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Päivi Jussila

PREVALENCE AND ASSOCIATED RISK FACTORS OF TEMPOROMANDIBULAR DISORDERS (TMD) IN THE NORTHERN FINLAND BIRTH COHORT (NFBC) 1966

UNIVERSITY OF OULU GRADUATE SCHOOL;
UNIVERSITY OF OULU,
FACULTY OF MEDICINE;
MEDICAL RESEARCH CENTER OULU;
OULU UNIVERSITY HOSPITAL

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Abstract

Temporomandibular disorders (TMD) are described as a variety of dysfunctions and pains related to the masticatory system. Clicking in the temporomandibular joints (TMJs) and pain in the masticatory muscles are the most common symptoms and signs of TMD. Other frequently reported symptoms are headache, facial pain, and symptoms in the ears. The prevalence of TMD signs in the adult population has been shown to vary between 33% and 86%, being more common in women than in men. TMD has been found to be most prevalent at 20–50 years of age. The aim of this cross-sectional study was to investigate the prevalence of TMD and associated risk factors in the Finnish adult population based on the Northern Finland Birth Cohort (NFBC) 1966.

Altogether 1 962 cohort subjects at the age of 46 years (1 050 women, 912 men) responded to questionnaires and participated in a clinical medical and dental examination in 2012–2013. The stomatognathic examination was performed according to a modified protocol of diagnostic criteria for TMD (DC/TMD).

The prevalence of TMD signs among the examined cohort subjects was 34.2%; women had clinical signs of TMD more often than men. Clinical signs were registered more often than self-reported TMD symptoms. The most common clinical signs were clicking in the TMJs (26.2%) and palpation pain in the masticatory muscles (11.2%). The most common diagnosis was disc displacement with reduction (7.0%).

TMD signs were associated with unstable occlusion. Occlusal disturbances were associated with palpation pain in the masticatory muscles, as well as myalgia and arthralgia diagnoses. Pain-related TMD symptoms and clinical signs correlated strongly with a poor self-reported health condition as well as with painful general health problems.

Keywords: cohort study, epidemiological study, Northern Finland Birth Cohort (NFBC) 1966, occlusion, temporomandibular disorders

Jussila, Päivi, Purentaelimistön toimintahäiriöiden esiintyvyys ja riskitekijät Pohjois-Suomen syntymäkohortti 1966:ssa.

Oulun yliopiston tutkijakoulu; Oulun yliopisto, Lääketieteellinen tiedekunta; Medical Research Center Oulu; Oulun yliopistollinen sairaala

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Tiivistelmä

Purentaelimistön toimintahäiriöt (engl. temporomandibular disorders, TMD) on yhteisnimitys leukanivelten, puremalihasten, hampaiston ja niihin liittyvien kudosten sairaus- ja kiputiloille. Leukanivelen naksuminen ja kipu purentaelimistön alueella ovat tavallisimmat oireet, mutta myös päänsärky, kasvokipu ja korvaoireet ovat yleisiä TMD-potilailla. Väestötutkimuksissa on havaittu suurta vaihtelua TMD:n esiintyvyydessä (33–86 %). TMD:n oireita sekä löydöksiä todetaan tavallisimmin 20–50-vuotiailla ja naisilla enemmän kuin miehillä. Tutkimuksen tarkoituksena oli selvittää TMD:n esiintyvyyttä ja riskitekijöitä suomalaisessa aikuisväestössä Pohjois-Suomen syntymäkohortti 1966:n (Northern Finland Birth Cohort, NFBC) aineistossa.

Vuosina 2012–2013 tutkittiin 1 962 kohortin henkilöä 46 vuoden ikäisinä (1 050 naista, 912 miestä). Tutkimus koostui kyselyistä sekä lääketieteellisestä ja suun terveydentilan kliinisestä tutkimuksesta. Purentaelimistön tutkimuksessa käytettiin kansainvälistä TMD:n diagnostista kriteeristöä (engl. diagnostic criteria for TMD, DC/TMD).

TMD-löydösten esiintyvyys tutkitussa kohorttiaineistossa oli 34,2 %. Kliiniset löydökset tutkituilla henkilöillä olivat yleisempiä kuin heidän raportoimansa oireet. Yleisimmät löydökset olivat leukanivelen naksuminen (26,2 %) ja palpaatiokipu puremalihaksissa (11,2 %). Yleisin diagnoosi oli leukanivelen välilevyn palautuva virheasento (7,0 %).

TMD-löydösten ja epästabiilin purennan välillä havaittiin yhteys. Purennassa olevien häiriöiden ja puremalihasten palpaatiokivun sekä leukanivelkivun välillä todettiin selvä yhteys. TMD-löydöksillä ja niihin liittyvillä kivuilla havaittiin tilastollisesti merkitsevä yhteys koettuun heikentyneeseen terveydentilaan sekä kivuliaisiin yleissairauksiin.

Asiasanat: epidemiologia, kohorttitutkimus, Pohjois-Suomen syntymäkohortti 1966, purenta, purentaelimistön toimintahäiriöt

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Oulu, 29.03.2019 *Päivi Jussila*

Abbreviations

CI	confidence interval
DC/TMD	diagnostic criteria for temporomandibular disorders
FM	fibromyalgia
IADR	International Association for Dental Research
ICP	intercuspal contact position
i.e.	id est
NFBC	Northern Finland Birth Cohort
OA	osteoarthritis
OPPERA	Orofacial Pain: Prospective Evaluation and Risk Assessment
OR	odds ratio
PA	psoriatic arthritis
RA	rheumatoid arthritis
RCP	retruded contact position
RDC/TMD	research diagnostic criteria for temporomandibular disorders
SES	socioeconomic status
SHIP	Study of Health in Pomerania
TMD	temporomandibular disorders
TMJ	temporomandibular joint
χ^2	Chi-Square

Original publications

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

I Jussila, P., Kiviahde, H., Näpänkangas, R., Päkkilä, J., Pesonen, P., Sipilä, K., Pirttiniemi, P., Raustia, A. (2017). Prevalence of Temporomandibular Disorders (TMD) in the Northern Finland Birth Cohort (NFBC) 1966. *Journal of Oral & Facial Pain and Headache, 31*(2), 159–164. https://doi.org/10.11607/ofph.1773

II Jussila, P., Krooks, L., Näpänkangas, R., Päkkilä, J., Lähdesmäki, R., Pirttiniemi, P., Raustia, A. (2018). The Role of Occlusion in Temporomandibular Disorders (TMD) in the Northern Finland Birth Cohort (NBFC) 1966. *Journal of Craniomandibular & Sleep Practice,* https://doi.org/10.1080/08869634.2017.1414347 [Epub ahead of print]

III Jussila, P., Knuutila, J.*, Salmela, S.*, Näpänkangas, R., Päkkilä, J., Pirttiniemi, P., Raustia, A. (2018). Association of risk factors with temporomandibular disorders in Northern Finland Birth Cohort 1966. *Acta Odontologica Scandinavica, 76*(7), 525-529. https://doi.org/10.1080/00016357.2018.1479769

*The authors contributed equally to the study.

Contents

1 Introduction

Temporomandibular disorders (TMD) are described as painful and dysfunctional conditions related to the masticatory system and associated structures (Okeson, 2013). The most common symptoms and signs are clicking in the temporomandibular joints (TMJs), pain in the TMJs and masticatory muscles, and restricted movements of the mandible. Facial pain, headache and non-specific symptoms in the neck or shoulders, and problems in the ears are also frequently reported by TMD patients (Okeson, 2013). Self-reported TMD symptoms have been shown to be common in the general population (25–50%), while clinical signs of TMD have been found even more often (33–86%), being one of the most common musculoskeletal pains in all age groups (Wänman, 1996; Carlsson, 1999; Rutkiewicz, Könönen, Suominen-Taipale, Nordblad, & Alanen, 2006; Anastassaki Köhler, Hugoson, & Magnusson, 2012; Okeson, 2013; Yekkalam & Wänman, 2014a).

