws from normal alignment (Lombardi & Bailit 1972). The difference between malocclusion and normal occlusion is not unambiguous (Harris & Corruccini 2008). Epidemiologic data regarding malocclusion are an important part in treatment planning and oral health-care management. Despite this, there is scarce epidemiological malocclusion data available related to Finnish adult population. In addition, the number of adults seeking orthodontic treatment has increased in the last few years (Michelotti & Iodice 2010).

Temporomandibular disorders (TMD) is a collective term for pain and dysfunction conditions related to the temporomandibular joints (TMJs), the masticatory muscles and associated structures (Okeson 2013). The aetiology of TMD is multifactorial and the occlusion as an aetiological factor of TMD is one of the most disputed topics in dentistry (Chisnou et al. 2015, Okeson 2013).

Traditionally, diagnostics and treatment planning in orthodontics are based on anamnesis, clinical examination and analysis of study models and lateral skull radiographs (Mitchell 2013). Increasing concern about radiation exposure from lateral skull radiographs has raised the role of photographs in imaging malocclusions and facial profile (Dimaggio et al. 2007, Kale-Varlk 2008). Profile photographs are a low-cost and non-invasive tool to detect facial soft tissue characteristics (Kale-Varlk 2008, Staudt & Kiliaridis 2009, Wasserstein et al. 2015).

The present study was designed to investigate the prevalence of malocclusion traits and orthodontic treatment, the role of occlusion in TMD, and the association of facial soft tissue characteristics with anterior malocclusions and facial aesthetics among mid-adulthood subjects in the Northern Finland Birth Cohort 1966 (NFBC1966).
2 Review of the literature

2.1 Malocclusion

2.1.1 Definition and classifications of malocclusion

In the late 1900s, modern orthodontics was developed by Edward H. Angle (Proffit et al. 2013). He has been regarded as the founder of orthodontics and he also was interested in occlusion in natural dentition. In the 1890s, Angle developed the first definition of normal occlusion and classified malocclusions into three classes based on the sagittal occlusal relationships of the first permanent molars (Angle 1899). Class I malocclusion exhibits a normal relationship of the first molars. In class II malocclusion, the lower first molar is positioned distally compared to the maxillary first molar. In class III malocclusion, the lower first molar is positioned abnormally mesially compared to the upper first molar.

Andrews (1972) introduced six occlusal characteristics to describe normal occlusion. The six keys to normal occlusion are correct molar relationship, correct crown angulation and inclination, no rotations, no spaces, and a plane of occlusion ranging from flat to a slight curve of Spee (Andrews 1972). Today, the concept of occlusion includes not only morphological characteristics but also functional and aesthetic aspects (Svedström-Oristo et al. 2001). Good function has been considered to be the most important characteristic of an acceptable occlusion (Svedström-Oristo et al. 2001).

Malocclusion is a complex concept because there is no specific threshold to separate good occlusion and malocclusion (Harris & Corruccini 2008). According to Lombardi and Bailit (1972), the concept of malocclusion includes all deviations of the dentition and jaws from normal alignment. Malocclusion thus comprises malpositioning of individual teeth, discrepancies between tooth and jaw, and malrelations of the dental arches (Lombardi & Bailit 1972). It has also been proposed that “malocclusion is any disharmonious variation from the accepted or theoretical normal arrangements of the teeth. But, in nature some degree of variation among individuals of a species is always present” (Grainger 1967).

Malocclusions can be observed in three planes of space: sagittal, vertical and transversal (Figure 1.). Angle’s classification describes malocclusion in the sagittal plane based on molar relationship. One can also examine incisor relationship in the sagittal plane, and this malocclusion can be detected by increased or decreased
overjet (Figure 1A.). Overjet is a horizontal distance between the labial surfaces of the central upper and lower incisors (Harris & Corruccini 2008). The incisor relationship also describes vertical malocclusions which can be detected by increased overbite and anterior open bite (Figure 1A.). Overbite is the vertical distance between the incisal edges of the central upper and lower incisors (Harris & Corruccini 2008). In anterior open bite malocclusion, the incisors do not meet each other in occlusion and there is a vertical gap between the upper and lower incisor edges (Harris & Corruccini 2008). When looking at dental arches in transversal plane, lateral crossbite and scissors bite malocclusions can be detected (Figure 1B; and 1C.). In lateral crossbite, maxillary buccal cusps occlude too lingually (Björk et al. 1964). In scissors bite, maxillary lingual cusps occlude too buccally and the cusps have passed each other (Björk et al. 1964).

An important clinical issue is whether malocclusion is of dental or skeletal origin. Skeletal malocclusions are a result of defective jaw relationships in any combination of the three planes of space and can be detected by radiography (Proffit et al. 2013). By contrast, dental malocclusions are generated by malposition of the teeth, as well as rotation, abnormal angulations and tipping of the teeth (Harris & Corruccini 2008).
2.1.2 Prevalence of malocclusion

Prevalence of malocclusion in children

Most of the epidemiological studies concerning malocclusion have concentrated on children and adolescents. There are several epidemiological studies which have shown the prevalence of malocclusion in Finnish child population (Hannuksela 1977, Heikinheimo 1978, Kerosuo et al. 1991, Keski-Nisula et al. 2003, Myllärniemi 1970). Myllärniemi (1970) investigated the prevalence of malocclusion in groups of different development stages of the dentition among Finnish rural children. In that study, crowding was significantly more prevalent among girls, while boys presented more often with a distal occlusion in the deciduous and permanent dentitions (Myllärniemi 1970). The prevalence of malocclusion was approximately three times higher in the permanent dentition compared to deciduous dentition, and the most common malocclusion in permanent dentition was deep bite (Myllärniemi 1970).

Hannuksela (1977) examined the prevalence of malocclusion in 9-year-old Finnish schoolchildren. In that study, the total prevalence of malocclusion was 60.2 per cent (Hannuksela 1977), which is higher compared to the 38.9 per cent detected by Myllärniemi in mixed dentition (Myllärniemi 1970). The most common malocclusions were crowding (25.9%) and Class II occlusion (15.0%) (Hannuksela 1977). Differences between genders were not registered.

Heikinheimo (1978) studied 7-year-old Finnish children to determine the need of orthodontic treatment. The prevalence of malocclusion in that study (Heikinheimo 1978) was in the line with the study of Hannuksela (Hannuksela 1977) except for higher prevalence of deep bite.

Kerosuo et al. (1991) studied the prevalence of occlusal anomalies in 12- to 18-year-old Finnish urban schoolchildren. In their study, increased overjet and deep bite were more common among boys than girls. The proportion of children without any occlusal or space anomalies was 12 per cent. Crowding (40%) was found to be the most prevalent type of malocclusion, while anterior open bite (1%), scissors bite (3%), and lateral crossbite (6%) were rare in this adolescent population. (Kerosuo et al. 1991)

Keski-Nisula et al. (2003) investigated malocclusion in early mixed dentition. The prevalence of malocclusion varied between 67.7 per cent and 92.7 per cent depending on threshold level. The study showed that overbite of 4 mm or more was
more common than overjet of 4 mm or more among children aged 4.0–7.8 years. (Keski-Nisula et al. 2003)

Thilander and Myrberg (1973) studied the prevalence of malocclusion among Swedish schoolchildren. In their study, increased overbite was more common than overjet, and crossbite was detected as the most prevalent occlusal anomaly (Thilander & Myrberg 1973). A Swedish study on 3-year-old children showed malocclusion traits (70%) to be common in early childhood as well (Dimberg et al. 2010). In that study, the most frequent malocclusions were anterior open bite, Class II malocclusion, increased overjet, and posterior crossbite (Dimberg et al. 2010). Tausche et al. (2004) investigated the prevalence of malocclusion in early mixed dentition among German children. According to their study, increased overjet and overbite were the most common types of malocclusion (Tausche et al. 2004). A high prevalence of malocclusion traits (93%) in Italian school children has been detected (Ciuffolo et al. 2005). In addition, boys showed an increased overbite more often than girls (Ciuffolo et al. 2005).

Prevalence of malocclusion in adults

In Finland, most of the epidemiological malocclusion studies have so far concentrated on children and adolescents. There are only few epidemiological malocclusion studies based on adults (Laine & Hausen 1983, Pietilä & Nordblad 2008). In the study of Laine and Hausen (1983), the study population consisted of 451 Finnish university students. Laine and Hausen (1983) reported that 42 per cent of the subjects had at least one occlusal anomaly, and the most frequent malocclusions were crossbite (19%) and distal molar occlusion (15%). Subjects who had received orthodontic treatment demonstrated significantly higher frequency of overjet, anterior open bite and crossbite compared to untreated subjects (Laine & Hausen 1983). Because the size of the study population was relatively small and all subjects were selected university students, it is questionable to generalize these study results to describe Finnish adult population.

A more recent Finnish malocclusion study on adults is part of the Health 2000 Survey (Pietilä & Nordblad 2008). The age of the study population varied from 30 to 75 years or older. In this population-based investigation, the study population comprised 4,711 subjects and 31 per cent of the subjects displayed at least one occlusal deviation. The study showed that the most common malocclusions were anterior or lateral crossbite (18%), large overjet (7%) and scissors bite (6%). According to the inclusion criteria of the study, only malocclusion types including
an apparent risk of poor occlusion prognosis were examined. (Pietilä & Nordblad 2008)

When considering the prevalence of malocclusion in different adult populations, one must keep in mind that malocclusion traits also vary between countries due to different genetic background (Harris & Johnson 1991, Mossey 1999, Nikopensius et al. 2013, Xue et al. 2010). Another problem when comparing epidemiologic malocclusion studies is that individual studies have used different threshold level to separate continuous variables of malocclusion (overjet and overbite) from normal occlusion (Jago 1974). As noted, there is no clear border to separate most of the malocclusion traits from normal occlusion (McLain & Proffit 1985).


In Swedish adult population, the prevalence of malocclusion has been reported to vary between 17 and 53 per cent (Salonen et al. 1992). Crowding, Angle class II-1 and crossbite have been detected to be the most prevalent malocclusions among Swedish population (Salonen et al. 1992). Salonen et al. (1992) also found significant gender differences concerning malocclusions. Angle Class III malocclusion, spacing and unilateral crossbite were more common in men while women showed more often crowding (Salonen et al. 1992). Mohlin (1982) and Ingervall et al. (1978) have investigated malocclusions separately in women and men in Sweden. Based on these studies, women have more often distal molar occlusion compared to men (Ingervall et al. 1978, Mohlin 1982), and conversely, Swedish men show more often class III malocclusion (Salonen et al. 1992).

In the Netherlands, the most frequent malocclusions were class II malocclusion, overjet and deep bite (Burgersdijk et al. 1991). In Icelandic adult population, 33.9 per cent of the subjects had at least one malocclusion trait, and the most common findings were distal molar occlusion (27.7%), mandibular anterior crowding (13.4%), molar crossbite (11.9%) and increased overbite (11.8%) (Jonsson et al. 2007). In addition, significant sexual dimorphism was detected in the study, with male dominance for anterior crossbite, mesial occlusion and scissors bite (Jonsson et al. 2007).

In Germany, the most common malocclusions are reportedly anterior crowding (62.9%), increased overjet (36.8%), and distal occlusion (34.9%) (Hensel et al.
2003). The German study also showed sexual dimorphism concerning malocclusions so that anterior crowding, increased overjet and distal occlusion were more frequent among women, while spacing, edge-to-edge bite, excessive overbite and mesial occlusion were more prevalent in men (Hensel et al. 2003).

Partly different findings have been detected in epidemiological malocclusion studies conducted outside Europe (Brunelle et al. 1996, Haralur et al. 2014, McLain & Proffit 1985, Proffit et al. 1998, Tod & Taverne 1997). In the United States adult population, overbite was more common compared to overjet (Brunelle et al. 1996). In addition, a more recent study showed that increased overbite was more prevalent in the United States adult population in contrast to increased overjet (Proffit et al. 1998). Conversely, increased overjet was more common than increased overbite in an Australian adult study population (Tod & Taverne 1997). Tod and Taverne (1997) found no significant gender differences for malocclusions in Australia. Among the Saudi population, 42.8 per cent of the subjects were found to have malocclusion (Haralur et al. 2014).

Based on earlier published literature, the prevalence of malocclusion among adults seems to be high and quite at the same level compared to children and adolescents (McLain & Proffit 1985). There are several factors which might influence the prevalence of malocclusion in adulthood. Firstly, relapse and poor stability of the treatment results in the long term are common problems in orthodontics (Birkeland et al. 1997, Kerosuo et al. 2013). However, a recent study on treatment of Class II-2 malocclusion has shown very good long-term stability (Bock et al. 2017). The prevalence of malocclusion in adulthood is also affected by tooth loss (Liegeois & Limme 1992, Pedersen et al. 1978). Another factor is insufficient treatment during childhood due to limited access to orthodontic treatment or refusal from treatment. When considering the prevalence of malocclusion in adulthood, one must also pay attention to occlusal changes over time (Bishara et al. 1989, Bondevik 1998, Henrikson et al. 2001). Mandibular growth has been reported to continue in adulthood (Behrents 1985, Björk 1963). Behrents (1985) published a work in which he presented that men expressed mandibular growth at later age compared to women. In addition, several studies have shown that dental arches do not remain stable during adulthood (Bishara et al. 1989, Bondevik 1998, Bondevik 2015, Henrikson et al. 2001). Mesial drift and decrease of dental arch length has been reported in a longitudinal study (Harris 1997).
2.1.3 Orthodontic treatment

In Finland, orthodontic treatment for children and adolescents is mostly free of charge and takes place in municipal health centres (Pietilä et al. 2008). By contrast, orthodontic treatment for Finnish adults is chargeable, and only patients with severe malocclusion have access to subsidized oral special care. Today, the number of adult patients seeking orthodontic treatment has increased due to aesthetic awareness (Michelotti & Iodice 2010).

In Finland, the prevalence of orthodontic treatment experience among adults has been reported to vary from 11 per cent to 19 per cent (Laine & Hausen 1982, Pietilä & Nordblad 2008). Among young Finnish adults, 38.5 per cent of the subjects had received orthodontic treatment (Tuominen et al. 1994). Earlier studies both globally and in Finland have shown a higher frequency of women having received orthodontic treatment (Burgersdijk et al. 1991, Jonsson et al. 2007, Laine & Hausen 1982, Tod & Taverne 1997, Tuominen et al. 1994). The more frequent history of orthodontic treatment among women might be explained by differences in treatment seeking and treatment attitude between the genders; Finnish boys have been reported to be more satisfied with their occlusion without having had orthodontic treatment (Pietilä & Pietilä 1996).

An earlier Finnish study on adults has reported a higher frequency of malocclusion among adults with a history of orthodontic treatment than among adults naive to orthodontics (Laine & Hausen 1983). Similar results have been reported from elsewhere in Europe (Burgersdijk et al. 1991, Jonsson et al. 2007). The study results of an earlier Finnish study on adults indicates that orthodontic treatment in Finland has generally not been successful in eliminating malocclusion to normal or ideal level (Laine & Hausen 1983).

2.2 Temporomandibular disorders and occlusion

2.2.1 Definition of temporomandibular disorders

Temporomandibular disorders (TMD) is a collective term for pain and dysfunction conditions related to the temporomandibular joints (TMJs), the masticatory muscles and associated structures (Okeson 2013). TMD can also be defined as functional disturbances of the masticatory system (Okeson 2013). Over the years, the terminology associated with functional disturbances of the masticatory system has varied and several terms have been introduced (Bell 1982, Laskin 1969,
McNeill et al. 1980). Because of the great variety in terminology over the past years, the American Dental Association introduced the concept *temporomandibular disorders* in 1983 (Griffiths 1983).

The most common signs and symptoms of TMD are pain and tenderness in the TMJs and/or masticatory muscles, clicking and/or crepitus in the TMJs, and limitation and deviations of mandibular movements (Carlsson 1984, Dworkin & LeResche 1992, Okeson 2013). The most frequent symptom of TMD is pain either in masticatory muscles or in TMJs (Dworkin & LeResche 1992). The most typical age when symptoms of TMD occur is between 20 and 40 years (Marklund & Wänman 2010).

Epidemiological studies have reported that signs and symptoms of TMD are relatively common in populations (De Kanter et al. 1993, Kuttila et al. 1998, Rutkiewicz et al. 2006). The prevalence of TMD symptoms has been reported to vary from 25 to 50 per cent, while clinical findings of TMD have been shown to be even more frequent (38–90%) in adult populations (Carlsson 1999, Rutkiewicz et al. 2006). In addition, several studies have found a higher prevalence of TMD signs and symptoms in women than in men (Johansson et al. 2003, Jussila et al. 2017, Rutkiewicz et al. 2006).

TMD can be classified primarily into three diagnostic subgroups: artrogenous, myogenous and combined (McCreary et al. 1991, Schiffman et al. 1990). The subclassification of TMD is not, however, always unambiguous due to fluctuation of the diagnostic subgrouping (Kuttila et al. 1997). Dworkin and LeResche (1992) developed dual-axis research diagnostic criteria of TMD (RDC/TMD), which included both physical conditions (Axis I) and psychological issues (Axis II). Later, Schiffman et al. (2014) developed new dual-axis diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications (Schiffman et al. 2014). Based on DC/TMD, TMD diagnoses include myalgia, arthralgia, headache attributed to TMD, disc displacement with reduction, disc displacement without reduction, degenerative joint disease and subluxation (Schiffman et al. 2014).

### 2.2.2 Aetiology of TMD

Despite the abundance of published literature, the complex aetiology of TMD is not clearly understood. There is general support that TMD is determined by a dynamic interaction between biological, psychological and social factors (Carlson et al. 1993, Dworkin & Burgess 1987, Dworkin et al. 1990, Epker et al. 1999,
Fillingim et al. 2011, Kotiranta et al. 2014, Okeson 1995, Sipilä et al. 2013, Suvinen et al. 2005, Suvinen & Reade 1995). Earlier studies have shown that disturbed function of TMJ (Costen 1934, Farrar 1978, Reade 1984, Stegenga et al. 1989), masticatory muscles (Schwartz 1959, Yemm 1976) and occlusal factors (Agerberg & Carlsson 1973, Helkimo 1976) play a role as aetiologic factors of TMD. In addition, trauma (Brown 1997, De Boever & Keersmaekers 1996, Pullinger & Seligman 1991, Silvennoinen et al. 1998, Yun & Kim 2005) and parafunction (Berger et al. 2017, Blanco Aguilera et al. 2014, Jiménez-Silva et al. 2017) can also occur in the background of TMD. Signs and symptoms of TMD have been found to correlate with impaired general health (Johansson et al. 2004, Yekkalam & Wänman 2014). Somatic diseases such as headache and pain in the face, ear and neck are overrepresented among TMD patients (de Leeuw et al. 1994, Kuttila et al. 1999, Kuttila et al. 2004, Rauhala et al. 2000). Psychological problems such as depression have been shown to associate with pain-related symptoms of TMD (Sipilä et al. 2001) and depressiveness has been reported to increase the risk for chronic facial pain (Sipilä et al. 2013).

The role of occlusion in the aetiology of TMD

Occlusion as an aetiologic factor in the background of TMD has been widely disputed for many years (Okeson 2013). Today, the role of occlusion as an aetiologic factor of TMD is still controversial. The conclusion is that occlusion belongs to the factors related to TMD. Occlusion might affect TMD in two ways: acute changes in the occlusion can create a protective muscle co-contraction response or induce orthopaedic instability of the mandible. When considering the association between occlusal condition and TMD, one must take into account occlusion both statically and dynamically. (Okeson 2013)

Earlier studies have reported conflicting results regarding the potential association between occlusal factors and TMD. Several studies have shown scientific evidence for a relationship between occlusion and TMD (Egermark et al. 2003, Egermark-Eriksson et al. 1983, Egermark-Eriksson et al. 1990, Mohlin et al. 2004, Pullinger & Seligman 2000, Raustia et al. 1995a, Sari et al. 1999, Sipilä et al. 2002, Sipilä et al. 2006, Wang et al. 2009). Disturbances of occlusal relationships have been shown to be associated with morphological changes in TMJ internal structure (Raustia et al. 1995b). It has also been suggested that TMD patients might be more sensitive to even minor changes in occlusion (Le Bell et al. 2002). However, some of these earlier studies showed only a weak correlation
between occlusion and TMD (Egermark et al. 2003, Egermark-Eriksson et al. 1983, Egermark-Eriksson et al. 1990, Pullinger & Seligman 2000), and moreover, a number of studies have not detected any association at all between occlusal factors and TMD (Carlsson et al. 2002, LeResche 1997, Mohlin et al. 2007, Reynders 1990, Seligman & Pullinger 1991). Notably, most of the earlier studies have only focused on the association between occlusion and TMD without considering any causal factors.

2.2.3 Association of malocclusions with signs and symptoms of TMD

Even if the causal role of occlusion in TMD is still controversial, several studies have reported a correlation between TMD signs and symptoms and malocclusions (Alamoudi 2000, Celić et al. 2002, Raustia et al. 1995a). Based on the earlier studies, TMD has been reported to be associated with crossbite, anterior open bite, deep bite, Angle Class II malocclusion, Angle Class III malocclusion and increased overjet (Alamoudi 2000, Celić et al. 2002, Egermark et al. 2003, Egermark-Eriksson et al. 1990, Haralur et al. 2014, Jämsä et al. 1988, Marklund & Wänman 2010, Mohlin & Kopp 1978, Mohlin & Thilander 1984, Pullinger & Seligman 2000, Sari et al. 1999, Schmitter et al. 2007, Thilander et al. 2002). In addition, crowding has been found to be more common among TMD subjects compared to non-TMD subjects (Mohlin et al. 2004). Furthermore, subjects with a higher number of missing posterior teeth have been reported to have a higher prevalence of TMD (Wang et al. 2009). By contrast, some earlier studies have found no association between malocclusion and self-reported TMD symptoms (Gesch et al. 2005, John et al. 2002).

Anterior open bite has been shown to increase the risk for myofascial pain (Schmitter et al. 2007). In addition, anterior open bite has been demonstrated to be associated with internal derangement (Byun et al. 2005) and osteoarthritis of the TMJ (Seligman & Pullinger 1989). Anterior crossbite has been found to be associated with a reduced eminence height of TMJ (Wohlberg et al. 2012). Posterior crossbite has been shown to be associated with disk displacement, and increased overjet has been detected among osteoarthrosis patients (Pullinger et al. 1993, Pullinger & Seligman 2000).

Earlier studies have also investigated a correlation between TMD and occlusal interferences between the upper and lower jaw. Occlusal interferences have been reported to be more important than morphologic malocclusion in explaining the
existence of TMD (Egermark-Eriksson et al. 1983). Significant correlation has been shown between TMD and mediotrusive interferences as well as RCP-ICP slide (Haralur et al. 2014). In addition, TMD signs have been demonstrated to correlate weakly with mediotrusive interferences in a young adult population (Celić et al. 2002). The length of the sagittal RCP-ICP slide and its lateral deviation have been shown to correlate with the signs and symptoms of TMD (Raustia et al. 1995a). In addition, mediotrusive interferences have been detected among patients with mandibular pain and dysfunction (Mohlin & Kopp 1978).

2.2.4 The role of orthodontic treatment in TMD

During the last decades, the role of orthodontic treatment as a contributing or risk factor for development of TMD has been disputed. At least two different factors have been introduced to explain how orthodontic treatment might affect TMD (Michelotti & Iodice 2010, Olsson & Lindqvist 2002). It has been speculated whether internal derangement may be the consequence of the changes in condylar position during orthodontic treatment (Michelotti & Iodice 2010). Orthodontically treated subjects have shown more often flattening of the articular surface and subcortical sclerosis in panoramatomograms than untreated individuals (Peltola 1993). Lateral malocclusions have been detected to show a more asymmetric position of the condyles (Pirttiniemi et al. 1991). In addition, condyle position asymmetry has been found more often in TMD patients, and significant correlation has been detected between signs and symptoms of TMD and occlusal variables describing asymmetry (Raustia et al. 1995a). Therefore, the authors discussed the indications for orthodontic treatment to prevent the predisposing influence of occlusal discrepancy on TMD (Raustia et al. 1995a). Along with changes in condylar position, another possible explanatory factor for the effect of orthodontic treatment on TMD might be occlusal interferences (Olsson & Lindqvist 2002).

Earlier studies have found differences between orthodontically treated and untreated subjects regarding the prevalence of TMD (Egermark & Thilander 1992, Henrikson et al. 2000). In the study of Henrikson et al. (2000), the prevalence of muscular signs of TMD decreased among orthodontically treated Class II subjects two years after treatment. In addition, functional occlusal interferences were reduced in orthodontically treated subjects compared to untreated Class II group and normal occlusion group (Henrikson et al. 2000). An earlier study has found less frequent symptoms of TMD after orthodontic treatment (Olsson & Lindqvist 1995). No propensity for increased prevalence of TMD signs has been found among

Some studies found no differences regarding the symptoms of TMD when comparing orthodontically treated and untreated subjects (Dahl et al. 1988, Egermark et al. 2003, Sadowsky & Polson 1984). A lower percentage of TMD symptoms has been detected among orthodontically treated subjects compared to untreated group, even if the differences were not statistically significant (Sadowsky & Polson 1984). On the other hand, in a Japanese study no differences were found between orthodontically treated and untreated subjects concerning the incidence of TMD signs (Hirata et al. 1992). A more recent study has shown that orthodontic treatment is not related to signs and symptoms of TMD (Macfarlane et al. 2009). Based on a meta-analysis, traditional orthodontic treatment has not been shown to increase the prevalence of TMD (Kim et al. 2002). According to a review article, orthodontic treatment carried out during adolescence does not in general affect the risk for development of TMD in adulthood (McNamara et al. 1995).

Along with conventional orthodontic treatment, several studies have investigated the effect of orthognathic surgery on TMD (Abrahamsson et al. 2013, Panula et al. 2000, Rusanen et al. 2008, Wolford et al. 2003). Changes of the facial skeleton after orthognathic surgery in patients with dentofacial deformities might affect TMJs, masticatory muscles, surrounding soft tissues and changes of TMJ symptoms (Jung et al. 2015). Improved occlusal relationships between the upper and lower jaw, meaning improved masticatory function, have been noted as greatly increased electromyographic activity in masticatory muscles during chewing after mandibular sagittal split osteotomy (Raustia & Oikarinen 1994). The signs and symptoms of TMD have been reported to decrease significantly after surgical/orthodontic or orthodontic treatment (Rusanen et al. 2008, Silvola et al. 2015). In addition, longitudinal studies have reported a lower prevalence of signs and symptoms of TMD after orthognathic surgery (Abrahamsson et al. 2013, Panula et al. 2000). Panula et al. (2000) found a significant decrease in headache, joint pain on palpation and muscle palpation tenderness after orthognathic surgery. It has also been found that the association between self-reported symptoms of TMD and severity of malocclusion in orthognathic-surgical patients is not unambiguous (Svedström-Oristo et al. 2016). On the other hand, significant worsening of the TMJ dysfunction has been reported after orthognathic surgery (Wolford et al. 2003). In addition, orthognathic patients have developed condylar resorption after surgery (Wolford et al. 2003). It has been concluded that orthognathic surgery seems to
have a mainly positive outcome regarding TMD pain in patients with dentofacial deformities (Abrahamsson et al. 2013, Panula et al. 2000, Silvola et al. 2015).

2.3 Facial soft tissue characteristics

2.3.1 Cephalometric analysis

The craniofacial complex can be divided into five structural categories: the cranium and cranial base, the skeletal maxilla, the skeletal mandible, maxillary dentoalveolar structures, and mandibular dentoalveolar structures (Proffit et al. 2013). Cephalometry is a study of the facial bones based on the analysis and interpretation of the patients’ radiographs (Mitchell 2013). Cephalometric analysis is usually performed by examining lateral skull radiographs (Mitchell 2013). Cephalometrics is an essential diagnostic tool for orthodontist to examine malocclusion and skeletal pattern of the craniofacial complex (Proffit et al. 2013). The purpose of cephalometric analysis is to find out how the cranial base, teeth and jaws are related to each other (Proffit et al. 2013). Cephalometric analysis typically includes localization of the cephalometric landmarks, determination of cephalometric planes, linear and angular measurements, and interpretation of the study results, preferably based on normal values of the same population.

Although cephalometrics have traditionally focused on skeletal and dental measurements, towards the end of the past millennium more attention has been paid on measurement of facial soft tissue characteristics (Bergman 1999). There is a large body of published literature regarding associations between facial soft tissue features and skeletal pattern (Halazonetis 2007, Kasai 1998, Rose et al. 2003, Saxby & Freer 1985, Staudt & Kiliaridis 2009). Hard tissue variables, such as sagittal relationship between the jaws (ANB-angle), lower facial height, point A convexity and position of the lower incisors have been reported to be associated with facial soft tissue profile (Kasai 1998, Saxby & Freer 1985, Staudt & Kiliaridis 2009).

Cephalometric facial soft tissue analysis

Cephalometric facial soft tissue analyses are important in diagnostics, treatment planning and for understanding possible changes occurring in facial appearance as a result of orthodontic treatment (Bergman 1999, Holdaway 1983). However, the
interpretation of facial soft tissue analysis is not simple because cephalometric values might be influenced by several factors, such as skeletal relationships, position of the teeth, soft tissue thickness, ethnic origin, gender and age (Bergman 1999, Saxby & Freer 1985). Moreover, they can be altered by momental factors related to muscular activity, lip position and facial expression at the time of exposure, particularly in children. Cephalometric analysis of facial soft tissue is also an important part of the treatment plan in orthognathic surgery (Oh et al. 2017). A good occlusion based on the conventional cephalometrics does not always produce a balanced facial structure (Bergman 1999).

Most of the earlier studies have investigated facial soft tissue features using lateral skull radiographs (AlBarakati 2011, Halazonetis 2007, Saxby & Freer 1985). Radiation exposure by cephalometric radiographs and radiation protection concerns have recently raised the role of profile photographs in soft tissue facial analysis (Diamaggio et al. 2007, Kale-Varlk 2008). Correlation between hard and soft tissue variables has been reported to be higher when measurements have been performed from lateral cephalograms compared to profile photographs (Staudt & Kiliaridis 2009). A more recent study has shown, however, that the analysis of profile photographs is a noteworthy method to study sagittal soft tissue relationships (Wasserstein et al. 2015).

### 2.3.2 Linear and angular facial measurements

Quantitative facial soft tissue profile analysis based on photographs can be divided into two categories: linear and angular facial analyses (Fernández-Riveiro et al. 2002, Fernández-Riveiro et al. 2003). Several authors have studied the soft tissue facial profile by using linear measurements (Arnett & Bergman 1993a, Arnett & Bergman 1993b, Burstone 1958, Holdaway 1983, Ricketts 1968, Subtelny 1959). Subtelny (1959) observed that facial soft tissue changes occurring during growth are not analogous to changes in the skeletal profile. Various authors have introduced new linear measurement variables to be used. Ricketts (1968) described the aesthetic E-plane and E-line while Holdaway (1983) introduced the H-line. The importance of natural head position in the soft tissue facial analysis has earlier been demonstrated (Arnett & Bergman 1993a). A study based on facial photographs described linear measurements of the soft tissue facial profile in an attempt to identify an average profile of young white adults (Fernández-Riveiro et al. 2002).

Numerous soft tissue angular variables have also been described by various authors (Anić-Milosević et al. 2008, Arnett & Bergman 1993a, Arnett & Bergman 1993b, Arnett & Bergman 1993c).
1993b, Fernández-Riveiro et al. 2003, Holdaway 1983, Merrifield 1966). For example, the H-angle (formed by the soft tissue facial plane and harmony line) (Holdaway 1983), the Z-angle (formed by the profile line and the Frankfurt plane) (Merrifield 1966) and angle of convexity (Legan & Burstone 1980) have been created to evaluate facial soft tissue profile. The Z-angle describes the lower facial relationship in the facial profile (Merrifield 1966). H-angle has been designed to measure prominence of the upper lip or retrognathism of the soft tissue chin (Holdaway 1983). Several studies have also investigated facial profile among different malocclusions in relation to the angle of facial convexity (Arnett & Bergman 1993a, Arnett & Bergman 1993b, Godt et al. 2013).

2.3.3 Facial aesthetics

Along with favourable occlusion, a harmonious and balanced facial appearance is one of the main goals in orthodontic treatment (Bergman 1999, Spyropoulos & Halazonetis 2001). Therefore, facial soft tissue studies have traditionally concentrated on facial aesthetics (Merrifield 1966, Peck & Peck 1970). Examination of facial appearance is an essential part in comprehensive treatment planning because orthodontic treatment may alter facial soft tissue characteristics. Profile outline has traditionally been used to evaluate facial attractiveness (Spyropoulos & Halazonetis 2001).

Facial aesthetics is also commonly a major reason why patients seek orthodontic treatment (McKiernan et al. 1992, Nurminen et al. 1999, Silvola et al. 2014). Improved facial appearance can affect individuals’ self-esteem and social interaction (Knight & Keith 2005). In addition, aesthetic change in the craniofacial complex is related to patient’s emotional wellness (Ackerman 2006). Treatment of severe malocclusions has been demonstrated to improve the aesthetic satisfaction and oral health-related quality of life (Silvola et al. 2014).

Due to the subjective nature of the evaluation of facial aesthetics, several previous studies have used different panel groups to assess facial attractiveness (Maple et al. 2005, Naini et al. 2012, Romani et al. 1993). A panel study, based on professionals and laypersons, is an essential research method for the orthodontist, since professional opinion regarding facial appearance may not be in line with the patient’s perception. Earlier panel studies have shown contradictory results regarding agreement of facial attractiveness between professionals and laypersons. Some studies have found agreement in perception of facial attractiveness between orthodontist or orthodontic residents and laypersons (Maple et al. 2005, Shelly et
al. 2000, Soni et al. 2016). Conversely, other studies found no agreement with respect to facial attractiveness between orthodontist and laypersons (Bell et al. 1985, Cochrane et al. 1997, Cochrane et al. 1999). Orthognathic patients have been demonstrated to be more critical than laypersons in their aesthetic opinion regarding sagittal position of the mandible (Naini et al. 2012).