The need for TMD treatment based on subjective symptoms has been reported to vary, while the diagnosed need for treatment has been shown to be lower (De Kanter, Käyser, Battistuzzi, Truin, & Van 't Hof, 1992; Kuttila, Niemi, Kuttila, Alanen, & Le Bell, 1998; Magnusson, Egermark, & Carlsson, 2002; Al-Jundi, John, Setz, Szentpétery, & Kuss, 2008; Progiante *et al.*, 2015). According to current knowledge, the etiology of TMD is multifactorial and complex. Biological and psychological characteristics combined with social factors have been found to predict or increase the risk of developing TMD (Ohrbach *et al.*, 2011; Huhtela *et al.*, 2016). In addition, correlations between facial and neck traumas and onset of TMD have also been reported (Rauhala, Oikarinen, Järvelin, & Raustia, 2000; Okeson, 2013; Häggman-Henrikson, Rezvani, & List, 2014; Häggman-Henrikson, Lampa, Marklund, & Wänman, 2016). Occlusal factors, parafunctions, bruxism, and TMJ hyperlaxity or hypermobility have also been presented as etiological factors of TMD (Okeson, 2013). The role of occlusion in the etiology of TMD is controversial (De Boever, Carlsson, & Klineberg, 2000; Okeson, 2013), and the association between TMD symptoms and signs and occlusal disturbances is not clear (Seligman & Pullinger, 1991; Pullinger, Seligman, & Gornbein, 1993; Pullinger & Seligman, 2000). However, occlusion might have a more important role in TMD than generally has been accepted, especially in cases of intra-articular disorders of the TMJ (Raustia, Pirttiniemi, & Pyhtinen, 1995; Raustia, Pyhtinen, & Tervonen, 1995; Pullinger & Seligman, 2000; Tallents, Macher, Kyrkanides, Katzberg, & Moss, 2002; Rusanen, Pirttiniemi, Tervonen, & Raustia, 2008).

The present epidemiological cross-sectional study was conducted to investigate the prevalence and associated risk factors of TMD in the Finnish adult population based on the Northern Finland Birth Cohort (NFBC) 1 966 subjects living in the Oulu region during 2012–2013, when the subjects were 46 years old.

2 Review of the literature

2.1 Temporomandibular disorders (TMD)

Temporomandibular disorders (TMD) are "a collective term embracing a number of clinical problems that involve the masticatory muscles and the temporomandibular joints (TMJs), or both, and associated structures" (Okeson, 1996). TMD has been described as a recurrent or chronic musculoskeletal disorder (Okeson, 2013). Female dominance has been shown and fluctuation of TMD symptoms and signs has been found to be more persistent in women than in men (De Kanter *et al*., 1993; Wänman, 1996; Kuttila *et al*., 1998; Johansson, Unell, Carlsson, Söderfeldt, & Halling, 2003; Rutkiewicz *et al.*, 2006).

The most common symptoms and signs of TMD are sounds in the TMJs, pain and stiffness or fatigue in the masticatory muscles, and limitations and pain in mandibular movements. Headache, facial pain, and symptoms in the throat (i.e. difficulties in swallowing and using one's voice), neck, shoulders or ears are also common in TMD patients (Okeson, 2013).

2.2 Epidemiology of TMD

TMD symptoms have been found in 25–50% and clinical signs in 33–86% of the population (De Kanter *et al.*, 1993; Rutkiewicz *et al.*, 2006; Anastassaki Köhler *et al.*, 2012), while the diagnosed need for treatment has been shown to be lower (De Kanter *et al.*, 1992; Wänman, 1996; Kuttila *et al.*, 1998; Magnusson *et al.*, 2002; Nilsson, List, & Drangsholt, 2005; Al-Jundi *et al*., 2008; Progiante *et al.*, 2015). TMD has been recorded in all age groups and found to be most common at 20–50 years of age (De Kanter *et al.*, 1993; Kuttila *et al.*, 1998; Al-Jundi *et al.*, 2008; Anastassaki Köhler *et al.*, 2012; Slade *et al.,* 2013a; Yekkalam & Wänman, 2014). A positive correlation between aging and TMD has been noted in adult population-based studies (Kuttila *et al.*, 1998; Nilsson *et al.*, 2005; Rutkiewicz *et al.*, 2006). On the other hand, the oldest age groups have been found to have less TMD symptoms than younger ones (Slade *et al.*, 2013a; Yekkalam & Wänman, 2014).

The Study of Health in Pomerania (SHIP) in Germany was a five-year epidemiological longitudinal adult population-based study in which signs of TMD were found to develop in 4% of subjects per year (Kindler *et al.*, 2012). The

OPPERA study in the USA (The Orofacial Pain: Prospective Evaluation and Risk Assessment) was a nationally representative, cross-sectional survey of adults (Slade *et al.*, 2013a). New TMD cases, especially facial pain, developed in 3.9% of subjects per year. Fatigue or stiffness in the masticatory muscles was the most commonly recorded non-painful symptom. It was concluded that TMD incidence was higher in females (3.6%) than in males (2.8%), and most prevalent at the age of 50 years (Slade *et al.*, 2013a).

An adult Brazilian community population was studied in 2011–2012 to assess TMD symptoms and signs. The prevalence of TMD was found to be 36.2%, but the need for treatment was much lower, being 5.1% (Progiante *et al.*, 2015). In Southern Sweden, the prevalence of TMD symptoms investigated by a questionnaire (63% response rate) was found to be 11% (Gillborg, Åkerman, Lundegren, & Ekberg, 2017).

Large variation in the prevalence of TMD (26.5–71.9%) has been shown in younger age groups (Augusto, Perina, Penha, Dos Santos, & Oliveira, 2016; Loster, Osiewicz, Groch, Ryniewicz, & Wieczorek, 2017; Tecco *et al.*, 2017; Bertoli *et al.*, 2018). The prevalence of TMD in young adults in Poland was studied and 26.5% of the participants received at least one TMD diagnosis (Loster *et al.*, 2017). Muscular disorders were the most often diagnosed condition and 14.6% of the same group was reported to have pain, somatization or depression (Loster *et al.*, 2017). In a systematic review and meta-analysis concerning clinical signs of TMD in adolescents and children, the average prevalence was found to be 16% (da Silva *et al.*, 2016). In Finland, 35% of children 6 to 8 years of age have been shown to have at least one clinical sign of TMD (Vierola *et al.*, 2012).

The prevalence of TMD in the Finnish population was earlier found to be most common in adult females, and the active treatment need was 4.5% in men and 13.5% in women (Kuttila *et al.*, 1998). The prevalence of TMD was studied also as a part of the Health 2000 survey, where a nationally representative sample including over 8 000 adult subjects was studied. The signs of TMD were more common in women than in men, and 38% of the subjects had at least one sign of TMD (Rutkiewicz *et al.*, 2006).

2.3 Etiology of TMD

The etiology of TMD is complex and multifactorial. Overloading and several other factors affecting the masticatory system at the same time may have a role in the development of TMD (Ohrbach & List, 2013; Okeson, 2013). A biopsychosocial

model explaining TMD includes interaction between biological and biomechanical factors, neuromuscular, psychological, hormonal, genetic, and social factors (Smith *et al.*, 2011; Chen, Nackley, Miller, Diatchenko, & Maixner, 2013; Fillingim *et al.*, 2013; Ohrbach & List, 2013; Okeson, 2013; Kotiranta, Suvinen, & Forssell, 2014).

Female gender and 20–50 years of age have been shown to increase the risk for TMD (Kuttila *et al.*, 1998; Al-Jundi *et al.*, 2008; Anastassaki Köhler *et al.*, 2012; Okeson, 2013). Generalized pain and pain disorders related to neurological or somatic aspects have also been shown to correlate with TMD (Okeson, 1996; Sipilä *et al.*, 2011). Impaired general health has been found to have a part in the etiology of TMD (Okeson, 2013; Crincoli, Di Comite, Di Bisceglie, Fatone, & Favia, 2015), and so has socioeconomic status (SES), which affects an individual's lifestyle and well-being (Glymour, Avendano, & Kawachi, 2014).