Previous studies have shown that both sagittal and vertical proportions of facial soft tissue have an influence on facial attractiveness (Johnston et al. 2005a, Johnston et al. 2005b, Varlik et al. 2010). Normal sagittal position of the mandible and normal lower anterior facial height have been demonstrated as the most important characteristics for aesthetic facial appearance (Johnston et al. 2005a, Johnston et al. 2005b, Naini et al. 2012, Varlik et al. 2010). On the other hand, the more extreme the deviations in vertical and sagittal dimensions the less attractive has been the perception of facial appearance by raters (Maple et al. 2005).

2.3.4 Facial soft tissue profile and malocclusion

Earlier studies have demonstrated that facial soft tissue characteristics are related to malocclusions (Bittner & Pancherz 1990, Dimaggio et al. 2007, Godt et al. 2013, Maurya et al. 2014).

Children and adolescents

Godt et al. (2013) investigated the correlation between facial morphology and sagittal and vertical malocclusions in 4- to 6-year-old children by 3D photographs. According to the study, Class II malocclusion with increased overjet and Class III malocclusion with decreased overjet influenced soft tissue morphology. Class III children demonstrated increased total face angle (glabella-subnasale-pogonion) and more concave profiles compared to the control group. Class II malocclusion was shown to associate with a more anterior upper lip position. (Godt et al. 2013)

Dimaggio et al. (2007) studied the relationship between posterior occlusion and soft tissue profile in 6-year-old children by 2D profile photographs. The study showed that all angular variables and facial heights were significantly influenced by variation in molar relationship (Dimaggio et al. 2007). For example, the facial convexity angle was largest in children with Class III malocclusion while the SN-SI–angle (subnasale–nasion–sublabiale, cutaneous analogue of ANB-angle) was greatest in children with Class II malocclusion (Dimaggio et al. 2007). Based on
3D soft tissue facial analysis on children, more convex faces in the sagittal plane have been detected among Class II subjects (Ferrario et al. 1994).

Bittner and Pancherz (1990) have studied sagittal and vertical malocclusion and their relationship to facial morphology in 12- to 14-year-old children by facial photographs and lateral headfilms. According to the study, large overjet was most related to facial appearance. In contrast, overbite and negative overjet could not be detected on facial photographs. Thus, skeletal Class I and Class III malocclusions were found to be problematic to detect from facial photographs. (Bittner & Pancherz 1990)

Wasserstein et al. (2015) compared lateral photographic and radiographic sagittal analyses in relation to Angle’s classification among adolescents. According to the study, Class III malocclusion has the most characteristic soft tissue pattern. The soft tissue angles A-N-B and A-N-Pog were reported to be significantly different in Angle Class III malocclusion compared to Class I and Class II malocclusions. (Wasserstein et al. 2015)

Adults

Staudt and Kiliaridis (2009) examined 2D profile photographs and lateral cephalograms among young men in an attempt to detect Class III skeletal discrepancies. According to the study, facial soft tissue features correlated highly with skeletal structures of skeletal Class III subjects. Therefore, the authors of the study concluded that profile photographs are reliable to detect a skeletal Class III discrepancy. (Staudt & Kiliaridis 2009)

Maurya et al. (2014) investigated soft tissue features of Class II-1 malocclusion in young adult population using lateral cephalograms. A more convex soft tissue profile has been reported among Class II malocclusion (Hameed et al. 2008, Maurya et al. 2014).

Saxby and Freer (1985) studied dentoskeletal variables in relation to the soft tissue profile in females. In their study, overbite was negatively correlated with horizontal position of the soft tissue B-point and its relation to soft tissue A-point (Saxby & Freer 1985). On the other hand, overjet has only been shown to correlate with upper lip convexity (Saxby & Freer 1985).

Even though previous studies have found associations between malocclusions and facial soft tissue characteristics, none of the past studies included a large cross-sectional cohort of middle-aged patients. In addition, most of the earlier investigations have been based on lateral skull radiographs. An earlier profile
photograph study concluded that profile photographs could be useful for initial consultations and screening of populations (Staudt & Kiliaridis 2009). Therefore, deeper understanding is needed in order to conclude the underlying occlusal relationships by evaluating facial soft tissue features using 2D profile photographs.
3 Aims of the study

This study was designed and carried out to increase understanding and knowledge about the relationships between occlusal features and function and facial aesthetics in adults. It was based on the Northern Finland Birth Cohort 1966 (NFBC1966). The specific research objectives were:

1. To investigate the prevalence of malocclusion traits and orthodontic treatment in middle-aged Finns (I).
2. To investigate the role of occlusion in TMD including orthodontically treated individuals (II).
3. To study how deviations from normal overbite and overjet are reflected in adults’ soft tissue facial profile (III).
4. To study whether there is agreement between orthodontists’, dentists’ and laypersons’ perceptions of facial aesthetics (IV).

The working hypothesis was that there are differences in the prevalence of malocclusions between genders and between orthodontically treated and untreated groups (I). In study II, the hypothesis was that occlusal factors are associated with TMD. It was also hypothesized that sagittal and vertical occlusal relationships affect facial soft tissue profile (III). Facial aesthetics was hypothesized to be associated with both facial sagittal and vertical soft tissue characteristics (IV).
4 Subjects and methods

4.1 Subjects

The study population for this investigation belongs to the Northern Finland Birth Cohort 1966 (NFBC1966). The NFBC1966 is an epidemiological and longitudinal research programme and its main goal is to improve the health and well-being of the population in Northern Finland. The research programme is supervised by the Department of Health Sciences, Faculty of Medicine, University of Oulu. The NFBC1966 consists of 12,058 live-born individuals who were born in the two northernmost provinces of Finland, Oulu and Lapland, in 1966. These children correspond to 96.3 per cent of all births in Oulu and Lapland in 1966 (Rantakallio 1988).

All subjects of the NFBC1966 participated in follow-up examinations during their lives at the ages of 6–12 years, 14–16 years, 31 years and 46 years. The first two follow-up examinations included registration of variables related to general health. The 31-year follow-up study also included a questionnaire concerning facial pain. Of the 12,058 individuals of the whole cohort, 10,321 were alive in 2012; 3,150 of them lived in the city of Oulu (or within a radius of 100 km) and were invited to take part in the clinical oral and dental examination. In 2012, a 46-year follow-up study included a clinical oral and dental health examination with occlusal assessment and cariological, periodontological and stomatognathic examination. Of the invited individuals, 1,964 (912 men, 1,052 women) volunteered to participate in the clinical examination.

4.1.1 Study design

In study I, the material consisted of 1,964 individuals (1,052 women, 912 men) who all participated in the clinical oral and dental health examination. In study II, the total number of subjects was 1,962 (1,050 women, 912 men) since two subjects were excluded due to their refusal to give their data for the investigation after study I. The subjects were included in study III if they had full records from the clinical examination and the diagnostic quality of the photographs was good. In addition, subjects with craniofacial syndromes or severe facial deformities were excluded. Based on these criteria, the study population in study III comprised 1,630 individuals (711 men and 919 women). In study IV, two study groups and one
control group were selected based on linear and angular facial soft tissue measurements. Based on the lower anterior facial height (LAFH) and soft tissue ANB-angle, the following subgroups were created: LAFH min (30 subjects), LAFH max (30 subjects), ANB min (30 subjects) and ANB max (30 subjects) (Table 1). A more detailed description of the study groups in study IV is shown in Table 1. For the control group, subjects were first sorted with LAFH%. A median value was located and 100 subjects nearest to the centre point of the study population were chosen. The same sorting was performed for soft tissue ANB. After sorting, both lists were compared with each other, and 30 subjects, who were presented in most median values, were chosen as control group members. Regarding the LAFH groups, LAFH min group included the first 30 subjects with the smallest LAFH values while LAFH max group consisted of the first 30 subjects with the greatest LAFH values. ANB min and max groups were selected analogously to the LAFH groups. The total number of subjects in study IV was 147, since three subjects were included both in extreme cases of lower anterior facial height (LAFH) and soft tissue ANB (ANB min and LAFH min; ANB max and LAFH max).

Table 1. The study groups in study IV.

<table>
<thead>
<tr>
<th>Study groups</th>
<th>N</th>
<th>Gender</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low LAFH</td>
<td>30</td>
<td>8 men, 22 women</td>
<td>48.1-54.3%</td>
</tr>
<tr>
<td>High LAFH</td>
<td>30</td>
<td>17 men, 13 women</td>
<td>64.5-70.8%</td>
</tr>
<tr>
<td>Low ANB-angle</td>
<td>30</td>
<td>5 men, 25 women</td>
<td>0.1-2°</td>
</tr>
<tr>
<td>High ANB-angle</td>
<td>30</td>
<td>24 men, 6 women</td>
<td>12.3-14.7°</td>
</tr>
<tr>
<td>Control group</td>
<td>30</td>
<td>15 men, 15 women</td>
<td>59.1-59.7%; 6.7-7.4°</td>
</tr>
</tbody>
</table>

4.2 Methods

4.2.1 Questionnaires (I, II)

Subjects with a known postal address answered two questionnaires before attending the clinical examination. Questionnaire I included the subjects’ background information, lifestyle and health questions. Questionnaire I contained two questions (yes/no) related to TMD symptoms which have been demonstrated to be adequate for screening TMD pain (Nilsson et al. 2006):

1. Do you have pain in your temples, temporomandibular joints, face, or jaw?
2. Do you have pain when you open your mouth wide or chew?

In questionnaire 2, the questions were related to economy, work and mental resources. During the clinical examination, all subjects answered dental health-related questionnaire 3. Questionnaire 3 included further questions (yes/no) related to TMD, and questions 2-6 were based on the modified Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) (Schiffman 2010):

1. Have you had pain in areas of your face, jaws, temples, ears, or behind your ears during the prior 30 days?
2. During the prior 30 days, have you felt pain that was modified by jaw movement, function, parafunction, or being at rest?
3. Have you had jaw locking in the closed position that restricted maximum mouth opening?
4. Did this restricted opening cause difficulty in mastication?
5. Have you had clicking noises in the TMJ during opening or closing jaw movements or during mastication?
6. Have you had crepitation in the TMJ during opening or closing jaw movements or during mastication?

Questionnaire 3 also contained two questions (yes/no) about eventual previous orthodontic treatment:

1. Have you undergone orthodontic treatment before the age of 20?
2. Have you undergone orthodontic treatment after the age of 20?

4.2.2 Clinical examination (I-IV)

Occlusal assessment and measurements (I, II, III)

The clinical oral and dental health examination was performed at the Institute of Dentistry, University of Oulu. The standardized clinical examination that included intraoral occlusal measurements was carried out by six calibrated dentists and a golden standard. The occlusion registration was based on the criteria described earlier (Björk et al. 1964, Harris & Corruccini 2008). The occlusion was investigated in all three planes: overjet in sagittal plane, overbite and anterior open bite in vertical plane, as well as lateral crossbite and scissors bite in transversal plane (Figure 1. on page 19). Crowding was not registered.
Overjet and overbite were measured in the maximal inter-cuspal position to the nearest full millimetre with a manual scaler. Overjet was measured from the labial surface of the right central maxillary incisor to the labial surface of the right central mandibular incisor (Harris & Corruccini 2008). Negative overjet was recorded if the mandibular incisor located more labially compared to the maxillary incisor. Overbite was measured from the incisal edge of the maxillary right central incisor to the incisal edge of the right central mandibular incisor (Harris & Corruccini 2008). In cases when a negative value was registered, the negative overbite was marked as anterior open bite and the value was measured to the nearest full millimetre. Lateral crossbite was recorded if one or more buccal cusps of the maxillary teeth occluded lingually to the buccal cusps of the corresponding mandibular teeth (Björk et al. 1964). Analogously, scissors bite was registered if one or more lingual cusps of the maxillary teeth occluded buccally to the corresponding mandibular teeth (Björk et al. 1964).

In study I, the subjects were divided into three subgroups based on overjet and overbite. In overbite cases, the subgroups were overbite 6–7 mm, overbite > 7 mm and anterior open bite. Concerning overjet, the subgroups were overjet 6–9 mm, overjet > 9 mm and negative overjet (anterior crossbite). These subgroups were compared to control groups, overjet 0–5 mm and overbite 0–5 mm. In study II, the subgroups of overbite were overbite < 0 mm (anterior open bite) and overbite > 5 mm. Concerning overjet, the subgroups were overjet < 0 mm (negative overjet) and overjet > 5 mm. In subgroup analysis of study III, only severe anterior malocclusions were analysed, and thus the subgroups for overbite and overjet were ≥ 5 mm and ≤ 0 mm.

**Stomatognathic examination (II)**

In study II, a clinical stomatognathic examination was based on the modified protocol of DC/TMD (Schiffman 2010). TMD signs recorded in this investigation were clicking in TMJs, crepitus in TMJs, limited mouth opening (< 40 mm), pain in masticatory muscles and pain in TMJs. The subject was considered positive for TMD if one or more signs of TMD occurred in the clinical examination. TMJ noises (clicking and crepitus) were registered during opening and closing movements and during protrusive and lateral excursive movements. The registration of crepitus was performed at a distance of 15 cm. Maximum mouth opening as well as lateral and protrusive movement (< 7 mm restricted) were also measured. During the examination, the subjects answered if they felt familiar pain in the TMJ area or
masticatory muscles in any movements. If the subjects had earlier had pain in the same location during the past 30 days, the condition was defined as familiar pain. The temporalis and masseter muscles were palpated bilaterally screening for familiar pain on palpation with a pressure of 1.0 kg in the masticatory muscles and around the TMJ pole. The lateral pole of the TMJ was palpated with a pressure of 0.5 kg. The calibration of the palpation force was based on a digital postage scale.

The TMD diagnostics was based on the modified DC/TMD protocol (Schiffman 2010). The TMD diagnoses were myalgia, arthralgia, disc displacement with reduction, disc displacement without reduction and degenerative joint disease. More detailed criteria for diagnoses are presented in Table 2.

Occlusal interferences were registered at different contact positions of the mandible (Dawson 1989). Tooth contacts were recorded in laterotrusion and protrusive mandibular movements. In laterotrusive mandibular movement, the tooth contacts were registered at the position of lateral gliding up to 3 mm from ICP as canine guidance and interferences (Okeson 2013). Canine guidance was registered if maxillary and mandibular canines came into contact during lateral movements of the mandible. Correspondingly, interferences were registered if there was guidance in the premolar and/or molar area, guidance in the incisor area or mediotrusive contact. In protrusive mandibular movement, tooth contacts were registered if the tooth contacts appeared on the anterior teeth and interferences were registered if the tooth contacts appeared on the posterior teeth. In addition, the clinical examination included the registration of RCP and ICP contact positions. The protocol included the registration of the length of sagittal RCP-ICP slide and lateral deviation between RCP-ICP.

After the clinical examination, TMD signs and diagnoses were compared with the occlusal variables which included overjet (< 0 mm and > 5 mm), overbite (< 0 mm and > 5 mm), anterior crossbite, lateral crossbite, lateral scissor bite, length of RCP-ICP slide (3–5 mm), lateral deviation of RCP-ICP slide (over 0 mm), and interferences in laterotrusive and protrusive mandibular movements.
### Table 2. Subdiagnoses of TMD.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myalgia</td>
<td>Reported pain in areas of the face, jaws, temples, ears, or behind the ears; pain modified by movement during the prior 30 days; and familiar pain in the masticatory muscles during jaw movements and/or pain on palpation in any of the muscle sites</td>
</tr>
<tr>
<td>Arthralgia</td>
<td>Reported pain in areas of the face, jaw, temples, ears, or behind the ears; pain modified by movement during the prior 30 days; and familiar pain in the TMJ during jaw movement and/or pain on palpation in the right or left TMJ</td>
</tr>
<tr>
<td>Disc displacement with reduction</td>
<td>Reported history of clicking noises in the TMJ and TMJ clicking recorded by the examiner during opening and closing movements, or during opening or closing movements and in either protrusive or lateral movement</td>
</tr>
<tr>
<td>Disc displacement without reduction</td>
<td>Self-reported jaw locking in closed position and restricted maximum assisted opening</td>
</tr>
<tr>
<td>Degenerative joint disease</td>
<td>Self-reported history of noises in the TMJ and TMJ crepitus recorded by the examiner</td>
</tr>
</tbody>
</table>

### Clinical photographs (III, IV)

Standardized clinical photographs were taken at the time of the clinical examination. The protocol included two frontal (basic and smile) and one profile 2D photograph from each subject under general illumination. In study III, only profile photographs were used, while both frontal (basic facial expression) and profile photographs were used in study IV. The facial photographs were taken without eyeglasses. The type of camera used was Canon 600D with a Canon EF-S 60 mm F/2.8 MACRO USM objective. During the photography, the position of the subject was determined by a mark on the floor. The camera was mounted on a tripod and the distance between the camera and the subject was 190 cm. Camera settings were f/5.6 and ISO/200. In cases of extreme height deviations between the subject and the camera, the subject either sat on a saddle chair (tall subject) or stood (short subject), and the height of the camera was adjusted.
4.2.3 Facial soft tissue measurements (III, IV)

Profile photographs were transferred to ViewBox software (dHAL Software, Kifissia, Athens, Greece) and facial soft tissue profile was analysed. In soft tissue cephalometrics, 11 soft tissue landmarks were digitized by a single examiner (LK) (Table 3.) (Figure 2.). As an objective to carry out soft tissue measurements, a vertical reference line was designed at 70 degrees to the line connecting Tragus and Nasion (Figure 3.). Selection of this vertical reference line was based on an earlier profile image study (Wasserstein et al. 2015). In order to evaluate its reliability and reproducibility, a pilot study on 30 randomly selected subjects was performed. When the head was placed in natural head position, the line between Tragus and Nasion (Tr-Na) formed a 70-degree angle with a true vertical line (μ = 69.83; SD = 1.95). This line was named as Tragus line in the present study. The soft tissue cephalometric analyses were based on linear and angular measurements and calculations of ratios (Table 4.). After digitization of soft tissue points, all measurements were calculated automatically in the Viewbox software. Intra-examiner reliability was tested with redigitization of 200 randomly selected photographs 4 weeks after the beginning of the analyses by the same examiner. All facial soft tissue measurements were performed within 8 weeks.

Table 3. Soft tissue landmarks.

<table>
<thead>
<tr>
<th>Soft tissue point</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glabella</td>
<td>The most prominent point of the forehead as it appears on a profile picture</td>
</tr>
<tr>
<td>Nasion</td>
<td>The deepest point of the curvature between glabella and the bridge of the nose</td>
</tr>
<tr>
<td>Pronasale</td>
<td>The most prominent point of the nose on the horizontal axis</td>
</tr>
<tr>
<td>Subnasale</td>
<td>The deepest point of the curvature connecting the nose to the upper lip</td>
</tr>
<tr>
<td>FA-point of the upper lip</td>
<td>The most prominent point of the upper lip</td>
</tr>
<tr>
<td>A-point</td>
<td>The deepest point of the curvature between subnasale and FA point of the upper lip</td>
</tr>
<tr>
<td>FA-point of the lower lip</td>
<td>The most prominent point of the lower lip</td>
</tr>
<tr>
<td>Pogonion</td>
<td>The most anterior point of the chin</td>
</tr>
<tr>
<td>B-point</td>
<td>The deepest point of the curvature between pogonion and FA point of the lower lip</td>
</tr>
<tr>
<td>Gnathion</td>
<td>The most anterior-inferior point of the chin</td>
</tr>
<tr>
<td>Menton</td>
<td>The most inferior point of the chin</td>
</tr>
</tbody>
</table>
Fig. 2. Soft tissue points. Image copyright was licensed from 123RF Ltd (Hong Kong, China).

Fig. 3. Tragus line. A vertical reference line was designed at 70 degrees to the line connecting Tragus and Nasion.
Table 4. Linear and angular measurements for evaluation of facial profile.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-point – B-point to Tragus line</td>
<td>The distance from A-point to Tragus line minus the distance from B-point to Tragus line</td>
</tr>
<tr>
<td>Upper lip to Tragus line</td>
<td>The distance between the FA-point of the upper lip and Tragus line</td>
</tr>
<tr>
<td>Lower lip to Tragus line</td>
<td>The distance between the FA-point of the lower lip and Tragus line</td>
</tr>
<tr>
<td>Pogonion to Tragus line</td>
<td>The distance between Pogonion and Tragus line</td>
</tr>
<tr>
<td>Convexity subnasale</td>
<td>The angle between the lines connecting Glabella – Subnasale – Pogonion</td>
</tr>
<tr>
<td>Tragus Pogonion to Tragus line</td>
<td>The ratio of the linear distances between Tragus – Pogonion and Tragus –</td>
</tr>
<tr>
<td>Tragus – Subnasale (%)</td>
<td>Subnasale</td>
</tr>
<tr>
<td>Tragus- Nasion to Tragus – Subnasale (%)</td>
<td>The ratio of the linear distances between Tragus – Nasion and Tragus –</td>
</tr>
<tr>
<td>Tragus – A-point to Tragus – Subnasale (%)</td>
<td>Subnasale</td>
</tr>
<tr>
<td>Tragus – B-point to Tragus – Subnasale (%)</td>
<td>The ratio of the linear distances between Tragus – B-point and Tragus –</td>
</tr>
<tr>
<td>Tragus – Subnasale (%)</td>
<td>Subnasale</td>
</tr>
<tr>
<td>Lower facial height (%)</td>
<td>The ratio of the distances between Subnasale – Menton and Nasion – Menton</td>
</tr>
<tr>
<td>Upper facial height (%)</td>
<td>The ratio of the distances between Nasion – Subnasale and Nasion – Menton</td>
</tr>
<tr>
<td>Soft tissue ANB-angle</td>
<td>The angle between the lines connecting A-point – Nasion – B-point</td>
</tr>
</tbody>
</table>

4.2.4 Evaluation of facial aesthetics (IV)

The study of facial aesthetics was based on vertical and sagittal facial soft tissue measurements. Lower anterior facial height (LAFH, %) was selected to describe facial vertical proportion and soft tissue ANB as the sagittal jaw relationships (Table 4.). One profile and one frontal (basic facial expression) photograph from each subject was placed in random order and numbered into the software Microsoft PowerPoint. Each slide consisted of profile and frontal photographs of the same subject. The size of the photographs was fixed at 16.8 x 11.2 cm. The photograph presentation was shown to three panel groups: 5 orthodontists (2 men, 3 women; mean age = 53.8 years; range = 35–62 years), 5 dentists (4 were specialist in prosthodontics and stomatognathic physiology) (5 women; mean age = 56.2 years; range 47–68 years) and 5 laypersons (3 men, 2 women; mean age = 41.4 years;
range 30–53 years). The orthodontists and dentists were personnel at the Research Unit of Oral Health Sciences, University of Oulu. The laypersons were statisticians at the Faculty of Medicine, University of Oulu. The raters sat undisturbed in the same room and the photograph presentation was viewed with a data projector. Each slide was shown to raters for 10 seconds. After every 10th slide, there was a 10-second break. Before the beginning of the judging, the raters were instructed to pay attention only to facial appearance and to assess facial aesthetics independently. During the evaluation of the photographs each rater filled a paper form of 100-mm Visual Analogue Scale (VAS) to assess facial appearance. In the Visual Analogue Scale, a response of 0 mm meant “very unattractive” and a response of 100 mm meant “very attractive”. After the photograph presentation, the results were measured with an accuracy of one millimetre using a ruler.

4.3 Statistics

The data were analysed using IBM SPSS Statistics versions 22.0, 23.0, and 25.0 and R software version 3.3.2. The results of the statistical analyses were interpreted as statistically significant if P-value was less than 0.05. Correlation coefficient was interpreted weak if strength of association was 0.1–0.2, moderate if strength of association was 0.3–0.5 and strong if values ranged from 0.6 to 1.0.

In study I, the statistical analyses were performed using Pearson’s Chi-square test and Fisher’s exact test because of the categorical variables. The differences between the genders and between treated and untreated groups were tested with the tests mentioned above. The relation between scissors bite and increased overbite, between negative overjet and crossbite on premolars, as well as between deep bite and missing teeth was analysed with Pearson’s Chi-square test of independence.

In study II, Pearson’s Chi-square test was used to calculate gender differences of occlusal disturbances. The association between TMD signs and occlusal factors was tested with binary logistic regression models by R software. In this investigation, the odds ratios (OR) and 95% confidence intervals (95% CI) were accommodated for gender. The analyses concerning orthodontically treated groups were performed with Pearson’s Chi-square test and Fisher’s exact test. These tests were used to calculate differences in TMD signs and diagnoses as well as in occlusal interferences between orthodontically treated and untreated subjects.

In study III, the gender dimorphism was tested with independent sample t-tests for all facial profile measurements. Because of the significant gender differences in facial profile, the data of the measurements were divided based on gender. Multiple
linear regression models were performed to test the association between profile measurements, and overjet and overbite. Assumptions of normality and linearity were analysed with Histograms and P-P plots of the regression standardized residual values for overjet and overbite (Appendix, Supplementary Figures 1–2.). In regression models, overjet and overbite represented dependent variables and the profile measurements were independent variables. In order to test subjects with severe anterior malocclusions, a separate multiple regression model was performed. The separate analysis was based on subgroups with extreme overjet and overbite values.

In study IV, parametric methods were chosen to analyse the data since the VAS scores were normally distributed. Paired samples t-test was selected to study the differences in aesthetic evaluation between the panel groups. Differences between LAFH min, LAFH max and control group as well as between ANB min, ANB max and control group were analysed with ANOVA with Tukey’s post hoc test. In order to study the association in aesthetic VAS scores between different panel groups, Pearson correlation coefficient was calculated. Associations between anterior lower facial height (LAFH) and soft tissue ANB-angle in relation to aesthetic assessment (VAS) of the three panel groups were investigated with quadratic regression models.

### 4.4 Error of the method

#### 4.4.1 Error of the method in the clinical examination (I, II, III)

The repeatability of the clinical examination was confirmed by having the investigators train under experienced a specialized dentist before the beginning of the study. Inter-examiner agreement was determined regularly in follow-ups during the clinical examination by a gold standard senior dentist (Table 5.).
Table 5. Intra- and inter-examiner agreements (N_{intra-examiner}=96, N_{inter-examiner}=100).

<table>
<thead>
<tr>
<th>Examiner</th>
<th>Intra-examiner agreement</th>
<th>Inter-examiner agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC overjet</td>
<td>ICC overbite</td>
</tr>
<tr>
<td>1</td>
<td>0.908</td>
<td>0.762</td>
</tr>
<tr>
<td>2</td>
<td>0.989</td>
<td>0.929</td>
</tr>
<tr>
<td>3</td>
<td>0.966</td>
<td>0.923</td>
</tr>
<tr>
<td>4</td>
<td>0.966</td>
<td>0.922</td>
</tr>
<tr>
<td>5</td>
<td>0.964</td>
<td>0.803</td>
</tr>
<tr>
<td>6</td>
<td>0.943</td>
<td>0.865</td>
</tr>
<tr>
<td>Total</td>
<td>0.969</td>
<td>0.912</td>
</tr>
</tbody>
</table>

ICC= Intra Class Correlation.

4.4.2 Error of the method in facial soft tissue measurements (III, IV)

During the soft tissue profile measurements, 200 randomly selected photographs were re-digitized four weeks after the first digitization by the same examiner (LK). In order to test the error of the method, Bland-Altman plots (Bland & Altman 1986) were constructed, and the two measurements demonstrated very high agreement (Figure 4.). Based on the Bland-Altman plots, the random error of the digitization method was considered to be non-significant.

A)
Fig. 4. The Bland-Altman plots for A) A-point – B-point to tragus line, B) upper lip to Tragus line, C) pogonion to tragus line. The horizontal axis represents the mean of two measurements and the vertical axis the difference between two measurements.
4.4.3 Error of the method in aesthetic evaluation (IV)

In order to test error of the method, 12 randomly selected photographs were re-evaluated at the end of the judging by each panel member. Paired samples t-test was selected to test intra-rater reliability of the aesthetic evaluation. No statistically significant differences were found in intra-class ratings (Table 6.). These values justified the subsequent analyses of the data.

Table 6. Error of the method in aesthetic panel evaluation.

<table>
<thead>
<tr>
<th>Panel groups</th>
<th>N_rater</th>
<th>N_evaluation</th>
<th>VAS 1</th>
<th>VAS 2</th>
<th>Difference</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthodontists</td>
<td>5</td>
<td>60</td>
<td>5.58</td>
<td>5.52</td>
<td>0.06</td>
<td>0.557</td>
</tr>
<tr>
<td>Dentists</td>
<td>5</td>
<td>60</td>
<td>5.63</td>
<td>5.65</td>
<td>-0.02</td>
<td>0.894</td>
</tr>
<tr>
<td>Laypersons</td>
<td>5</td>
<td>60</td>
<td>5.41</td>
<td>5.44</td>
<td>-0.03</td>
<td>0.821</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>180</td>
<td>5.54</td>
<td>5.53</td>
<td>0.01</td>
<td>0.930</td>
</tr>
</tbody>
</table>

4.5 Ethical considerations

The Ethical Committee of the Northern Ostrobothnia Hospital District had approved the study on 22 September 2011 (74/2011) and 17 September 2012 (227/2012). Participation in the study was voluntary for the subjects and they received health information in the clinical examination. The subjects had the right to refuse from participation at any time point during the study. In case of treatment need, the subjects were referred to treatment.
5 Results

The study results are displayed in the order of the original articles. Roman numerals refer to the original articles.

5.1 Prevalence of malocclusion traits (I)

The prevalence of malocclusion traits is presented in Tables 7–9. According to the results, 39.5 per cent of the subjects had at least one malocclusion trait. Malocclusion traits were significantly more prevalent among men (44.1%) than among women (35.5%) ($p<0.001$).

Regarding the vertical incisor relationship, the frequency of overbite $\geq 6$ mm was 11.7 per cent (Table 7.). Anterior open bite was shown to be rare (1.3%) in this adult population (Table 7.). Overbite 6–7 mm ($p=0.016$), overbite $>7$ mm ($p=0.030$) and overbite $\geq 6$mm ($p=0.001$) were significantly more prevalent among men than among women (Table 7.). More women (89.5%) than men (84.2%) had normal occlusion regarding vertical incisor relationships ($p<0.001$) (Table 7.).

Table 7. Vertical incisor relationship.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women (n)</th>
<th>(%)</th>
<th>Men (n)</th>
<th>(%)</th>
<th>Total (n)</th>
<th>(%)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal 0-5 mm</td>
<td>933</td>
<td>89.5</td>
<td>760</td>
<td>84.2</td>
<td>1693</td>
<td>87.0</td>
<td>0.000</td>
</tr>
<tr>
<td>Overbite 6-7 mm</td>
<td>83</td>
<td>8.0</td>
<td>101</td>
<td>11.2</td>
<td>184</td>
<td>9.5</td>
<td>0.016</td>
</tr>
<tr>
<td>Overbite $&gt;7$ mm</td>
<td>16</td>
<td>1.5</td>
<td>27</td>
<td>3.0</td>
<td>43</td>
<td>2.2</td>
<td>0.030</td>
</tr>
<tr>
<td>Overbite $\geq 6$ mm</td>
<td>99</td>
<td>9.5</td>
<td>128</td>
<td>14.2</td>
<td>227</td>
<td>11.7</td>
<td>0.001</td>
</tr>
<tr>
<td>Anterior open bite</td>
<td>10</td>
<td>1.0</td>
<td>15</td>
<td>1.7</td>
<td>25</td>
<td>1.3</td>
<td>0.171</td>
</tr>
</tbody>
</table>

Pearson’s Chi-square test. Incisor relationship vertical could not be registered in 19 subjects.

Sagittal incisor relationships are displayed in Table 8. According to the results, the prevalence of overjet $\geq 6$ mm (9.7%) was less common compared to the frequency of overbite $\geq 6$ mm (11.7%) (Tables 7–8). Negative overjet was uncommon in this adult population (1.2%) and showed significant gender dimorphism with male dominance ($p<0.001$) (Table 8.).
Table 8. Sagittal incisor relationship.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women</th>
<th>Men</th>
<th>Total</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
<td>(%)</td>
</tr>
<tr>
<td>Normal 0-5 mm</td>
<td>928</td>
<td>89.1</td>
<td>803</td>
<td>89.0</td>
</tr>
<tr>
<td>Overjet 6-9 mm</td>
<td>94</td>
<td>9.0</td>
<td>70</td>
<td>7.8</td>
</tr>
<tr>
<td>Overjet &gt; 9 mm</td>
<td>16</td>
<td>1.5</td>
<td>9</td>
<td>1.0</td>
</tr>
<tr>
<td>Overjet ≥ 6 mm</td>
<td>110</td>
<td>10.6</td>
<td>79</td>
<td>8.8</td>
</tr>
<tr>
<td>Negative overjet</td>
<td>4</td>
<td>0.4</td>
<td>20</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Pearson's Chi-square test. Incisor relationship sagittal could not be registered in 20 subjects.*

The prevalence of crossbite and scissors bite is presented in Table 9. According to the results, lateral crossbite (17.9%) was the most common malocclusion in this study. Men presented a higher prevalence of crossbite on left premolars (8.1%) than women (5.5%) \(p=0.021\). In addition, men presented a tendency for higher prevalence of total crossbite \(p=0.051\) and scissors bite \(p=0.078\). More transversal variation on the left than on the right side was seen, particularly in men (Table 9.). The prevalence of scissors bite was 7.6 per cent in this adult population (Table 9.). No significant gender differences were found concerning scissors bite (Table 9.).