Traumas in the face or neck have been shown to be etiological factors associated with TMD (Seligman & Pullinger, 1996; Rauhala *et al.*, 2000; Okeson, 2013; Häggman-Henrikson *et al.*, 2014, Häggman-Henrikson *et al.*, 2016). Parafunctions and bruxism (Jiménez-Silva, Peña-Durán, Tobar-Reyes, & Frugone-Zambra, 2017), as well as TMJ hyperlaxity or hypermobility, are also related to TMD (Wang, Hayami, & Kapila, 2007; Okeson, 2013). Regardless of the controversial evidence, occlusal factors have been suspected of having a role in the etiology of TMD, and they have been mentioned as one of the major etiological factors, especially in the intra-articular disorders of the TMJ (Kirveskari, Alanen, & Jämsä, 1992; Kirveskari & Alanen, 1993; Raustia *et al.*, 1995a, 1995b; Kirveskari, Jämsä, & Alanen, 1998; Pullinger & Seligman, 2000; Carlsson, Magnusson, & Egermark, 2004; Wang *et al.*, 2009; Okeson, 2013).

2.3.1 Gender

Female dominance in TMD symptoms and signs has been found in several studies (De Kanter *et al.*, 1993; LeResche, Saunders, Von Korff, Barlow, & Dworkin, 1997; Kuttila *et al.*, 1998; Rauhala *et al*., 2000; Rutkiewicz *et al.*, 2006). Women have also been shown to have more severe TMD than men, especially pain on palpation in the masticatory muscles, regardless of the age of the subject (Kuttila *et al.*, 1998; Nilsson *et al.*, 2005; Rutkiewicz *et al.*, 2006; Slade *et al.*, 2013a). TMD-related pain in women has been noted to be most prevalent during reproductive age, becoming less prevalent after menopause. Estrogen hormone level has been shown to have a dual role in TMD by affecting pain processing and also the TMJ structures (LeResche *et al*., 1997; Wang, Chao, Wan, & Zhu, 2008; Yu, Eto, Akishita, Okabe,

& Ouchi, 2009; Berger *et al*., 2015). Estrogen has been found to increase pain sensation, and psychological status in females has been suspected of having some impact on estrogen level (Suvinen & Reade, 1995; Wang *et al.*, 2007). The testosterone hormone level has been suggested to have a protective role in the development of TMJ pain in males (Fischer, Clemente, & Tambeli, 2007).

The majority of TMD patients seeking treatment for TMD symptoms have been reported to be adult women (Scrivani, Keith, & Kaban, 2008). Women have been found to be more pain-sensitive and have more widespread and chronic pain than men (Carlsson, 1999; Fillingim, King, Ribeiro-Dasilva, Rahim-Williams, & Riley, 2009; Chen *et al*., 2012; Chen *et al*., 2013).

2.3.2 Psychological factors

Psychological problems such as anxiety, depression or somatization have been found to predict more TMD or chronic pain compared with somatic factors (Fillingim *et al.*, 2013; Slade *et al.*, 2013a; De La Torre Canales *et al.*, 2018). Among chronic pain patients with myofascial pain syndrome, a major depressive disorder has been found to be common (Altindag, Gur, & Altindag, 2008). Pain perception generally has presented as being dependent upon psychological state or condition, and TMD patients seem to differ from non-TMD subjects in terms of their psychological features (Fillingim *et al.*, 2013). Catastrophizing (i.e. irrational thoughts and poor outcomes), increased awareness of somatic symptoms, coping, and self-efficacy have been shown to affect chronic TMD pain (Turner, Dworkin, Mancl, Huggins, & Truelove, 2001; Suvinen, Reade, Hanes, Könönen, & Kemppainen, 2005).

The interaction between psychological, somatic, and social factors has been shown to be associated with pain and dysfunction conditions (Sipilä *et al.*, 2001; Kindler *et al.*, 2012; Chen *et al.*, 2013; Fillingim *et al.*, 2013; Ohrbach & List, 2013). Sleep disorders, depressiveness, and stress have been found to correlate with bruxism and they have also been shown to increase the risk for TMD symptoms in both genders (Huhtela *et al.*, 2016). Ahlberg *et al.*, (2005) concluded that sleep disorders and bruxism may be concomitantly associated with the development of orofacial pain. Bruxism has been suggested to have psychosocial etiology (Olkinuora, 1972; Manfredini, Landi, Fantoni, Segu, & Bosco, 2005; Ahlberg *et al*., 2013) and it has been described as centrally mediated neurologic activity related to sleep disorders (Manfredini, De Laat, Winocur, & Ahlberg, 2016). Autonomic

regulation of circulation and muscle activation have also been presented as being related to bruxism (Sjöholm, Lehtinen, & Helenius, 1995).

Sleep disorders or poor sleep quality have been shown to correlate with pain sensation and perception of stress, which may be associated with first-onset TMD pain (Kotiranta *et al.*, 2015; Sanders *et al.*, 2017). A significant association between obstructive sleep apnea symptoms and TMD has been shown (Cunali *et al.*, 2009; Sanders *et al.*, 2013).

2.3.3 Pain and related general health factors

Pain has been shown to be the major reason for seeking treatment for TMD (Schiffman *et al.*, 2014; Yekkalam & Wänman, 2014). The fluctuation of TMD symptoms affects the quality of life intermittently or chronically, and a correlation between TMD treatment need and use of general health care services has been shown (Kirveskari & Alanen, 1993; Kuttila, Kuttila, Le Bell, & Alanen, 1997). Impaired health has been related to occurrence of multiple pain conditions (Korszun, Papadopoulos, Demitrack, Engleberg, & Crofford, 1998; Bassols, Bosch, Campillo, Cañellas, & Baños, 1999; Sipilä *et al.*, 2011). TMD patients have been noted to have a high prevalence of pain in the multiple joints of the body compared with individuals without TMD. Lower back, neck, and shoulder pain have been shown to be associated with TMD (Ohrbach *et al.*, 2011; Sipilä *et al.*, 2011; Bonato *et al.*, 2016; Contreras, Fernandes, Ongaro, Campi, & Gonçalves, 2018). In addition, chronic muscle pain (for example fibromyalgia (FM)), gastrointestinal diseases, and depression symptoms interact with poor self-rated physical ability (Means-Christensen, Roy-Byrne, Sherbourne, Craske, & Stein, 2008; Hung, Liu, Yang, & Wang, 2016). Comorbid pains with increased pain intensity and numerous previous health care visits have been found to decrease prognosis of treatment of TMD pain (Forssell, Kauko, Kotiranta, & Suvinen, 2017). TMJ pain has been found to be more common and more severe in headache patients (Di Paolo *et al.*, 2017). Gillborg *et al.,* (2017) found headaches and self-reported poor general health to be related to painful TMD. Headache intensity has been shown to be an important factor related to muscle pain and treating TMD has been found to significantly decrease headache frequency and intensity of muscle contraction headache or combination headache (Forssell, Kirveskari, & Kangasniemi, 1985; Ekberg, & Nilner, 2006; Doepel, Nilner, Ekberg, & Le Bell, 2012).

Intra-articular joint disorders

Intra-articular disorders of the TMJ are structural disorders that include TMJ disc displacements and degenerative joint diseases. Disc displacement may occur with or without reduction. In some cases, disc displacement with reduction develops into disc displacement without reduction, and further to degenerative joint disease (Okeson, 2013). Arthralgia is described as a pain-related condition in the TMJs (Okeson, 2013; Schiffman *et al.*, 2014).

Degenerative joint disease (i.e. osteoarthritis, OA) is the most common form of arthritis of the TMJ, being in many cases a painful and destructive unilateral process affecting the articular surfaces of the condylar head, the mandibular fossa and the articular tubercle (Okeson, 2013). Genetic and anatomical factors as well facial traumas may predispose to the development of degenerative joint disease (Boering, Stegenga, & de Bont, 1990; Raustia *et al.*, 1994). Breakdown of the articular cartilage and pathological changes in the underlying bone and articular disc associate with increased production of matrix-degrading enzymes in joint cavity have been shown to cause pain and/or dysfunctional movements of the mandible (Tiilikainen, Pirttiniemi, Kainulainen, Pernu, & Raustia, 2005). Tissue degeneration has been considered the TMJ's response to an increased or constant load (de Souza, Lovato da Silva, Nasser, Fedorowicz, & Al-Muharraqi, 2012; Okeson, 2013). During aging the joints become more susceptible to biomechanical overloading or traumas (Loeser, 2012).