When the relationship between scissors bite and overbite was studied, the association between these two malocclusions was significant \(p<0.001\). Regarding the subjects with scissors bite, 23.6 per cent of the subjects were also diagnosed with overbite \(≥6\) mm. Conversely, subjects without scissors bite were diagnosed with increased overbite in 10.7 per cent of the cases. The association between negative overjet and crossbite on left premolars was statistically significant \(p<0.001\). In 41.7 per cent of the cases, subjects with negative overjet were also diagnosed with crossbite on the left premolars, reflecting progenic occlusion. By contrast, subjects without negative overjet had crossbite on the left premolars in 6.3 per cent of the cases.
Table 9. Transversal malocclusion.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women</th>
<th></th>
<th>Men</th>
<th></th>
<th>Total</th>
<th></th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td>Crossbite on right premolars</td>
<td>72</td>
<td>6.9</td>
<td>67</td>
<td>7.4</td>
<td>139</td>
<td>7.1</td>
<td>0.664</td>
</tr>
<tr>
<td>Crossbite on left premolars</td>
<td>57</td>
<td>5.5</td>
<td>73</td>
<td>8.1</td>
<td>130</td>
<td>6.7</td>
<td>0.021</td>
</tr>
<tr>
<td>Crossbite on right molars</td>
<td>71</td>
<td>6.8</td>
<td>76</td>
<td>8.4</td>
<td>147</td>
<td>7.6</td>
<td>0.183</td>
</tr>
<tr>
<td>Crossbite on left molars</td>
<td>50</td>
<td>4.8</td>
<td>49</td>
<td>5.4</td>
<td>99</td>
<td>5.1</td>
<td>0.530</td>
</tr>
<tr>
<td>Crossbite total (lateral)</td>
<td>170</td>
<td>16.3</td>
<td>178</td>
<td>19.7</td>
<td>348</td>
<td>17.9</td>
<td>0.051</td>
</tr>
<tr>
<td>Scissors bite on right premolars</td>
<td>31</td>
<td>3</td>
<td>35</td>
<td>3.9</td>
<td>66</td>
<td>3.4</td>
<td>0.274</td>
</tr>
<tr>
<td>Scissors bite on left premolars</td>
<td>38</td>
<td>3.6</td>
<td>48</td>
<td>5.3</td>
<td>86</td>
<td>4.4</td>
<td>0.074</td>
</tr>
<tr>
<td>Scissors bite on right molars</td>
<td>7</td>
<td>0.7</td>
<td>4</td>
<td>0.4</td>
<td>11</td>
<td>0.6</td>
<td>0.502</td>
</tr>
<tr>
<td>Scissors bite on left molars</td>
<td>5</td>
<td>0.5</td>
<td>6</td>
<td>0.7</td>
<td>11</td>
<td>0.6</td>
<td>0.588</td>
</tr>
<tr>
<td>Scissors bite total</td>
<td>69</td>
<td>6.6</td>
<td>79</td>
<td>8.7</td>
<td>148</td>
<td>7.6</td>
<td>0.078</td>
</tr>
</tbody>
</table>

Pearson’s Chi-square test. Transversal malocclusion could not be registered in 17 subjects because of missing teeth.

The prevalence of malocclusion traits with respect to orthodontic treatment is shown in Table 10. According to the results, no statistically significant differences in the prevalence of malocclusions were found between orthodontically treated and untreated subjects (Table 10.).
Table 10. Prevalence of malocclusion traits in orthodontically treated and untreated subjects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treated (n)</th>
<th>Treated (%)</th>
<th>Untreated (n)</th>
<th>Untreated (%)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overjet 6 mm or over</td>
<td>36</td>
<td>10.3</td>
<td>147</td>
<td>9.6</td>
<td>0.690</td>
</tr>
<tr>
<td>Negative overjet</td>
<td>3</td>
<td>0.9</td>
<td>21</td>
<td>1.4</td>
<td>0.601</td>
</tr>
<tr>
<td>Overbite 6 mm or over</td>
<td>45</td>
<td>12.8</td>
<td>179</td>
<td>11.6</td>
<td>0.549</td>
</tr>
<tr>
<td>Anterior open bite</td>
<td>4</td>
<td>1.1</td>
<td>18</td>
<td>1.2</td>
<td>1.000</td>
</tr>
<tr>
<td>Crossbite on premolars</td>
<td>49</td>
<td>13.9</td>
<td>174</td>
<td>11.3</td>
<td>0.176</td>
</tr>
<tr>
<td>Crossbite on molars</td>
<td>41</td>
<td>11.6</td>
<td>162</td>
<td>10.5</td>
<td>0.551</td>
</tr>
<tr>
<td>Scissors bite on premolars</td>
<td>17</td>
<td>4.8</td>
<td>113</td>
<td>7.3</td>
<td>0.091</td>
</tr>
<tr>
<td>Scissors bite on molars</td>
<td>7</td>
<td>2.0</td>
<td>14</td>
<td>0.9</td>
<td>0.092</td>
</tr>
</tbody>
</table>

Variables were tested with Pearson’s Chi-square test and Fisher’s exact test. Overjet and negative overjet could not be registered in 75 subjects. Overbite, open bite and scissors bite on molars could not be registered in 74 subjects. Crossbite and scissors bite on premolars could not be registered in 72 subjects.

5.2 Prevalence of previous orthodontic treatment (I)

The prevalence of previous orthodontic treatment experience is presented in Table 11. Altogether 18.6 per cent of the subjects reported having had orthodontic treatment (Table 11.). Women showed significantly higher previous orthodontic treatment experience (20.3%) than men (16.6%) in this adult population ($p=0.041$). Orthodontic treatment experience before the age of 20 was more common (13.8%) compared to the treatment experience in adulthood (6.2%).

Table 11. Previous orthodontic treatment experience.

<table>
<thead>
<tr>
<th>Treatment experience</th>
<th>Women (n)</th>
<th>Women (%)</th>
<th>Men (n)</th>
<th>Men (%)</th>
<th>Total (n)</th>
<th>Total (%)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20 years</td>
<td>151</td>
<td>14.8</td>
<td>113</td>
<td>12.7</td>
<td>264</td>
<td>13.8</td>
<td>0.186</td>
</tr>
<tr>
<td>&gt; 20 years</td>
<td>70</td>
<td>6.9</td>
<td>48</td>
<td>5.4</td>
<td>118</td>
<td>6.2</td>
<td>0.185</td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>20.3</td>
<td>148</td>
<td>16.6</td>
<td>355</td>
<td>18.6</td>
<td>0.041</td>
</tr>
</tbody>
</table>

Pearson’s Chi-square test. Treatment experience could not be registered in 55 subjects.
5.3 Association between signs and diagnoses of TMD and occlusal variables (II)

When association between TMD diagnoses and occlusal variables (malocclusions and occlusal interferences) was studied, two statistically significant relationships were found. A statistically significant association was found between myalgia and lateral scissors bite \((p=0.034)\) as well as between arthralgia and lateral deviation in RCP-ICP slide \((p=0.005)\).

The association between TMD signs and occlusal variables is shown in Table 12. Limited mouth opening showed significant association with lateral crossbite \((\text{OR}=2.35; \text{95\% CI}=1.33–4.17)\), scissors bite \((\text{OR}=2.13; \text{95\% CI}=1.00–4.53)\) and lateral deviation in RCP-ICP slide \((\text{OR}=2.27; \text{95\% CI}=1.11–4.65)\) (Table 12.). Pain in masticatory muscles was significantly associated with overjet < 0 mm \((\text{OR}=4.37; \text{95\% CI}=1.33–14.41)\) and RCP-ICP slide (3-5 mm) \((\text{OR}=2.43; \text{95\% CI}=1.06–5.60)\) (Table 12.). When analysing laterality, pain in the right masticatory muscles \((\text{OR}=1.88, \text{95\% CI}=1.08–3.28)\) was associated with lateral deviation in RCP-ICP slide to the left. Scissors bite on the left side was associated with crepitus in both TMJs \((\text{left OR}=2.52, \text{95\% CI}=1.27–4.99; \text{right OR}=2.05, \text{95\% CI}=1.01–4.19)\).
Table 12. Logistic regression analysis of associations between TMD signs and occlusal variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Limited mouth opening</th>
<th>Clicking in TMJs</th>
<th>Crepitus in TMJs</th>
<th>Pain in masticatory muscles</th>
<th>Pain in TMJs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
</tr>
<tr>
<td>Female gender</td>
<td>2.80 (1.61-4.88)</td>
<td>1.41 (1.15-1.74)</td>
<td>1.60 (1.16-2.20)</td>
<td>2.79 (2.02-3.86)</td>
<td>2.44 (1.76-3.37)</td>
</tr>
<tr>
<td>Overbite &lt; 0 mm</td>
<td>0.95 (0.11-8.31)</td>
<td>1.10 (0.42-2.92)</td>
<td>1.80 (0.56-5.85)</td>
<td>1.73 (0.54-5.57)</td>
<td>1.06 (0.29-3.86)</td>
</tr>
<tr>
<td>Overbite &gt; 5 mm</td>
<td>1.93 (0.98-3.83)</td>
<td>1.16 (0.84-1.60)</td>
<td>1.17 (0.71-1.91)</td>
<td>1.18 (0.74-1.86)</td>
<td>1.10 (0.68-1.79)</td>
</tr>
<tr>
<td>Overjet &lt; 0 mm</td>
<td>0.00 (0.00- inf)</td>
<td>1.48 (0.53-4.13)</td>
<td>0.84 (0.17-4.05)</td>
<td>4.37 (1.33-14.41)</td>
<td>1.73 (0.44-8.81)</td>
</tr>
<tr>
<td>Overjet &gt; 5 mm</td>
<td>0.63 (0.26-1.56)</td>
<td>1.15 (0.81-1.63)</td>
<td>0.82 (0.47-1.44)</td>
<td>0.93 (0.57-1.53)</td>
<td>1.01 (0.61-1.67)</td>
</tr>
<tr>
<td>Anterior crossbite</td>
<td>0.71 (0.23-2.15)</td>
<td>0.89 (0.58-1.39)</td>
<td>1.25 (0.69-2.27)</td>
<td>0.82 (0.43-1.56)</td>
<td>0.96 (0.51-1.80)</td>
</tr>
<tr>
<td>Lateral crossbite</td>
<td>2.35 (1.33-4.17)</td>
<td>0.92 (0.69-1.23)</td>
<td>0.99 (0.65-1.51)</td>
<td>0.85 (0.56-1.28)</td>
<td>1.13 (0.76-1.69)</td>
</tr>
<tr>
<td>Scissors bite</td>
<td>2.13 (1.00-4.53)</td>
<td>0.81 (0.54-1.21)</td>
<td>1.30 (0.75-2.23)</td>
<td>0.96 (0.55-1.68)</td>
<td>1.04 (0.59-1.84)</td>
</tr>
<tr>
<td>RCP-ICP slide (3-5 mm)</td>
<td>1.55 (0.34-7.09)</td>
<td>0.76 (0.34-1.69)</td>
<td>0.22 (0.03-1.63)</td>
<td>2.43 (1.06-5.60)</td>
<td>1.39 (0.52-3.71)</td>
</tr>
<tr>
<td>Deviation in RCP-ICP</td>
<td>2.27 (1.11-4.65)</td>
<td>1.05 (0.71-1.56)</td>
<td>1.51 (0.90-2.54)</td>
<td>1.29 (0.77-2.15)</td>
<td>1.45 (0.87-2.41)</td>
</tr>
<tr>
<td>LTR interferences</td>
<td>0.91 (0.51-1.61)</td>
<td>1.04 (0.82-1.33)</td>
<td>1.07 (0.75-1.53)</td>
<td>1.15 (0.83-1.61)</td>
<td>0.90 (0.63-1.28)</td>
</tr>
<tr>
<td>PTR interferences</td>
<td>0.87 (0.40-1.92)</td>
<td>0.89 (0.64-1.22)</td>
<td>1.07 (0.68-1.69)</td>
<td>0.80 (0.51-1.27)</td>
<td>1.11 (0.71-1.72)</td>
</tr>
</tbody>
</table>

OR = odds ratio, CI = confidence interval.
5.4 Distribution of TMD signs and diagnoses in subjects having had orthodontic treatment (II)

According to the results, TMD was significantly slightly more prevalent in orthodontically treated (47.8%) than in untreated subjects (41.3%) ($p=0.027$). Distribution of TMD signs in subjects having received orthodontic treatment is presented in Table 13. Clicking in TMJs (29.2%) was the most common TMD sign in subjects having received orthodontic treatment (Table 13.). Crepitus in TMJs was more common among orthodontically treated (14.2%) than among untreated subjects (7.8%) and this difference was statistically significant ($p=0.001$).

Table 13. Distribution of TMD signs in subjects with orthodontic treatment experience (N=353).

<table>
<thead>
<tr>
<th>TMD signs</th>
<th>Treated (n)</th>
<th>Treated (%)</th>
<th>Untreated (n)</th>
<th>Untreated (%)</th>
<th>$\chi^2$ value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicking in TMJs</td>
<td>90</td>
<td>29.2</td>
<td>353</td>
<td>25.0</td>
<td>2.356</td>
<td>0.125</td>
</tr>
<tr>
<td>Crepitus in TMJs</td>
<td>36</td>
<td>14.2</td>
<td>90</td>
<td>7.8</td>
<td>10.230</td>
<td>0.001</td>
</tr>
<tr>
<td>Limited mouth opening (&lt; 40 mm)</td>
<td>15</td>
<td>4.3</td>
<td>56</td>
<td>3.6</td>
<td>0.324</td>
<td>0.569</td>
</tr>
<tr>
<td>Pain in masticatory muscles</td>
<td>44</td>
<td>12.5</td>
<td>169</td>
<td>10.9</td>
<td>0.732</td>
<td>0.392</td>
</tr>
<tr>
<td>Pain in TMJs</td>
<td>41</td>
<td>11.6</td>
<td>154</td>
<td>9.9</td>
<td>0.911</td>
<td>0.340</td>
</tr>
</tbody>
</table>

When analysing treatment experience separately before and after 20 years, crepitus in TMJs was significantly more common among subjects having had orthodontic treatment before the age of 20 (14.1%) compared to untreated subjects (8.2%) ($p=0.010$) (Table 14.). Subjects having received orthodontic treatment after the age of 20 showed no statistically significant difference in TMD signs compared to untreated subjects (Table 15.). Clicking in TMJs was significantly more common among subjects having had orthodontic treatment in childhood (30.9%) compared to subjects having received treatment after the age of 20 (21.6%) ($p=0.038$).
Table 14. Distribution of TMD signs in subjects with orthodontic treatment experience < 20 yrs (N = 263).

<table>
<thead>
<tr>
<th>TMD signs &lt; 20 yrs</th>
<th>Treated</th>
<th>Untreated</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicking in TMJs</td>
<td>71 (30.9)</td>
<td>372 (25.0)</td>
<td>0.057</td>
</tr>
<tr>
<td>Crepitus in TMJs</td>
<td>26 (14.1)</td>
<td>100 (8.2)</td>
<td>0.010</td>
</tr>
<tr>
<td>Limited mouth opening (&lt; 40 mm)</td>
<td>12 (4.6)</td>
<td>59 (3.6)</td>
<td>0.439</td>
</tr>
<tr>
<td>Pain in masticatory muscles</td>
<td>32 (12.2)</td>
<td>181 (11.0)</td>
<td>0.580</td>
</tr>
<tr>
<td>Pain in TMJs</td>
<td>31 (11.8)</td>
<td>164 (10.0)</td>
<td>0.368</td>
</tr>
</tbody>
</table>

Table 15. Distribution of TMD signs in subjects with orthodontic treatment experience > 20 yrs (N = 116).

<table>
<thead>
<tr>
<th>TMD signs</th>
<th>Treated</th>
<th>Untreated</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicking in TMJs</td>
<td>22 (21.6)</td>
<td>421 (26.0)</td>
<td>0.319</td>
</tr>
<tr>
<td>Crepitus in TMJs</td>
<td>13 (14.0)</td>
<td>113 (8.6)</td>
<td>0.081</td>
</tr>
<tr>
<td>Limited mouth opening (&lt; 40 mm)</td>
<td>5 (4.3)</td>
<td>66 (3.7)</td>
<td>0.0191</td>
</tr>
<tr>
<td>Pain in masticatory muscles</td>
<td>18 (15.5)</td>
<td>195 (10.9)</td>
<td>0.125</td>
</tr>
<tr>
<td>Pain in TMJs</td>
<td>18 (15.5)</td>
<td>177 (9.9)</td>
<td>0.052</td>
</tr>
</tbody>
</table>

1 Fisher’s exact test.

Distribution of TMD diagnoses in subjects is shown in Table 16. Degenerative joint disease (8.0%) and arthralgia (6.8%) were the most common TMD diagnoses in orthodontically treated subjects (Table 16.). Based on the results, degenerative joint disease was significantly more prevalent among orthodontically treated (8.0%) than among untreated subjects (4.7%) (p=0.012).
### Table 16. Distribution of TMD diagnoses in subjects with orthodontic treatment experience (N = 353).

<table>
<thead>
<tr>
<th>TMD diagnoses</th>
<th>Treated</th>
<th>Untreated</th>
<th>( \chi^2 ) value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myalgia</td>
<td>23</td>
<td>4.8</td>
<td>1.825</td>
<td>0.177</td>
</tr>
<tr>
<td>Arthralgia</td>
<td>24</td>
<td>5.1</td>
<td>1.648</td>
<td>0.199</td>
</tr>
<tr>
<td>Disk displacement with reduction</td>
<td>23</td>
<td>7.4</td>
<td>0.313</td>
<td>0.576</td>
</tr>
<tr>
<td>Disk displacement without reduction</td>
<td>0</td>
<td>0.3</td>
<td>1.000</td>
<td>1</td>
</tr>
<tr>
<td>Degenerative joint disease</td>
<td>28</td>
<td>4.7</td>
<td>6.261</td>
<td>0.012</td>
</tr>
</tbody>
</table>

\(^1\) Fisher’s exact test.

When analysing treatment experience separately before and after 20 years, degenerative joint disease was significantly more common among subjects having had treatment before the age of 20 (8.4%) compared to untreated subjects (4.8%) \((p=0.015)\) (Table 17.). Conversely, arthralgia presented with a significantly higher frequency among subjects having received treatment after the age of 20 (11.3%) than among untreated subjects (5.1%) \((p=0.004)\) (Table 18.). Arthralgia was significantly more common among subjects having had orthodontic treatment in adulthood (11.3%) compared to subjects having received treatment before the age of 20 (5.0%) \((p=0.021)\).

### Table 17. Distribution of TMD diagnoses in subjects with orthodontic treatment experience < 20 yrs (N=263).

<table>
<thead>
<tr>
<th>TMD signs</th>
<th>Treated</th>
<th>Untreated</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myalgia</td>
<td>15</td>
<td>82</td>
<td>0.625</td>
</tr>
<tr>
<td>Arthralgia</td>
<td>13</td>
<td>90</td>
<td>0.716</td>
</tr>
<tr>
<td>Disk displacement with reduction</td>
<td>19</td>
<td>118</td>
<td>0.993</td>
</tr>
<tr>
<td>Disk displacement without reduction</td>
<td>0</td>
<td>4</td>
<td>1.000(^1)</td>
</tr>
<tr>
<td>Degenerative joint disease</td>
<td>22</td>
<td>78</td>
<td>0.015</td>
</tr>
</tbody>
</table>

\(^1\) Fisher’s exact test.

---
Table 18. Distribution of TMD diagnoses in subjects with orthodontic treatment experience > 20 yrs (N=116).

<table>
<thead>
<tr>
<th>TMD signs</th>
<th>Treated</th>
<th>Untreated</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
</tr>
<tr>
<td>Myalgia</td>
<td>10</td>
<td>8.6</td>
<td>87</td>
</tr>
<tr>
<td>Arthralgia</td>
<td>13</td>
<td>11.3</td>
<td>90</td>
</tr>
<tr>
<td>Disk displacement with reduction</td>
<td>5</td>
<td>4.3</td>
<td>132</td>
</tr>
<tr>
<td>Disk displacement without reduction</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Degenerative joint disease</td>
<td>9</td>
<td>7.8</td>
<td>91</td>
</tr>
</tbody>
</table>

1 Fisher’s exact test.

5.5 Distribution of occlusal interferences according to orthodontic treatment in subjects with TMD (II)

Frequencies of occlusal interferences in subjects with TMD are presented in Table 19. No significant differences in distribution of occlusal interferences were found between orthodontically treated and untreated subjects with TMD (Table 19.). According to the results, laterotrusion interferences (75.2%) were the most common interferences in orthodontically treated subjects (Table 19.). Conversely, RCP-ICP slide (3–5 mm) was shown to be quite rare (2.4%) among subjects with orthodontic treatment experience (Table 19.).

Table 19. Distribution of occlusal interferences according to orthodontic treatment in subjects with TMD.

<table>
<thead>
<tr>
<th>Interferences</th>
<th>Treated</th>
<th>Untreated</th>
<th>$\chi^2$ value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
<td>(%)</td>
</tr>
<tr>
<td>Protrusion interferences</td>
<td>41</td>
<td>24.8</td>
<td>205</td>
<td>32.7</td>
</tr>
<tr>
<td>Laterotrusion interferences</td>
<td>124</td>
<td>75.2</td>
<td>471</td>
<td>75.1</td>
</tr>
<tr>
<td>RCP-ICP slide (3-5 mm)</td>
<td>4</td>
<td>2.4</td>
<td>14</td>
<td>2.2</td>
</tr>
<tr>
<td>Deviation in RCP-ICP &gt; 0 mm</td>
<td>10</td>
<td>6.1</td>
<td>43</td>
<td>7.0</td>
</tr>
</tbody>
</table>

1 Fisher’s exact test.

5.6 Gender differences in facial soft tissue profile (III)

Soft tissue differences in facial profile between genders are presented in Table 20. According to the results, most of the profile measurements showed significant gender dimorphism (Table 20.). No gender differences were found in
measurements of convexity subnasale ($p=0.206$) and Tragus – B-point to Tragus – Subnasale ($p=0.469$) (Table 20.). Due to significant gender differences in most of the facial profile variables, the data were stratified based on gender in later analyses.

Table 20. Gender dimorphism of facial profile measurements ($N_{male}=711$, $N_{female}=919$).

<table>
<thead>
<tr>
<th>Profile measurements</th>
<th>Gender</th>
<th>Mean</th>
<th>SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-point – B-point to Tragus line (mm)</td>
<td>M</td>
<td>3.10</td>
<td>1.63</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>2.50</td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td>Upper lip to Tragus line (mm)</td>
<td>M</td>
<td>3.36</td>
<td>1.95</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>3.00</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td>Lower lip to Tragus line (mm)</td>
<td>M</td>
<td>2.74</td>
<td>2.21</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>2.19</td>
<td>2.05</td>
<td></td>
</tr>
<tr>
<td>Pogonion to Tragus line (mm)</td>
<td>M</td>
<td>1.5</td>
<td>3.01</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.94</td>
<td>2.83</td>
<td></td>
</tr>
<tr>
<td>Convexity Subnasale (degree)</td>
<td>M</td>
<td>170.3</td>
<td>6.3</td>
<td>0.206</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>170.7</td>
<td>6.28</td>
<td></td>
</tr>
<tr>
<td>Tragus – Pogonion to Tragus – Subnasale (%)</td>
<td>M</td>
<td>114.40</td>
<td>4.77</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>113.78</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>Tragus – Nasion to Tragus – Subnasale (%)</td>
<td>M</td>
<td>97.40</td>
<td>3.28</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>98.45</td>
<td>3.26</td>
<td></td>
</tr>
<tr>
<td>Tragus – A-point to Tragus – Subnasale (%)</td>
<td>M</td>
<td>100.76</td>
<td>1.25</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>100.38</td>
<td>1.11</td>
<td></td>
</tr>
<tr>
<td>Tragus – B-point to Tragus – Subnasale (%)</td>
<td>M</td>
<td>105.01</td>
<td>3.73</td>
<td>0.469</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>105.15</td>
<td>3.40</td>
<td></td>
</tr>
<tr>
<td>Lower facial height (%)</td>
<td>M</td>
<td>59.70</td>
<td>2.31</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>58.97</td>
<td>2.24</td>
<td></td>
</tr>
<tr>
<td>Upper facial height (%)</td>
<td>M</td>
<td>42.16</td>
<td>2.35</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>42.83</td>
<td>2.30</td>
<td></td>
</tr>
</tbody>
</table>

M=male, F=female.
5.7 Correlation between facial soft tissue profile, and overbite and overjet (III)

5.7.1 Entire sample population

The correlation between facial profile and overjet as well as overbite is presented in Table 21. According to the results, a significant moderate correlation between facial profile and overjet ($R^2_{\text{males}}= 0.296$; $R^2_{\text{females}}= 0.279$) was detected (Table 21.).

Table 21. Multiple regression models for overjet and overbite within genders.

<table>
<thead>
<tr>
<th>Malocclusion</th>
<th>Gender</th>
<th>$R^2$</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overjet</td>
<td>Males</td>
<td>0.296</td>
<td>$&lt; 0.001$</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>0.279</td>
<td>$&lt; 0.001$</td>
</tr>
<tr>
<td>Overbite</td>
<td>Males</td>
<td>0.200</td>
<td>$&lt; 0.001$</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>0.167</td>
<td>$&lt; 0.001$</td>
</tr>
</tbody>
</table>

Predictors: (Constant), A-point – B-point to Tragus line, Tragus – A-point to Tragus – Subnasale, Tragus – Nasion to Tragus – Subnasale, Lower facial height, Tragus – Pogonion to Tragus – Subnasale, Upper lip to Tragus line, Tragus – B-point to Tragus – Subnasale, Convexity subnasale, Lower lip to Tragus line, Pogonion to Tragus line, A-point to Tragus line, Upper facial height, B-point to Tragus line.

The effect of separate profile measurements on overjet is displayed in Table 22. Based on the multiple linear regression models, the upper lip to Tragus line (the anterior-posterior position of the upper lip) showed a strong association with overjet both in men ($p<0.001$) and women ($p<0.001$) (Table 22.). In addition, the positions of soft tissue A-point to the face (Tragus – A-point to Tragus – Subnasale) and soft tissue B-point to the face (Tragus – B-point to Tragus – Subnasale) were moderately to strongly associated with overjet in both genders (Table 22.). The Tragus – Nasion to Tragus – Subnasale also showed a significant association with overjet ($p_{\text{male}}< 0.001$; $p_{\text{female}}< 0.001$) (Table 22.).
Table 22. Multiple linear regression models for overjet.

<table>
<thead>
<tr>
<th>Profile measurements</th>
<th>Gender</th>
<th>Standardized Coefficients-Beta</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-point – B-point to Tragus line (mm)</td>
<td>M</td>
<td>1.050</td>
<td>0.339</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1.390</td>
<td>0.080</td>
</tr>
<tr>
<td>Upper lip to Tragus line (mm)</td>
<td>M</td>
<td>0.730</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.897</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lower lip to Tragus line (mm)</td>
<td>M</td>
<td>-0.429</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.053</td>
<td>0.708</td>
</tr>
<tr>
<td>Pogonion to Tragus line (mm)</td>
<td>M</td>
<td>0.176</td>
<td>0.436</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.208</td>
<td>0.378</td>
</tr>
<tr>
<td>Convexity subnasale (degree)</td>
<td>M</td>
<td>-0.084</td>
<td>0.423</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>-0.224</td>
<td>0.035</td>
</tr>
<tr>
<td>Tragus – Pogonion to Tragus – Subnasale (%)</td>
<td>M</td>
<td>-0.012</td>
<td>0.916</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.020</td>
<td>0.844</td>
</tr>
<tr>
<td>Tragus – Nasion to Tragus – Subnasale (%)</td>
<td>M</td>
<td>-0.469</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>-0.413</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tragus – A-point to Tragus – Subnasale (%)</td>
<td>M</td>
<td>0.349</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.417</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tragus – B-point to Tragus – Subnasale (%)</td>
<td>M</td>
<td>-0.567</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>-0.556</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lower facial height (%)</td>
<td>M</td>
<td>-0.493</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>-0.185</td>
<td>0.327</td>
</tr>
<tr>
<td>Upper facial height (%)</td>
<td>M</td>
<td>-0.644</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>-0.250</td>
<td>0.219</td>
</tr>
</tbody>
</table>

M=male, F=female.

Multiple linear regression models for overbite are presented in Table 23. According to the results, the position of soft tissue A-point to the face (Tragus – A-point to Tragus – Subnasale) was associated weakly to moderately with overbite ($p_{\text{male}}<0.001; p_{\text{female}}<0.001$) (Table 23.). In addition, the position of soft tissue B-point to the face (Tragus – B-point to Tragus – Subnasale) showed strong association with overbite ($p_{\text{male}}<0.001; p_{\text{female}}<0.001$) (Table 23.)
Table 23. Multiple linear regression models for overbite.

<table>
<thead>
<tr>
<th>Profile measurements</th>
<th>Gender</th>
<th>Standardized Coefficients-Beta</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-point – B-point to Tragus line (mm) M</td>
<td>0.935</td>
<td>0.424</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F -1.496</td>
<td>0.079</td>
<td></td>
</tr>
<tr>
<td>Upper lip to Tragus line (mm) M</td>
<td>0.286</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F 0.362</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td>Lower lip to Tragus line (mm) M</td>
<td>-0.239</td>
<td>0.098</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F -0.439</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Pogonion to Tragus line (mm) M</td>
<td>0.331</td>
<td>0.169</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F 0.176</td>
<td>0.436</td>
<td></td>
</tr>
<tr>
<td>Convexity subnasale (degree) M</td>
<td>0.109</td>
<td>0.328</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F -0.118</td>
<td>0.301</td>
<td></td>
</tr>
<tr>
<td>Tragus – Pogonion to Tragus – Subnasale (%) M</td>
<td>0.081</td>
<td>0.505</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F 0.209</td>
<td>0.059</td>
<td></td>
</tr>
<tr>
<td>Tragus – Nasion to Tragus – Subnasale (%) M</td>
<td>-0.448</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F -0.084</td>
<td>0.423</td>
<td></td>
</tr>
<tr>
<td>Tragus – A-point to Tragus – Subnasale (%) M</td>
<td>0.240</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F 0.349</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Tragus – B-point to Tragus – Subnasale (%) M</td>
<td>-0.569</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F -0.567</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Lower facial height (%) M</td>
<td>-0.108</td>
<td>0.653</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F -0.493</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>Upper facial height (%) M</td>
<td>-0.098</td>
<td>0.706</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F -0.644</td>
<td>0.008</td>
<td></td>
</tr>
</tbody>
</table>

M=male, F=female.

5.7.2 Subgroup analysis

In the entire sample population (n=1,630), most of the detected overjet and overbite values were within normal limits. In other words, 1,313 subjects were diagnosed with overjet of 1–4 mm, and 1,158 subjects presented with overbite of 1–4 mm. In order to analyse subjects with deviant anterior occlusal relationships, a multiple linear regression analysis was performed based on the subgroups with extreme overjet and overbite values (Table 24.).

According to the results, a strong association between facial soft tissue characteristics and negative overjet (R=0.665, p=0.011) was observed (Table 24.). In addition, significant moderate correlations between facial soft tissue characteristics and increased positive overjet (R=0.400, p<0.001) and deep bite (R=0.342, p<0.001) were detected (Table 24.).
Table 24. Multiple regression models for extreme overjet and overbite values.

<table>
<thead>
<tr>
<th>Malocclusion</th>
<th>N</th>
<th>Mean</th>
<th>R²</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overjet ≥ 5 mm</td>
<td>261</td>
<td>6.30</td>
<td>0.163</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Negative overjet ≤ 0 mm</td>
<td>56</td>
<td>-0.70</td>
<td>0.442</td>
<td>0.011</td>
</tr>
<tr>
<td>Deep bite ≥ 5 mm</td>
<td>389</td>
<td>5.81</td>
<td>0.117</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Open bite ≤ 0 mm</td>
<td>84</td>
<td>-0.48</td>
<td>0.150</td>
<td>0.509</td>
</tr>
</tbody>
</table>

Predictors: (Constant), A-point – B-point to Tragus line, Tragus – A-point to Tragus – Subnasale, Tragus – Nasion to Tragus – Subnasale, Lower facial height, Tragus – Pogonion to Tragus – Subnasale, Upper lip to Tragus line, Tragus – B-point to Tragus – Subnasale, Convexity subnasale, Lower lip to Tragus line, Pogonion to Tragus line, A-point to Tragus line, Upper facial height, B-point to Tragus line.

5.8 Aesthetic evaluation (IV)

5.8.1 Differences in perceived attractiveness between the panel groups

Aesthetic evaluation VAS mean scores are presented in Table 25. Range (SD) values in VAS scores were 4.0–7.9 (0.7) among orthodontists, 3.3–7.7 (0.9) among dentists, and 3.0–7.4 (0.9) among laypersons. Laypersons gave significantly lower aesthetic VAS scores compared to orthodontists and dentists, especially in the LAFH (lower anterior facial height) and control groups (Table 25.). Orthodontists gave significantly higher VAS scores than laypersons ($p=0.038$) in the ANB min group (Table 25.). In addition, orthodontists showed a tendency for higher VAS scores compared to dentists ($p=0.057$) in the ANB min group (Table 25.). All panel groups evaluated LAFH min faces to be more attractive than LAFH max faces (Table 25.). Pearson correlation coefficients for associations in aesthetic VAS scores between different panel groups varied between 0.733 and 0.839 ($p<0.001$ for all).
Table 25. Aesthetic evaluation VAS mean scores for different facial groups (n = 30 at each group) by evaluators’ occupation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>LAFH min</th>
<th>LAFH max</th>
<th>ANB min</th>
<th>ANB max</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthodontists</td>
<td>5.86</td>
<td>5.45</td>
<td>5.49</td>
<td>5.10</td>
<td>5.99</td>
</tr>
<tr>
<td>Dentists</td>
<td>5.83</td>
<td>5.49</td>
<td>5.27</td>
<td>5.15</td>
<td>6.11</td>
</tr>
<tr>
<td>Laypersons</td>
<td>5.24</td>
<td>5.03</td>
<td>5.26</td>
<td>5.21</td>
<td>5.70</td>
</tr>
<tr>
<td>p₁</td>
<td>0.612</td>
<td>0.616</td>
<td>0.057</td>
<td>0.614</td>
<td>0.177</td>
</tr>
<tr>
<td>p²</td>
<td>0.010</td>
<td>0.001</td>
<td>0.038</td>
<td>0.210</td>
<td>0.007</td>
</tr>
<tr>
<td>p³</td>
<td>0.009</td>
<td>&lt;0.001</td>
<td>0.967</td>
<td>0.667</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

p₁, orthodontists vs. dentists; p², orthodontists vs. laypersons; p³, dentists vs. laypersons.