Rheumatoid diseases

Major rheumatic diseases are rheumatoid arthritis (RA), juvenile rheumatoid arthritis, psoriatic arthritis, polymyalgia rheumatica, gout, and ankylosing spondylitis (Gabriel & Michaud, 2009). The prevalence of RA has been found to be under 1% of the adult populations (Englund *et al.*, 2010). RA is more common in women than in men, becoming more common in older age groups (Puolakka, Kautiainen, Pohjolainen, & Virta, 2010). RA is a chronic, systemic autoimmune disease characterized by chronic inflammation and synovial hyperplasia, which usually affects multiple joints. The presence of degenerative bony changes in the TMJ are common, and the most prevalent changes of TMJ are flattening of the condylar head, erosions, and osteophytes. TMJs have commonly been found to be affected in patients with RA (Helenius *et al.*, 2006). Often the TMJ may be the first

joint affected asymptomatically in RA and hidden structural damage can be found in imaging (Cordeiro *et al*., 2016).

Psoriasis is a chronic, seronegative, often remitting and relapsing inflammatory condition involving several tissues and membranes (Crincoli *et al.*, 2015). Patients with psoriatic arthritis (PA) have been found to have symptoms of TMD (i.e. facial pain and changes in chewing function) and disease that affects the TMJs (Könönen, 1987; Badel, Savić Pavičin, Krapac, Zadravec, & Rosić, 2012; Crincoli *et al.*, 2015).

Fibromyalgia (FM) has been defined as a connective tissue disease involving generalized and widespread deep chronic pain conditions or disorders with sleep problems, cognitive impairment, fatigue, and other symptoms (Arnold *et al*., 2018). The etiology of FM is not known (Plesh, Wolfe, & Lane, 1996; Arnold *et al.*, 2018). Interactions of physiological, emotional, and cognitive challenges are often related to chronic pain in FM and TMDs, and TMD symptoms are common in FM patients (Plesh *et al.*, 1996; Okeson, 2013; Moreno-Fernández *et al.*, 2017). Patients with FM have been shown to have a lower pain threshold (Plesh *et al.*, 1996; Farella *et al.*, 2000) and more severe manifestations of all disease measures compared with those without FM (Wolfe, Michaud, Li, & Katz, 2010). Patients with FM have been found to score lower in work ability, health assessments, and functional disability, and FM may lead to general dissatisfaction with one's health (Plesh *et al.*, 1996).

2.3.4 Occlusal factors

The role of occlusion in the etiology of TMD has remained controversial (Okeson, 2013), and the association between occlusal factors and TMD symptoms and signs is not obvious (Seligman & Pullinger, 1991). Several earlier studies have not strongly supported occlusal etiology in TMD and no single or dominant factor has been found to differentiate TMD patients from subjects without TMD (Egermark-Eriksson, Carlsson, Magnusson, & Thilander, 1990; Pullinger *et al*., 1993; McNamara, Seligman, & Okeson, 1995; Kitai, Takada, Yasuda, Verdonck, & Carels, 1997; Pullinger & Seligman, 2000). However, occlusion and occlusal interferences have been found to be associated with TMD (Kirveskari *et al.*, 1992: Kirveskari & Alanen, 1993; Kirveskari *et al.*, 1998; Le Bell, Jämsä, Korri, Niemi, & Alanen, 2002; Okeson, 2013). Asymmetric positions of condyles have been found in lateral malocclusions (Pirttiniemi, Raustia, Kantomaa, & Pyhtinen, 1991) and condyle position asymmetry has been found in TMD subjects, correlating significantly with symptoms and signs of TMD (Raustia *et al.*, 1995a, 1995b).

Some studies have indicated that the role of occlusion in TMD may be more important than it has been generally accepted, especially in cases of intra-articular disorders of the TMJ (Raustia *et al.*, 1995a, 1995b; Tallents *et al.*, 2002; Rusanen *et al.*, 2008). Occlusal disturbances existing more frequently in TMD patients than in healthy subjects include significant overjet (> 5 mm), skeletal anterior open bite, increased slide (> 2 mm) between the retruded contact position and the intercuspal contact position (RCP-ICP), deviations in RCP-ICP slide, and loss of molar support (Pullinger *et al.*, 1993; Raustia *et al.*, 1995a, 1995b; Pullinger & Seligman, 2000; Luder, 2002; Wang *et al.*, 2009). Morphological characteristics as well as good functional and esthetic aspects are included in good occlusion (Svedström-Oristo, Pietilä, Pietilä, Alanen, & Varrela, 2001). Acute changes in occlusal relationships may affect the function of the masticatory muscles, and by affecting the orthopedic stability of the mandible, may lead to TMD symptoms and increased risk for developing TMD (Wang *et al.*, 2009; Okeson, 2013).

A correlation between TMD, severity of TMD, and orthodontic treatment has not been conclusively found. Severe malocclusions before orthodontic or orthognathic treatment may predispose to degenerative TMJ changes (Taşkaya-Yilmaz, Oğütcen-Toller, & Saraç, 2004; Rusanen *et al.*, 2008). Subjects who had undergone orthodontic treatment have not been shown to have an increased risk of developing TMD (McNamara *et al.*, 1995; Egermark, Magnusson, & Carlsson, 2003; Mohlin *et al.*, 2004). Headache and signs of TMD have been reported to be reduced significantly after orthognathic treatment (Panula, Somppi, Finne, & Oikarinen, 2000). An association between self-reported TMD symptoms and severity of malocclusion has not been confirmed (Svedström-Oristo, Ekholm, Tolvanen, & Peltomäki, 2016), but on the other hand, treatment of severe malocclusion has been found to decrease facial pain (Pahkala & Heino, 2004; Abrahamsson, Henrikson, Bondemark, & Ekberg, 2015; Silvola *et al.*, 2016).

2.4 Diagnostic classifications

Various classifications of TMD have been presented over the decades. Studies of functional disturbances in the masticatory system have been carried out using questionnaires and clinical examinations to clarify the etiology of TMD and to improve treatment of TMD subjects (Okeson, 2013).

Helkimo (1974) developed a clinical dysfunction index (D_i) to characterize the severity of dysfunction numerically to facilitate evaluation of the need for treatment. The index is based on both information about subjective symptoms (A_i anamnestic

dysfunction index, based on the patient's symptoms) and on signs found in a clinical stomatognathic examination, D_i (i.e. clinical dysfunction index based on signs of TMD).

The classification given by the American Academy of Orofacial Pain (AAOP) (Okeson, 1996) is based on the criteria defined by de Leeuw *et al.*, (1994) and the corresponding guidelines of the American Academy of Orofacial Pain (McNeill, 1993). The protocol consists of stress, parafunctions, jaw movements, tenderness or sounds in the TMJ, palpation of both the neck and masticatory muscles, headaches, and the maxillomandibular relationship. Four subgroups according to TMD symptoms and signs are: mainly myogenous, mainly arthrogenous, combined myogenous and arthrogenous, and non-classified subjects, i.e. those with physical and psychological problems such as anxiety, depression, anger or stress and not fitting into any of the diagnostic subgroups.

Diagnostic criteria for TMD (RDC/TMD) were developed by Dworkin and LeResche (1992) for research purposes. This dual diagnosis consists of both physical conditions (Axis I) and psychosocial aspects (Axis II) and has been shown to be reliable and valid for diagnosing the most common pain-related TMD and for one TMJ intra-articular disorder (Dworkin & LeResche, 1992).