5.8.2 Comparisons between the study groups and the control group

Regarding LAFH groups, the LAFH max group differed from the control group statistically significantly in all panel groups’ evaluations (p_{orthodontists}=0.011, p_{dentists}=0.008, p_{laypersons}=0.015) while the LAFH min group did not (p_{orthodontists}=0.767, p_{dentists}=0.360, p_{laypersons}=0.786). Regarding the ANB groups, the ANB max group differed from the control group significantly in all panel groups’ assessments (p<0.001 among orthodontists and dentists, p_{laypersons}=0.036) while the ANB min group differed from the control group among orthodontists (p=0.003) and dentists (p<0.001), but not among laypersons (p=0.070).

5.8.3 Association between facial attractiveness and facial characteristics

Entire sample population

For ANB, mean (SD) values were 1.36° (0.54°) among the ANB min group, 12.92° (0.62°) among the ANB max group, and 7.06° (0.21°) among the control group. Curve estimation showed a quadratic association between aesthetic VAS evaluation and ANB-angle for all panel groups: R²=0.268 (p<0.001) among orthodontists (Figure 5a), R²=0.195 (p<0.001) among dentists (Figure 5b), and R²=0.067 (p=0.048) among laypersons (Figure 5c).
Mean (SD) value for LAFH was 53.25% (1.27%) among the LAFH min group, 65.33% (1.23%) among the LAFH max group, and 59.41% (0.20%) among the control group. The best fitting model for the association between aesthetic VAS and LAFH was the quadratic model for all panel groups: $R^2=0.063$ ($p=0.059$) among orthodontists (Figure 6a), $R^2=0.064$ ($p=0.057$) among dentists (Figure 6b), and $R^2=0.050$ ($p=0.108$) among laypersons (Figure 6c).

Fig. 5. Quadratic regression models for association between VAS scores and ANB-angle at different panel groups: (a) Orthodontists, (b) Dentists, (c) Laypersons.
Fig. 6. Quadratic regression models for association between VAS scores and LAFH% at different panel groups: (a) Orthodontists, (b) Dentists, (c) Laypersons.

**Differences between male and female faces**

The association between ANB-angle and perceived facial attractiveness appeared to be highest among orthodontists ($R^2=0.276$, $p=0.001$ for males; $R^2=0.285$, $p=0.001$ for females) (Figure 7a). For dentists, the association was $R^2=0.188$ ($p=0.014$) among males and $R^2=0.231$ ($p=0.004$) among females (Figure 7b). For
laypersons, the association between VAS evaluation and ANB-angle was $R^2=0.075$ ($p=0.201$) among males and $R^2=0.269$ ($p=0.001$) among females (Figure 7c).

Fig. 7. Quadratic regression models for association between VAS scores and ANB-angle at different panel groups: (a) Orthodontists, (b) Dentists, (c) Laypersons.

Associations between LAFH and perceived attractiveness among orthodontists ($R^2=0.146$, $p=0.054$ for males; $R^2=0.058$, $p=0.244$ for females) and laypersons ($R^2=0.044$, $p=0.436$ for males; $R^2=0.064$, $p=0.211$ for females) were non-significant (Figures 8a and 8c). For dentists, a weak association was found among males ($R^2=0.172$, $p=0.031$) while among females the association between LAFH
and perceived facial attractiveness was non-significant ($R^2=0.032$, $p=0.471$) (Figure 8b).

Fig. 8. Quadratic regression models for association between VAS scores and LAFH\% at different panel groups: (a) Orthodontists, (b) Dentists, (c) Laypersons.
6 Discussion

6.1 The prevalence of malocclusion traits and orthodontic treatment

The present study was designed to investigate the prevalence of malocclusion traits among 1,964 mid-adulthood subjects in the Northern Finland Birth Cohort 1966. The overall prevalence of malocclusion traits in this study was 39.5 per cent when crowding was excluded. This finding is in line with the 42 per cent detected in a previous Finnish study on adults (Laine & Hausen 1983). In the Health 2000 Survey, 31 per cent of the subjects had one or more occlusal deviation (Pietilä & Nordblad 2008). A lower prevalence of malocclusion in this earlier Finnish study on adults can be explained by the different study design. In the Health 2000 Survey, only malocclusions including an apparent risk of poor occlusion prognosis were examined (Pietilä & Nordblad 2008). When interpreting the study results, one must also take into account that crowding was not recorded in the present study.

The most common malocclusion trait in the present study was lateral crossbite (17.9%). This study result is in concordance with the 19 per cent prevalence observed among Finnish university students (Laine & Hausen 1983). Anterior or lateral crossbite was also detected as the most common malocclusion in the Health 2000 Survey (Pietilä & Nordblad 2008). When crowding is excluded, the present study and the earlier Finnish studies demonstrate that crossbite is the most common malocclusion in the Finnish adult population. In comparison with the present study results, a lower prevalence of lateral crossbite has been reported among adult populations in Sweden (Salonen et al. 1992), Germany (Hensel et al. 2003) and Iceland (Jonsson et al. 2007).

Along with lateral crossbite, the most common malocclusions in the present study were increased overbite ≥ 6 mm (11.7%) and overjet ≥ 6mm (9.7%). In the study of Laine and Hausen (1983), the prevalence of deep bite was only 3 per cent. However, the methodological section of this study does not reveal how deep bite was specified (Laine & Hausen 1983). The prevalence of overjet ≥ 6 mm in the present study was higher compared to the Health 2000 Survey (Pietilä & Nordblad 2008) and the earlier Finnish study on adults (Laine & Hausen 1983). A possible explanation for the higher prevalence of overjet detected in the present study compared to earlier studies might be a different cut-off point of overjet (Pietilä &
Nordblad 2008) and age differences of the study populations (Laine & Hausen 1983).

Anterior open bite (1.3%) and negative overjet (1.2%) were both quite rare in this adult population. Regarding anterior open bite, a higher frequency was registered in the Health 2000 Survey (Pietilä & Nordblad 2008) and in Dutch (Burgersdijk et al. 1991) and German (Hensel et al. 2003) adult populations. Nevertheless, the prevalence of anterior open bite in the present study is in line with that reported for Icelandic adult population (Jonsson et al. 2007). Regarding negative overjet, the present study demonstrated that it was very rare in Northern Finland adult population. This is in line with the earlier studies that have shown that negative overjet is uncommon in Finland (Laine & Hausen 1983) and generally in other European adult populations (Burgersdijk et al. 1991, Hensel et al. 2003, Jonsson et al. 2007).

The present study showed a significant gender dimorphism regarding the overall prevalence of malocclusion. Men showed a higher prevalence of crossbite on the left, increased overbite and negative overjet. Male dominance in the prevalence of malocclusion has not earlier been reported in Finland. In the study of Laine and Hausen (1983), some gender variation in the prevalence of malocclusion occurred even though the differences were not statistically significant. Deep bite has been found to be more common in Finnish boys than in girls (Mylärniemi 1970). Deep bite has also been found to be more prevalent among men in the German adult population (Hensel et al. 2003). Male dominance in the prevalence of negative overjet has also been detected in Swedish (Salonen et al. 1992) and British (Lavelle 1976) populations. Male dominance in left lateral crossbite and negative overjet and the significant relationship between these malocclusions can be explained by prognathic malocclusion. The results of the present study are in accordance with the earlier study demonstrating sexual dimorphism in late mandibular growth (Behrents 1985). An earlier Finnish study on adults also detected a positive association between negative overjet and crossbite (Laine 1985).

In this study, no statistically significant difference in the prevalence of malocclusions was found with respect to experience of orthodontic treatment. This study result is opposite to an earlier Finnish study on adults (Laine & Hausen 1983). Higher frequencies of malocclusions have been detected among subjects having received orthodontic treatment in earlier studies (Burgersdijk et al. 1991, Jonsson et al. 2007, Laine & Hausen 1983). A higher prevalence of malocclusion among orthodontically treated subjects in some studies might reflect unstable or unsuccessful treatment results (Jonsson et al. 2007, Laine & Hausen 1983). The
prevalence of malocclusion in adulthood might be influenced by relapse of the treatment results, insufficient treatment in childhood due to small extent of the treatment and normal occlusal changes over time (Heikinheimo et al. 2012, Jonsson et al. 2007). The present study indicates that orthodontic treatment provided in childhood in Northern Finland has been sufficient in reducing malocclusion traits to the level observed in the general population. The present study results also reflect the lack of systematic screening of malocclusions in Northern Finland in the 1970s and the beginning of 1980s, which might have caused variation in the degree of treatment. Common recommendations for selecting children for orthodontic treatment were first introduced by the Medical Board of Finland in 1988 (Medical Board of Finland 1988). These criteria were modified from those in Graingers’ Treatment Priority Index (Grainger 1967).

In the present study, the extent of previous orthodontic treatment experience was 18.6 per cent, which is in line with the earlier Finnish study on adults (age group 30–44 years, 19%) (Pietilä & Nordblad 2008). In contrast, the prevalence of orthodontic treatment experience among Finnish university student was only 11 per cent (Laine & Hausen 1982). Possible explanations for the difference in the prevalence of orthodontic treatment between the present study and the earlier study could be the geographic location and different period of time. In the present study, the subjects lived in close proximity to a large health centre while the previous study included more rural areas and possibly more basic-level healthcare (Laine & Hausen 1982). In addition, orthodontic treatment became more common in Finland in the 1980s, which might explain the lower frequency of orthodontic treatment experience in the earlier Finnish study on adults (Laine & Hausen 1982). A more recent study of young Finnish adults showed a higher prevalence of previous orthodontic treatment experience compared to the present study (Tuominen et al. 1994). However, most of the subjects in the earlier study came from cities and especially from the Helsinki region (Tuominen et al. 1994). The authors of the earlier investigation suggest that a possible explanation for the relatively high prevalence of earlier orthodontic treatment experience might be the good access to care in the Helsinki region (Tuominen et al. 1994).

In this study, women had a history of orthodontic treatment more frequently than men. The study result is in line with earlier studies (Burgersdijk et al. 1991, Jonsson et al. 2007, Laine & Hausen 1982). Among young Finnish adults, more women than men had received orthodontic treatment but the difference was not statistically significant in the study of Tuominen et al. 1994. A male dominance in the prevalence of malocclusion and a lower experience of orthodontic treatment
among males can be explained by gender differences in treatment seeking and in attitude towards treatment. Men have been reported to be more often satisfied with their dentition compared to women among young Finnish adults (Tuominen et al. 1994). Among Finnish adolescents, boys have been shown to be more satisfied than girls with the alignment of their teeth without having had orthodontic treatment, even though the gender difference was not statistically significant (Pietilä & Pietilä 1996).

6.2 Association of occlusion with TMD

This study showed a statistically significant association between occlusion and TMD. Based on a recent systematic review, occlusion is considered as a cofactor in the aetiology of TMD (Michelotti & Iodice 2010). The present study showed that occlusion seems to have a role in TMD and that occlusal disturbances should be considered as risk factors. However, understanding the causal-effect relationship between malocclusions and TMD is not possible based on association alone. In the case of causal-effect relationship, the association must be strong, but in addition, a more severe malocclusion must lead to more severe symptoms of TMD (Michelotti & Iodice 2010). Therefore, more studies are needed to evaluate the role of occlusion in the background of TMD.

Two significant relationships regarding the association between occlusal variables and diagnoses of TMD were found in the present study. Firstly, the association between myalgia and lateral scissors bite, and secondly, between arthralgia and lateral deviation in RCP-ICP slide showed to be statistically significant. Regarding the association between scissors bite and TMD, two earlier studies found no significant relationship (Kritsineli & Shim 1992, Sari et al. 1999). By contrast, scissors bite was shown to be significantly associated with clicking in TMJs (Riolo et al. 1987). The association between myalgia and lateral scissors bite might be explained by asymmetric position of the condyles (Pirttiniemi et al. 1991). According to earlier studies, lateral malocclusions showed a more asymmetric position of the condyles (Kecik et al. 2007, Pirttiniemi et al. 1991). In addition, the signs and symptoms of TMD have been shown to correlate with the length and lateral deviation of slide between RCP-ICP, deviation in protrusion and asymmetry in lateral cuspid occlusion (Raustia et al. 1995a).

In this study, limited mouth opening showed a significant association with lateral crossbite. Several earlier studies have also reported a significant association between crossbite and the signs and symptoms of TMD (Alamoudi 2000, Egermark...
et al. 2003, Egermark-Eriksson et al. 1990, Marklund & Wänman 2010). Compared to other malocclusions, posterior crossbite has been thought to have the largest effect on the function of the masticatory system (Michelotti & Iodice 2010). The present study indicates that lateral crossbite is related to internal derangements of TMJ. The present finding is in line with the earlier studies (Marklund & Wänman 2010, Pullinger et al. 1993, Pullinger & Seligman 2000). According to the general assumption, posterior crossbite may lead to alterations of the disc-condyle relationship, which in turn can lead to disc displacement and clicking of the joint (Buranastidporn et al. 2006, Egermark et al. 2003, Pullinger et al. 1993, Pullinger & Seligman 2000). An association between unilateral posterior crossbite and TMJ disc displacement with reduction has been found in an earlier study (Pullinger et al. 1993). Marklund and Wänman (2010) found that crossbite is related to the incidence and persistence of TMJ dysfunction, i.e. to alterations of the disc-condyle relationship.

In this study, pain in masticatory muscles was significantly associated with negative overjet and RCP-ICP slide (3–5 mm). An earlier study has demonstrated that a longer RCP-ICP slide associates with muscle tenderness (Ingervall et al. 1980). Previous studies have reported conflicting results regarding the relationship between negative overjet and TMD (John et al. 2002, Riolo et al. 1987, Sari et al. 1999, Thilander et al. 2002). No relationship has been found between negative overjet and self-reported symptoms of TMD (John et al. 2002). By contrast, negative overjet has been found to be significantly associated with joint noise and TMJ pain (Riolo et al. 1987). In addition, significant association has been detected between Angle Class III malocclusion and TMD (Sari et al. 1999, Thilander et al. 2002).

6.3 TMD and orthodontic treatment

The results of this study showed that some signs of TMD were significantly more common among orthodontically treated than among untreated subjects. This finding is in contrast with most of the results reported earlier. Based on review articles, most of the previous studies have not shown a significant relationship between orthodontic treatment and TMD (McNamara et al. 1995, Michelotti & Iodice 2010). In addition, traditional orthodontic treatment has not been shown to increase the prevalence of TMD (Kim et al. 2002). In a systematic review, none of the included studies suggested that orthodontic treatment caused TMD (Mohlin et al. 2007). On the contrary, a lower prevalence of TMD after orthodontic treatment
has been found in longitudinal studies (Henrikson et al. 2000, Olsson & Lindqvist 1995). Orthodontically treated subjects have demonstrated a lower prevalence of subjective symptoms of TMD compared to untreated subjects (Egermark & Thilander 1992). On the other hand, a longitudinal study has concluded that orthodontic treatment neither results in nor prevents TMD (Macfarlane et al. 2009).

The present study showed that clicking in TMJs was significantly more common in subjects having received orthodontic treatment in childhood compared to subjects having had treatment after the age of 20. It has earlier been concluded that orthodontic treatment does not have influence on TMJ clicking (Henrikson et al. 2000). On the other hand, a slight increase in joint clicking has been reported after orthognathic surgery (Panula et al. 2000).

In this study, crepitus in TMJs and degenerative joint disease were significantly more common among orthodontically treated than among untreated subjects. It is known that crepitus in TMJs is a clinical sign of degenerative joint disease (Schiffman et al. 2014). The results of the present study are in accordance with some earlier investigations (Pahkala & Heino 2004, Rodrigues-Garcia et al. 1998). The prevalence of creptation has been shown to increase after orthognathic surgery (Pahkala & Heino 2004). The authors of the earlier study reported that a possible explanation for the higher prevalence of crepitus after orthognathic treatment could be changes in condylar position which in turn may lead to degenerative changes in the articular joint surfaces (Rodrigues-Garcia et al. 1998). However, it must be taken into account that both of the earlier investigations were based on orthognathic surgery patients instead of traditional orthodontic treatment (Pahkala & Heino 2004, Rodrigues-Garcia et al. 1998). There have been contradictory results as to whether traditional orthodontic treatment might cause changes in condylar position (McNamara et al. 1995, Michelotti & Iodice 2010).

Higher frequency of arthralgia was found in subjects having been treated orthodontically in adulthood compared to subjects who had received orthodontic treatment in childhood. A possible explanation for this might be that the subjects who had received orthodontic treatment in adulthood had had malocclusions longer before getting treatment. Therefore, TMJs in those subjects have also been affected for a longer time by malocclusions. On the other hand, TMD symptoms may have been one of the reasons to seek orthodontic treatment in the first place.

Even though the orthodontically treated subjects in this study demonstrated higher prevalence of TMD signs and diagnoses, especially crepitus in TMJs and degenerative joint disease, one must take into account methodological limitations. In the present study, the orthodontic treatment experience was based on a
questionnaire which can affect the study results, by recall bias, for instance. In addition, the patients were only asked whether they had undergone orthodontic treatment without specifying different treatment types. In addition, no information was available regarding the condition of TMJs before orthodontic treatment.

6.4 Occlusal interferences in TMD subjects with orthodontic treatment experience

This study found no significant differences in distribution of occlusal interferences between orthodontically treated and untreated subjects with TMD. This finding is in line with a long-term study (Sadowsky & Polson 1984). In a prospective long-term study, the prevalence of occlusal interferences was on the same level in the orthodontic group as in the untreated group in the final follow-up, but no statistical analysis was performed (Egermark et al. 2005). A previous investigation has shown a lower prevalence of RCP/ICP interferences among orthodontically treated subjects compared to untreated subjects, which is an opposite result to the findings of the present study (Olsson & Lindqvist 2002).

6.5 Association between facial soft tissue profile and malocclusions

The study was carried out to evaluate the sagittal incisor relationship (overjet) and vertical incisor relationship (overbite) and their association with facial soft tissue profile. The present study demonstrated a significant association between malocclusions and facial soft tissue profile, which is in line with earlier investigations (Bittner & Pancherz 1990, Dimaggio et al. 2007, Godt et al. 2013, Maurya et al. 2014). The results of the present study showed a positive moderate correlation between facial profile and overjet in both genders. In addition, the correlation between overbite and facial profile was weak while this correlation was also detected to be significant in both genders. An earlier study also showed stronger correlation between overjet and facial soft tissue than between overbite and facial soft tissue (Saxby & Freer 1985). In addition, a large overjet has most often been shown to be reflected in facial morphology while negative overjet and overbite could not be detected from facial photographs (Bittner & Pancherz 1990). On the other hand, Class II malocclusion with increased overjet and Class III malocclusion with decreased overjet have been demonstrated to influence soft tissue morphology (Godt et al. 2013).
The results of the present study showed a weak to moderate correlation between facial soft tissue profile and incisor relationships. Variability in soft tissue thickness, ethnic origin, gender and age might influence cephalometric soft tissue values (Bergman 1999, Saxby & Freer 1985). A possible explanation for the quite low correlations in this adult population might be the growth process which occurs during lifetime (Pecora et al. 2008). A longitudinal cephalometric study has shown that facial soft tissues undergo significant changes during adulthood as part of the craniofacial complex growth (Pecora et al. 2008).

In the present study, the anterior-posterior position of the upper lip (upper lip to Tragus line) showed a strong association with overjet in both genders. This finding is similar to the results seen in earlier studies (Dimaggio et al. 2007, Godt et al. 2013, Hameed et al. 2008, Saxby & Freer 1985). Children with Class II malocclusion with increased positive overjet exhibited more anterior upper lip position (Godt et al. 2013). Overjet has been shown to correlate with upper lip convexity (Saxby & Freer 1985). The authors of the latter study supposed that the horizontal position of the upper incisor determines the horizontal position of the upper lip (Saxby & Freer 1985). In addition, more prominent lip profile has been detected among Class II subjects (Dimaggio et al. 2007, Hameed et al. 2008). The result of the present study indicates that overjet affects the anterior-posterior position of the upper lip.

The results of the present study showed that the positions of soft tissue A-point and soft tissue B-point were moderately to strongly associated with both overjet and overbite. The important role of soft tissue A- and B-points in the facial profile has also been detected in earlier studies (Saxby & Freer 1985, Wasserstein et al. 2015). It has been shown that soft tissue A-point and B-point belong to the most reliable soft tissue reference points (Wasserstein et al. 2015). In addition, the authors of an earlier study concluded that point-A convexity is a very important factor in determining the soft tissue outline (Saxby & Freer 1985).

It is interesting that the positions of soft tissue A- and B-points correlated with overbite. This finding is, however, in accordance with an earlier study (Saxby & Freer 1985). Overbite has been shown to correlate with the horizontal position of the soft tissue B-point and its relation to soft tissue A-point (Saxby & Freer 1985). One must, however, consider that the correlations detected were not very high (Saxby & Freer 1985). Moderate to strong association between the positions of soft tissue A- and B-points and overjet is in line with earlier literature (Wasserstein et al. 2015). An earlier study has shown that sagittal malocclusion and jaw relationships are associated with soft tissue A- and B-points (Wasserstein et al. 2015).
In other words, the soft tissue angle A’N’B’ has been shown to differ according to Angle’s classifications and a high correlation between skeletal ANB and A’N’B’ is evident (Wasserstein et al. 2015). The present study demonstrated that soft tissue A- and B-points are good predictors of anterior malocclusions.

Regarding severe sagittal malocclusions, a strong association was found between facial soft tissue profile and extreme negative overjet. This finding is in accordance with an earlier study that documented a significant association between Class III malocclusion and soft tissue profile characteristics (Staudt & Kiliaridis 2009). In the study by Staudt and Kiliaridis (2009), the authors concluded a high diagnostic value of profile photographs in detecting Class III malocclusion. Altogether, the present study indicates that it is not reliable to fully form an opinion about the underlying occlusal relationships of a patient by examining a 2D profile photograph except in cases with negative overjet.

### 6.6 Perception of facial aesthetics between the panel groups

This study showed significant differences in aesthetic evaluation between the panel groups based on raters’ education. The present results are in accordance with an earlier soft tissue profile study which found differences between dentists and laypersons in the assessment of profile attractiveness (Abu Arqoub & Al-Khateeb 2011). According to the results of the present study, orthodontists evaluated individuals with a prognathic mandible as more attractive compared to dentists and laypersons. However, four of the dentists were specialists in prosthetics and stomatognathic physiology, which might have affected the evaluation of facial attractiveness. Differences in the assessed level of facial attractiveness regarding prognathic mandible have earlier been found between orthodontists and laypersons (Sena et al. 2017). The previous investigation was, however, based on digitally manipulated facial profiles with different facial convexity angles of persons with different soft tissue ANB-angles whereas the present study was based on non-edited facial photos (Sena et al. 2017).

### 6.7 Association between facial sagittal and vertical characteristics and facial attractiveness

The present investigation demonstrated significant association between soft tissue ANB-angle and facial aesthetics, measured using VAS scores, in all panel groups. This result indicates that antero-posterior discrepancy or facial convexity, as
measured by soft tissue ANB-angle, is associated with facial attractiveness. This finding is in line with several previous studies (Johnston et al. 2005a, Kuroda et al. 2009, Naini et al. 2012, Sena et al. 2017). An earlier facial photograph study found strong association with sagittal position of the mandible and the level of facial attractiveness (Sena et al. 2017). In addition, both facial photo (Kuroda et al. 2009) and facial silhouette (Johnston et al. 2005a, Naini et al. 2012) studies have found sagittal prominence of the mandible to be an essential factor to determine the profile aesthetics. By contrast, an earlier facial photo study found only slight association between facial attractiveness and soft tissue ANB-angle (Knight & Keith 2005). When interpreting the results, one must keep in mind that the study of Knight & Keith (2005) was based on young adults while the present study material consisted of middle-aged adults. A longitudinal study has demonstrated that the craniofacial complex undergoes changes in soft and skeletal tissues from late adolescence to late adulthood (Pecora et al. 2008). In addition, a previous investigation (Bishara et al. 1998) found soft tissue profile changes during adulthood regarding facial convexity. The angle of soft tissue convexity has been observed to decrease between 25 and 45 years of age in both genders (Bishara et al. 1998).

Soft tissue ANB-angle explained 27 per cent of the variability in aesthetic VAS scores among orthodontists in the present study. The proportions among dentists and laypersons were 20 per cent and 7 per cent, respectively. This finding highlights the importance of the ANB-angle in the perception of facial aesthetics among orthodontists in contrast to dentists and especially in contrast to laypersons. A possible explanation for this might be differences in the perception of facial proportions and facial profile between orthodontists and laypersons. Due to education and training, orthodontists are probably more analytical when observing facial sagittal and vertical characteristics. In addition, orthodontists might be more sensitive to special aspects of the facial profile in comparison to laypersons (Ng et al. 2013). It has earlier been suggested that laypersons might highlight more the overall features of the face (Cochrane et al. 1997). Laypersons might also focus more on jaw shape, nose and hair colour (Cochrane et al. 1999).

According to quadratic regression model, perceived facial attractiveness was not significantly associated with lower anterior facial height. Only a weak association was found in male faces assessed by dentists. This result is parallel with findings of a cephalometric study, where it was reported that lower facial height did not significantly influence profile attractiveness among clinicians and laypersons (Chew et al. 2007). However, it has been shown that lower facial height affects perceived frontal facial attractiveness among laypersons when illustrated
with facial silhouettes (Varlik et al. 2010). It has also been demonstrated that both lower facial height and sagittal position of the mandible affect perceived facial attractiveness (Johnston et al. 2005a, Johnston et al. 2005b, Maple et al. 2005). A potential confounding factor in the present study might be overweight of the subjects. As an age-independent variable, overweight might hide and modify facial characteristics. It can also be speculated that in the presence of overweight the facial soft tissue features do not necessarily correspond equally well to the underlying skeletal characteristics.

According to earlier literature, gender is an important factor in aesthetic evaluation of facial features, and significant differences have been shown between genders related to facial attractiveness (Knight & Keith 2005, Orsini et al. 2006, Varlik 2010). This was confirmed by the present study. A slightly convex profile in female subjects was evaluated as most attractive by orthodontists and dentists. An earlier study showed a similar finding as professionals were found to prefer a slightly convex profile for females (Czarnecki 1993). However, no significant differences have been found among orthodontists in the perception of facial aesthetics between retrognathic and prognathic profiles (Orsini et al. 2006).

6.8 Strengths and weaknesses of the study

The study population of the present study was part of a large unselected population-based birth cohort, NFBC1966. The large population size increases the statistical significance, which is undoubtedly a major strength of this study. The two earlier epidemiologic malocclusion studies on Finnish adults have been based on selected populations (Laine & Hausen 1983, Pietilä & Nordblad 2008). In the study of Laine & Hausen (1983), the study population consisted of 451 Finnish university students. Because all subjects were selected university students, it is questionable to generalize the results of that study to describe Finnish adult population. In a more recent study, the population size was large, but only malocclusions including an apparent risk of poor prognosis for the occlusion were examined (Pietilä & Nordblad 2008).

Another methodological advantage of this study is the standardized clinical examination. The stomatognathic examination and the registration of occlusion was performed by six calibrated dentists. All investigators trained with experienced specialized dentists before the beginning of the study, which confirmed the repeatability of the examination. In addition, inter-examiner agreement was tested constantly during the clinical examination against a gold standard senior dentist.
Angle’s classes and crowding were not registered in the clinical examination, which can be seen as a limitation of this study, particularly as earlier studies have shown that crowding is among the most frequent forms of malocclusion in Europe (Hensel et al. 2003, Jonsson et al. 2007, Salonen et al. 1992). The evaluation of occlusal variables and malocclusion in sagittal, vertical, and transversal dimensions was, however, likely to reflect both inter-arch anteroposterior relationships as well as clinically significant crowding to a marked extent. Notably, collection of data on molar Angle’s classification particularly in an ageing population and without history of earlier dental treatment could be misleading, because the molar relationship is not neutral to eventual tooth extractions and hypodontia. Nevertheless, in study I, the comparison of the study results to earlier epidemiological investigations would have been easier if molar relationships had been examined. Study III showed that the positions of soft tissue A-point and soft tissue B-point to the face were strongly associated with both overjet and overbite. In addition, an earlier study has demonstrated that the soft tissue angle A’N’B’ differs according to Angle’s classifications (Wasserstein et al. 2015). Consequently, it would have been interesting to know if the positions of soft tissue A- and B-points would also have associated with Angle’s classes in this study.

A weakness in studies I and II is the lack of specificity of the questionnaire regarding earlier orthodontic treatment experience. In addition, no data were available regarding the subjects’ original diagnoses or earlier treatment and its objective. The subjects were only asked whether they had received orthodontic treatment before the age of 20 or after the age of 20 without specifying different orthodontic treatment types. Because the earlier orthodontic treatment experience was based on a questionnaire, distortion of the study results is possible due to recall bias.

In study III, measurements were based on two-dimensional photographs. Three-dimensional facial photographs would be more accurate to describe soft tissue morphology. In addition, another weakness of the study is that data on lip thickness was not available.

A major limitation in study IV is the subjective nature of perception of facial attractiveness. This can produce distraction between the raters. According to an earlier study, same positioning of the lines in VAS does not necessarily express the same feeling for different raters (Aitken 1969). Since all subjects were members of the NFBC1966, age variation did not exist. According to earlier literature, rater’s age (Kiekens et al. 2007, Kiekens et al. 2008, Türkkahraman & Gökalp 2004), gender (Cochrane et al. 1999, Kiekens et al. 2007, Türkkahraman & Gökalp 2004)
and education (Türkkahraman & Gökalp 2004) have an influence on perceived facial attractiveness. It has earlier been shown that females and younger individuals tend to be stricter raters of facial attractiveness than males and older adults (Foos et al. 2011, Soler et al. 2012). Due to the unequal distribution of raters’ gender in the present study, the influence of raters’ gender and education on perceived facial aesthetics could not be separated and examined. The mean age of the raters varied between 41 and 56 years of age and it was thus similar to the study population. It would have been better if there had been no age and gender variation among the raters and if all dentists had been general dentists. For study ethical reasons, the raters had to have permission to see the facial photos which limited the number and composition of the raters. Therefore, all laypersons were statisticians working at the Faculty of Medicine, University of Oulu. In addition, the effect of overweight on facial characteristics could have been analysed in more detail.

6.9 Clinical implications and future perspectives

This study showed a statistically significant association between morphological malocclusions, occlusal disturbances and TMD. The present study demonstrated that occlusal disturbances should be considered as potential risk factors of TMD.

Positive moderate correlation was found between facial soft tissue profile measurements and the severity of overjet. The facial profile was less affected by overbite. An increased concern about radiation exposure of lateral skull radiographs has recently raised the role of photographs in imaging of malocclusion and facial soft tissue profile (Dimaggio et al. 2007, Kale-Varlk 2008). In addition, profile photographs are a low-cost and non-invasive tool to document facial soft tissue characteristics (Kale-Varlk 2008, Staudt & Kiliaridis 2009, Wasserstein et al. 2015). This study presented mean values of the soft tissue profile measurements in a large homogeneous population of adults. The present results can be used as gold standard values in future studies in an attempt to examine whether it is possible to detect malocclusion from facial soft tissue profile photos. In other words, this study showed that anterior-posterior position of the upper lip and positions of soft tissue A- and B-points were moderately to strongly associated with sagittal incisor relationships.

The soft tissue profile was significantly affected among subjects with cases of negative overjet. Therefore, in patients with negative overjet, 2D profile photographs provide significantly relevant information regarding the underlying anterior occlusal relationships. It has already been demonstrated that profile
photographs can detect a skeletal Class III discrepancy with high probability (Staudt & Kiliaridis 2009). The authors of the earlier study concluded that even though lateral cephalograms might be indicated for differential diagnosis, profile photographs might be useful during the initial consultation (Staudt & Kiliaridis 2009). Related to screening of malocclusion, it is especially important to find children with skeletal Class III sufficiently early. Therefore, it would be interesting to study in the future if facial profile is sensitive for Class III discrepancy in all age groups.

Significant differences were found in the perception of facial attractiveness between orthodontists and laypersons regarding the soft tissue ANB-angle. Clinically, this highlights the importance of considering patient’s opinion on facial aesthetics regarding facial convexity in the orthodontic treatment plan. Interestingly, this investigation showed that soft tissue A- and B-points are good predictors for overjet, overbite and facial aesthetics.

Facial soft tissue profile was significantly associated with anterior malocclusions. The role of genetics in the development of malocclusion has been studied extensively (Cruz et al. 2011, Mossey 1999, Nikopensius et al. 2013, Xue et al. 2010). Earlier studies have also managed to quantify craniofacial variability among patients with identical malocclusion (Bui et al. 2006, Moreno Uribe et al. 2014). In the future, it would therefore be interesting to study if there are specific genetic loci related to facial characteristics and malocclusions.
7 Conclusions

I The most common malocclusion in the Finnish adult population in Northern Finland was lateral crossbite. A significant male dominance was demonstrated in the prevalence of malocclusion traits. Females showed a higher history of orthodontic treatment. This study indicates that orthodontic treatment carried out in childhood was, on average, adequate in reducing the prevalence of malocclusion traits to the level observed in the general population.

II A significant association was found between occlusion and TMD. TMD signs were associated with lateral crossbite, scissors bite, negative overjet and the length and lateral deviation in RCP-ICP slide. Orthodontically treated subjects presented more often with TMD than untreated subjects. Especially crepitus in TMJs and degenerative joint disease were significantly more common among orthodontically treated compared to untreated subjects.

III Moderate significant correlation was found between overjet and facial soft tissue profile while facial profile was less affected by overbite. Soft tissue A-point and soft tissue B-point are good predictors of overjet and overbite. A profile photograph provides significantly relevant information regarding the anterior occlusal relationships in negative overjet cases.

IV Facial sagittal dimensions appeared to influence facial aesthetics more than vertical characteristics in middle-aged Finnish adults. Soft tissue ANB-angle was more significant in explaining facial attractiveness among orthodontists than among dentists and laypersons. The overall perception of facial attractiveness related to facial characteristics differed between orthodontists, dentists and laypersons.
References


Fig. 9. Supplementary Figure 1. Histograms for overjet and overbite.
Fig. 10. Supplementary Figure 2. P-P plots of the regression standardized residual values for overjet and overbite.
Orginal articles


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MALOCCLUSIONS IN RELATION TO FACIAL SOFT TISSUE CHARACTERISTICS, FACIAL AESTHETICS AND TEMPOROMANDIBULAR DISORDERS IN THE NORTHERN FINLAND BIRTH COHORT 1966