Currently recommended international, evidence-based criteria for diagnosis, Diagnostic Criteria for TMD (DC/TMD), were presented at a symposium held in the general session at International Association for Dental Research (IADR) Conference in 2010 (Schiffman, 2010). Axis I protocol includes a screener for detecting both pain-related TMD and intra-articular disorder (Schiffman *et al.*, 2014). The Axis II protocol consists of questionnaires for screening pain intensity, pain-related disability, psychological factors, jaw functional limitations, and parafunctional behaviors. Locations of pain are recorded by the patients in a pain drawing (Schiffman *et al.*, 2014).

2.5 Treatment of TMD

Seeking treatment for TMD has been shown to be at the level of 3–7% in adult TMD patients (De Kanter *et al.*, 1992; Magnusson *et al.*, 2002), although the need for TMD treatment has been found to be higher (3–16%) (De Kanter *et al.*, 1992; Kuttila, 1998; Magnusson *et al.*, 2002; Al-Jundi *et al.*, 2008). A correlation between increased use of health care services and sick leaves and a need for TMD treatment has been shown (Kirveskari & Alanen, 1993; Kuttila *et al.*, 1997; Rantala *et al.*, 2003). Treatment of acute or chronic TMD is individual and focused on

reducing pain and functional overload on the muscles and TMJs to attain physiological functioning of the masticatory system. Conservative treatment methods include counseling and self-care, pain relieving medication, occlusal splints and other occlusal therapy, physiotherapy, and cognitive therapy (Okeson, 2013).

3 Aims of the study

The aims of this study were to investigate the prevalence and associated risk factors of temporomandibular disorders (TMD) in the Finnish adult population based on the Northern Finland Birth Cohort (NFBC) 1 966 subjects at the age of 46 years.

The specific aims were:

1. To investigate the prevalence of pain-related symptoms and clinical signs of TMD
2. To investigate the association of occlusal factors with TMD
3. To investigate the association between risk factors and pain-related TMD symptoms and clinical signs.

4 Material and methods

4.1 Subjects

The NFBC 1966 is an epidemiological research program concerning subjects in an unselected population born in 1966 in Oulu and Lapland, two Northern provinces in Finland (http://www.oulu.fi/nfbc/) (Rantakallio, 1988). The present follow-up of the cohort subjects was organized in 2012–2013. The target population for the study comprised 11 366 subjects. The invitation to attend the clinical medical and dental examination was sent to 3 150 subjects currently living in the Oulu region (range 100 km). Altogether 1 964 subjects (61.7%) attended the clinical examination. Participation in the study was voluntary and the subjects provided written consent. Two subjects forbade the use of their information and the total number of subjects for the analyses was 1 962 (1 050 women, 912 men).

The Ethical Committee of the Northern Ostrobothnia Hospital District has approved the study (74/2011). The research program was coordinated by the Department of Health Sciences, Faculty of Medicine, University of Oulu.

4.1.1 Questionnaires

Cohort subjects who were living with a known postal address (n = 10 321) received two questionnaires to be filled in at home: Questionnaire 1: the subject's background information, lifestyle, and health; and Questionnaire 2: the subject's economy, work, and mental resources.

The questions in Questionnaire 1 (response rate 66.5%, n = 6 868) concerning TMD symptoms according to Nilsson, List, & Drangsholt (2006) were:

1. Do you have pain in your temples, temporomandibular joints, face, or jaw? (with answer options: no / once a week / more often, dichotomised as no pain / pain)
2. Do you have pain when you open your mouth wide or chew? (with answer options: no / once a week / more often, dichotomised as no pain / pain)

The subjects who attended the clinical medical and dental examination (n = 1 962) also filled in Questionnaire 3: additional questions concerning dental health on the day of the examination before the clinical stomatognathic examination. Related to TMD, according to the modified diagnostic criteria of the DC/TMD question 1

categorized the subjects by TMD symptoms / no symptoms (symptom-free) (Paper I) and questions 2–6 were used in the diagnostic protocol of the DC/TMD.

1. During the prior 30 days, have you had pain in areas of your face, jaws, temples, ears or behind your ears? (with options yes/no)
2. During the prior 30 days, have you felt pain that was modified by jaw movement, function, parafunction or being at rest? (with options yes/no)
3. Have you had jaw locking in the closed position that restricted maximum mouth opening (with options yes/no)?
4. Did this restricted mouth opening cause difficulty in mastication (with options yes/no)?
5. Have you had clicking noises in the TMJ during opening or closing jaw movements or during mastication (with options yes/no)?
6. Have you had crepitation in the TMJ during opening or closing jaw movements or during mastication (with options yes/no)?

The information concerning subjective experience of previous orthodontic treatment (Paper II) was collected with Questionnaire 3. The questions were: "Have you undergone orthodontic treatment before the age of 20?" and "Have you undergone orthodontic treatment after the age of 20?" The experience of orthodontic treatment was dichotomized as "yes" or "no" and the experience was compared with TMD signs and diagnoses.

Background factors (Paper III) were based on Questionnaires 1 and 2. The question concerning marital status was determined: "Married / co-habiting" or "Single" and the question concerning living condition as "Living alone" or "Living with another". Education level was categorized as "Elementary school", "High school", or "University". Employment status was determined by "Working (full-time or part-time)", "Not working", "Retired", or "Other". Socioeconomic group was determined as "Entrepreneur", "White-collar worker", "Blue-collar worker", "Student", or "Retired". Self-rated health condition was assessed with the question: "How do you assess your general health at this moment?" and there were five options for answers on a Likert scale (very good, good, fair, poor, very poor), and for the analyses, the answers were categorized into three groups: "Good", "Fair", and "Poor".

Diseases were inquired with the question: "Do you have, or have you had symptoms, diseases, or traumas diagnosed by a physician?" and the answer options used for analyses were "Yes" or "No". The diseases chosen for analyses in the questionnaires were: depression, diabetes, fibromyalgia (FM), gastrointestinal

diseases (including celiac disease, colitis, Crohn's disease, and ulcer), migraine headache, osteoarthritis (including osteoarthritis in the ankles, feet, hips, knees, spine, shoulders, and TMJs), rheumatic diseases, sleep apnea, and thyroid diseases (both hypothyroidism and hyperthyroidism).

4.1.2 Clinical stomatognathic examination

A clinical dental examination was standardized and performed by six calibrated dentists (PJ was one of the examiners) at the Institute of Dentistry, University of Oulu. The examiners trained under experienced specialized dentists before the beginning of the study. During the study, intra-examiner agreement was regularly determined, and inter-examiner agreement was determined by a senior dentist serving as a gold standard. Concerning the stomatognathic examination variables, the intra-examiner agreement was on the range of 0.908–0.989 for overjet and 0.762–0.929 for overbite. The range of inter-examiner agreement varied for overjet and overbite from 0.763 to 0.938 and from 0.767 to 0.957, respectively (Krooks, Pirttiniemi, Kanavakis, & Lähdesmäki, 2016).

The clinical stomatognathic examination was performed using the modified protocol of the DC/TMD diagnostic protocol presented by Schiffman (2010) at the symposium at International Association for Dental Research (IADR) Conference in 2010.

The prevalence of TMD signs was recorded based on subjects having at least one sign of TMD in the clinical examination. The range of maximal opening movement without any assistance was measured by the examiner in millimeters, with vertical overbite added. Movement < 40 mm was considered restricted. Protrusive and lateral excursive movements were measured in millimeters, and movements < 7 mm were considered restricted. In measuring maximum assisted opening (MAO), the jaw was actively pushed by the examiner. In all movements the patients were asked if they felt "familiar" pain, which is defined as pain "similar to" or "like" pain he/she has had previously in that same location during the preceding 30 days.

The examiner recorded TMJ clicking on palpation during opening and closing movements, as well as in protrusive and lateral excursive movements, without any assistance by the examiner. The crepitus was registered at a 15-centimeter distance.

Familiar pain was registered in the masticatory muscles and TMJ on palpation. The temporal muscles were palpated bilaterally at one point in the anterior, middle, and posterior regions of the temporal muscle. The masseter muscles were

bilaterally palpated at one point in the origo, profunda, and insertion regions. Muscle palpation was done by applying a pressure of 1.0 kg (2–3 pounds). Palpation for experiencing the familiar pain in the TMJ was done by applying a pressure of 1.0 kg (2–3 pounds) around the TMJ pole, and 0.5 kg (1 pound) for the lateral pole of the TMJ. Palpation force calibration was calibrated with a digital postage scale.

4.1.3 TMD diagnoses

The TMD diagnoses were based on the DC/TMD protocol (Schiffman, 2014). The prevalence of TMD was recorded based on at least one clinical sign of TMD. Myalgia, arthralgia, disc displacement with reduction, disc displacement without reduction, and degenerative joint disease were recorded as:

- Myalgia: Subjects reported pain in areas of the face, jaws, temples, ears or behind the ears and the pain was modified by movement during the prior 30 days. In the clinical examination the subjects reported familiar pain in the masticatory muscles during jaw movements and/or (familiar) pain on palpation in the muscles.
- Arthralgia: Subjects reported pain in areas of the face, jaws, temples, ears or behind the ears and the pain was modified by movement during the prior 30 days. In the clinical examination the subjects reported familiar pain in the TMJs during jaw movement and/or (familiar) pain on palpation in the left or right TMJ (around the lateral pole or laterally).
- Disc displacement with reduction: Subjects reported a history of clicking noises in the TMJ, and TMJ clicking was recorded by the examiner during opening and closing movements, or during opening or closing movements and in either right/left lateral or protrusive movement.
- Disc displacement without reduction: Subjects reported jaw locking in the closed position, and in the clinical examination the MAO was restricted.
- Degenerative joint disease: Subjects reported a history of noises in the TMJ, and the TMJ crepitus was recorded by the examiner in the clinical examination.

4.1.4 Occlusal registration (Paper II)

Occlusal registration followed the criteria presented by Björk, Krebs, & Solow (1964) and Harris & Corrucini (2008). The occlusal variables used were overjet

(< 0 mm and > 5 mm), overbite (< 0 mm and > 5 mm), anterior crossbite, lateral crossbite, lateral scissor bite, amount of RCP-ICP slide (3–5 mm), lateral deviation of RCP-ICP slide (over 0 mm), and interferences in laterotrusive and protrusive mandibular movements.

Overjet was measured with a manual scaler in millimeters (with 1-mm intervals) horizontally in the intercuspal position from the right central maxillary incisor to the labial surface of the mandibular incisor (scale < 0 mm, 0–5 mm, 6–7 mm, > 7 mm). A negative value was recorded (negative overjet) in cases where the mandibular incisor was more labial than the maxillary incisor. Overbite was measured with a manual scaler in millimeters vertically in the maximum intercuspal position from the incisal edge of the maxillary right central incisor to the incisal edge of the mandibular central incisor (scale < 0 mm, 0–5 mm, 6–9 mm, > 9 mm). A negative value was recorded in anterior open bite cases. Lateral crossbites were recorded if one or more maxillary buccal cusps occluded lingually to the corresponding mandibular teeth. Scissor bite was recorded if the maxillary posterior teeth occluded entirely buccally compared with the opposing mandibular teeth.

Slide length between the retruded contact position and maximum intercuspal position (RCP-ICP) was registered in the values 0–2 mm and 3–5 mm. Deviation in the RCP-ICP to the left / right direction was registered in the values 0 mm and 1–3 mm (Okeson, 2013).

Tooth contacts in laterotrusive mandibular movements were recorded at the position of lateral gliding up to 3 mm from the ICP as canine guidance (maxillary and mandibular canines come into contact during lateral movements) and interferences (guidance in the premolar and/or molar area, or guidance in the incisor area or mediotrusive contacts). Tooth contacts in protrusive mandibular movement were recorded as tooth contacts occurring on the anterior teeth and interferences (on the posterior teeth or with interfering tooth contact in the protrusive movement).

4.1.5 Statistical analyses

Pearson's chi-square test and Fisher's exact test were used to evaluate the association between gender and signs of TMD and TMD diagnoses based on the modified DC/TMD protocol. Odds ratio and 95% confidence interval values were calculated with binary logistic regression to analyze the relationship between self-reported pain associated with TMD and TMD diagnoses based on the modified DC/TMD protocol (Paper I). In Paper II binary logistic regression models were also

used to analyze the correlation between TMD signs and occlusal factors. The prevalence of occlusal disturbances was calculated, and differences in prevalence between genders was illustrated graphically. The association between risk factors and TMD symptoms and signs was analyzed by cross tabulation, and a chi-square test and Fisher's exact test were used to disclose differences between groups (Paper III).

The difference between the groups was determined statistically significant at $p < 0.05$. All analyses were executed using IBM SPSS Statistics version 22.0 and R software (versions 3.1.2 and 3.3.2).

5 Results

5.1 Prevalence of TMD

The prevalence of TMD signs was 34.2% (women 40.8%, men 26.7%). The most common clinical TMD signs were clicking in the TMJs (26.2%) and pain on palpation in the masticatory muscles (11.2%) (Table 1). Women had highly significantly more TMD signs than men (Table 1), especially pain in masticatory muscles and in TMJs.

Table 1. Frequencies of clinical signs of TMD in the Northern Finland Birth Cohort 1966 (NFBC 1966) study group.

Clinical sign	n	%	χ^2-value	P-value
Limited mouth opening < 40 mm				
Women	53	5.1		
Men	19	2.1		
Total	72	3.7	12.138	< .001
Clicking in the temporomandibular joints				
Women	304	29.2		
Men	205	22.7		
Total	509	26.2	10.756	.001
Crepitus in the temporomandibular joints				
Women	118	11.3		
Men	69	7.6		
Total	187	9.6	7.633	.006
Pain in the masticatory muscles				
Women	159	15.3		
Men	59	6.5		
Total	218	11.2	37.410	< .001
Pain in the temporomandibular joints				
Women	144	13.8		
Men	58	6.4		
Total	202	10.4	28.699	< .001

According to Questionnaire 1 (questions by Nilsson *et al.*, 2006), a total of 16.3% (n = 305, women 21.0%, men 10.8%) of the cohort subjects had pain-related TMD symptoms (Figure 1). Based on Questionnaire 3 related to the DC/TMD diagnostic protocol, the prevalence of TMD symptoms was 18.5% (n = 353, women 26.1%, men 10.3%). Total of 61.1% (n = 215) of the subjects with TMD symptoms had

clinical signs of TMD, and on the other hand, 27.8% (n = 429) of the subjectively symptom-free subjects had signs of TMD in the clinical examination (women 32.2%, men 23.6%).

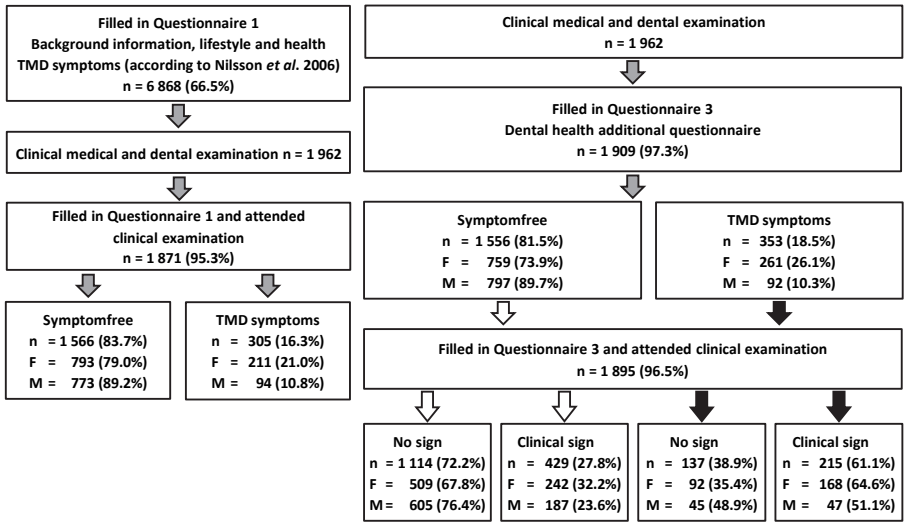

Fig. 1. Flow chart of subjective TMD symptoms and clinical signs in the NFBC 1966.

The most common TMD diagnosis based on the DC/TMD diagnostic protocol was disc displacement with reduction (7.0%) (Table 2). Arthralgia, degenerative joint disease, and myalgia were diagnosed in 5.3%, 5.1%, and 5.0% of the subjects, respectively. The frequency of these diagnoses was higher in women than in men. The most common diagnoses in women were disc displacement with reduction (8.4%) and arthralgia (8.2%) (Table 2). In men, the most common diagnoses were disc displacement with reduction (5.4%) and degenerative joint disease (3.7%). Arthralgia and myalgia were significantly more common in women than in men.

Table 2. Distribution of TMD diagnoses in the Northern Finland Birth Cohort 1966 (NFBC 1966) study group.

Diagnosis	women		men		total		χ^2-value	P-value
	n	%	n	%	n	%		
Myalgia	77	7.4	20	2.2	97	5.0	27.640	< .001
Arthralgia	85	8.2	18	2.0	103	5.3	36.453	< .001
Disc displacement with reduction	88	8.4	49	5.4	137	7.0	6.776	.009
Disc displacement without reduction	3	0.3	1	0.1	4	0.2		.628[1]
Degenerative joint disease	66	6.3	34	3.7	100	5.1	6.637	.010

[1] Fisher's exact test

When the self-reported pain-related symptoms were correlated with the diagnoses based on the DC/TMD diagnostic protocol, the TMD symptoms correlated strongly with myalgia and arthralgia (Table 3).

Table 3. Self-reported pain-related symptoms associated with TMD in relation to modified DC/TMD diagnostics protocol (Schiffman, 2010) in the Northern Finland Birth Cohort 1966 (NFBC 1966) study group.

Question	Myalgia (%)	Arthralgia (%)	Disk displacement with reduction (%)	Disk displacement without reduction (%)	Degenerative joint disease (%)
Do you have pain in your temples, face, TMJ, or jaws once a week or more?					
Yes (13.5%)	20.9	22.2	14.7	0.4	11.5
No (86.5%)	2.2	2.5	6.1	0.2	4.2
Total (100.0%)	4.7	5.1	7.2	0.2	5.2
OR[1,2]	11.69	11.05	2.65	2.15	2.97
95% CI[2]	(7.47, 18.30)	(7.17, 17.04)	(1.77, 3.97)	(0.22, 20.74)	(1.88, 4.69)
Do you have pain when you open your mouth wide or chew once a week or more?					
Yes (6.5%)	32.2	30.1	21.5	0.8	15.7
No (93.5%)	2.8	3.4	6.2	0.2	4.4
Total (100.0%)	4.7	5.0	7.2	0.2	5.1
OR[1,2]	16.65	12.17	4.14	4.85	4.07
95% CI[2]	(10.35, 26.78)	(7.55, 19.61)	(2.57, 6.65)	(0.50, 47.01)	(2.37, 6.98)

[1] odds ratio, [2] values were calculated with binary logistic regression

5.2 Occlusal factors

The most common occlusal disturbances were interferences in laterotrusive mandibular movements (29.5% in women, 27.7% in men), lateral crossbite (16.3% in women, 19.7% in men), and interferences in protrusive mandibular movement (15.2% in women, 15.9% in men) (Figure 2). Male dominance was found in most of the occlusal variables recorded except overjet > 5 mm and laterotrusive interferences (LTR). Men had significantly more anterior crossbite, overjet > 5 mm, overbite > 5 mm, and increased amount of RCP-ICP slide (3–5 mm) than women (Figure 2).

When malocclusions and occlusal interferences were compared with TMD diagnoses, a statistically significant association was found between lateral deviation in RCP-ICP slide and arthralgia ($p = 0.005$), as well as between lateral scissor bite and myalgia ($p = 0.034$).

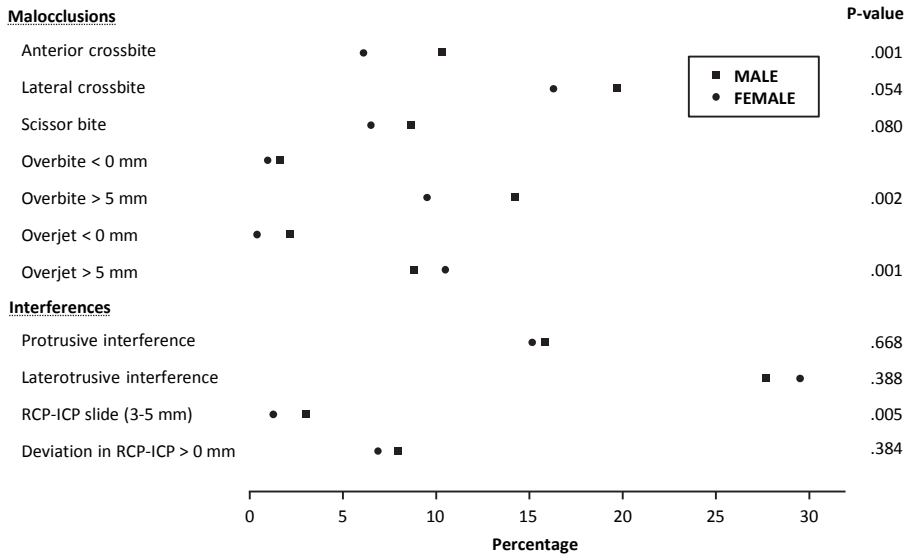

Fig. 2. Prevalence of occlusal variables in male and female subjects in the NFBC 1966.

Overjet < 0 mm and RCP-ICP slide (3–5 mm) were associated statistically significantly with pain in the masticatory muscles (Table 4). Lateral crossbite, scissor bite, and lateral deviation in RCP-ICP slide were significantly associated with limited mouth opening (< 40 mm). Laterality analyses showed that pain on palpation in the right masticatory muscles was associated with lateral deviation in

RCP-ICP slide to the left (OR = 1.88, 95% CI 1.08, 3.28). Crepitus in TMJs was associated with scissor bite on the left side (left TMJ OR = 2.52, 95% CI 1.27, 4.99; right TMJ OR = 2.05, 95% CI 1.01, 4.19).

Table 4. Logistic regression analysis of the association between occlusal variables and TMD signs in the NFBC 1966 subjects (n = 1 962).

Occlusal variable	Limited mouth opening		Clicking in TMJs[3]		Crepitus in TMJs		Pain in masticatory muscles		Pain in TMJs	
	OR[1]	95% CI[2]	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Overbite < 0 mm	0.95	(0.11, 8.31)	1.10	(0.42, 2.92)	1.80	(0.56, 5.85)	1.73	(0.54, 5.57)	1.06	(0.29, 3.86)
Overbite > 5 mm	1.93	(0.98, 3.83)	1.16	(0.84, 1.60)	1.17	(0.71, 1.91)	1.18	(0.74, 1.86)	1.10	(0.68, 1.79)
Overjet < 0 mm	0.00	(0.00, Inf)	1.48	(0.53, 4.13)	0.84	(0.17, 4.05)	4.37	(1.33, 14.41)	1.73	(0.44, 6.81)
Overjet > 5 mm	0.63	(0.26, 1.56)	1.15	(0.81, 1.63)	0.82	(0.47, 1.44)	0.93	(0.57, 1.53)	1.01	(0.61, 1.67)
Anterior crossbite	0.71	(0.23, 2.15)	0.89	(0.58, 1.39)	1.25	(0.69, 2.27)	0.82	(0.43, 1.56)	0.96	(0.51, 1.80)
Lateral crossbite	2.35	(1.33, 4.17)	0.92	(0.69, 1.23)	0.99	(0.65, 1.51)	0.85	(0.56, 1.28)	1.13	(0.76, 1.69)
Scissor bite	2.13	(1.00, 4.53)	0.81	(0.54, 1.21)	1.30	(0.75, 2.23)	0.96	(0.55, 1.68)	1.04	(0.59, 1.84)
RCP-ICP[4] slide (3–5 mm)	1.55	(0.34, 7.09)	0.76	(0.34, 1.69)	0.22	(0.03, 1.63)	2.43	(1.06, 5.60)	1.39	(0.52, 3.71)
Deviation in RCP-ICP	2.27	(1.11, 4.65)	1.05	(0.71, 1.56)	1.51	(0.90, 2.54)	1.29	(0.77, 2.15)	1.45	(0.87, 2.41)
Laterotrusive interferences	0.91	(0.51, 1.61)	1.04	(0.82, 1.33)	1.07	(0.75, 1.53)	1.15	(0.83, 1.61)	0.90	(0.63, 1.28)
Protrusive interferences	0.87	(0.40, 1.92)	0.89	(0.64, 1.22)	1.07	(0.68, 1.69)	0.80	(0.51, 1.27)	1.11	(0.71, 1.72)

[1] odds ratio , [2] confidence interval, [3] temporomandibular joints, [4] the slide between the retruded contact position (initial contact of a tooth or teeth during jaw closure) and maximal intercuspal contact position

The orthodontically treated subjects had more TMD (47.8%) than untreated subjects (41.3%). Crepitus and degenerative joint disease were significantly more common in orthodontically treated than in untreated subjects.

Table 5. Distribution of the signs and diagnoses of TMD in subjects with orthodontic experience in the NFBC 1966 (n = 1 962).

TMD	Treated		Untreated		χ^2-value	P-value
	n	%	n	%		
TMD signs						
Clicking in TMJs[2]	90	29.2	353	25.0	2.356	.125
Crepitus in TMJs	36	14.2	90	7.8	10.230	.001
Limited mouth opening (< 40 mm)	15	4.3	56	3.6	.324	.569
Pain in masticatory muscles	44	12.5	169	10.9	.732	.392
Pain in TMJs	41	11.6	154	9.9	.911	.340
TMD diagnoses						
Myalgia	23	6.5	74	4.8	1.825	.177
Arthralgia	24	6.8	79	5.1	1.648	.199
Disc displacement with reduction	23	6.5	114	7.4	.313	.576
Disc displacement without reduction	0	0	4	0.3		1.000[1]
Degenerative joint disease	28	8.0	72	4.7	6.261	.012

[1] Fisher´s exact test, [2] temporomandibular joints

5.3 Risk factors

Female gender and self-reported health condition had a strong correlation with pain-related symptoms and clinical signs of TMD (Table 6). Subjects with poor or fair health condition had more pain-related TMD symptoms and pain in the masticatory muscles and TMJs than subjects reporting good health condition. Education, living conditions, marital status, and socioeconomic group did not correlate with pain-related TMD symptoms or clinical TMD signs. On the other hand, the subjects who were not working or retired had a higher prevalence of pain-related TMD symptoms in the temples, TMJs, face or jaw than subjects who were currently working. The subjects with diagnosed depression, FM, OA, migraine, and rheumatic diseases were significantly associated with pain-related TMD symptoms. Thyroid diseases and gastrointestinal diseases were associated with pain on palpation in the masticatory muscles and TMJs. Rheumatic diseases correlated with crepitus in the TMJs, while sleep apnea was associated with clicking in the TMJs.

Table 6. The effect of risk factors on pain-related symptoms and clinical signs of TMD in the NFBC 1966 (n = 1 962).

Risk factors	Self-reported TMD symptoms				Clinical TMD signs									
	Pain in temples, TMJs, face or jaw		Pain during maximal mouth opening or chewing		Limited mouth opening (< 40 mm)		Clicking in TMJs		Crepitus in TMJs		Pain on palpation in masticatory muscles		Pain on palpation in TMJs	
	%	p	%	p	%	p	%	p	%	p	%	p	%	p
Gender		0.000		0.000		0.000		0.001		0.006		0.000		0.000
Male (n = 906)	8.30		4.10		2.10		22.7		7.60		6.50		6.40	
Female (n = 1 041)	17.9		8.50		5.10		29.2		11.3		15.3		13.8	
Employment status		n.s.[1]		0.015		n.s.		n.s.		n.s.		n.s.		n.s.
Working (n = 1 661)	12.7		5.8		3.7		26.4		9.5		10.7		10.1	
Not working (n = 98)	20.6		13.4		4.10		28.6		12.4		8.20		9.20	
Retired (n = 38)	21.6		11.1		10.5		27.0		10.8		15.8		15.8	
Other (n = 54)	16.4		7.3		0		20.8		11.3		18.5		9.3	
Self-reported health condition		0.000		0.000		n.s.		n.s.		n.s.		0.000		0.000
Good (n = 1 258)	10.0		5.20		3.30		26.2		9.80		7.90		7.90	
Fair (n = 560)	20.2		8.40		4.80		26.9		10.4		17.3		14.6	
Poor (n = 60)	23.0		13.1		3.30		22.4		1.70		20.0		21.7	
Depression		0.001		n.s.		n.s.		n.s.		n.s.		0.000		0.000
Yes (n = 195)	20.8		8.20		5.10		28.5		8.80		20.0		19.0	
No (n = 1 691)	12.6		6.20		3.60		26.0		9.90		10.1		9.30	
Fibromyalgia		0.000		0.001		n.s.		n.s.		0.021		0.001		0.001
Yes (n = 26)	37.0		22.2		7.70		11.5		23.1		30.8		30.8	
No (n = 1 863)	13.1		6.20		3.70		26.4		9.60		10.8		10.0	

Risk factors	Self-reported TMD symptoms				Clinical TMD signs									
	Pain in temples, TMJs, face or jaw		Pain during maximal mouth opening or chewing		Limited mouth opening (< 40 mm)		Clicking in TMJs		Crepitus in TMJs		Pain on palpation in masticatory muscles		Pain on palpation in TMJs	
	%	p	%	p	%	p	%	p	%	p	%	p	%	p
Gastrointestinal disease		.0041		n.s.		n.s.		n.s.		n.s.		0.001		0.004
Yes (n = 122)	19.7		8.20		4.90		29.5		8.20		20.5		18.0	
No (n = 1 737)	13.1		6.30		3.70		26.1		9.90		10.5		9.80	
Migraine headache		0.000		0.050		n.s.		n.s.		0.020		0.000		0.000
Yes (n = 352)	23.0		8.80		4.00		27.6		13.1		16.8		16.2	
No (n = 1 526)	11.4		6.00		3.70		25.8		9.00		9.80		8.90	
Osteoarthritis		0.004		0.001		n.s.		n.s.		0.040		n.s.		n.s.
Yes (n = 382)	18.0		9.90		4.70		26.4		12.6		11.8		10.5	
No (n = 1 472)	12.3		5.30		3.40		26.5		9.10		11.0		10.3	
Rheumatic disease		0.001		0.007		n.s.		n.s.		0.002		n.s.		n.s.
Yes (n = 81)	25.9		13.8		7.40		24.7		19.8		17.3		14.8	
No (n = 1 783)	13.0		6.10		3.60		26.3		9.30		10.8		10.0	
Thyroid disease		n.s.		n.s.		n.s.		n.s.		n.s.		0.033		0.013
Yes (n = 95)	20.0		8.40		7.40		26.6		10.6		17.9		17.9	
No (n = 1 765)	13.2		6.40		3.60		26.4		9.70		10.8		9.90	

[1] not significant

6 Discussion

6.1 Prevalence of TMD

The prevalence of TMD signs among the 46-year-old NFBC cohort subjects was 34.2%, which is in accordance with other population-based studies (Rutkiewicz *et al.*, 2006; Yekkalam & Wänman, 2014b; Progiante *et al.*, 2015; Yekkalam & Wänman, 2016). Contrarily, 38.9% of the subjectively symptomatic subjects had no clinical signs of TMD, while on the other hand, 27.8% of the symptom-free subjects had clinical TMD signs.

Clinical TMD signs were found to be more common than self-reported symptoms. TMD symptoms have been shown to fluctuate and the need for TMD treatment has been found to be lower than the prevalence of clinical TMD signs (Kuttila *et al.*, 1998; Progiante *et al.*, 2015). Pain has been found to be the main reason for seeking treatment for TMD (Yekkalam & Wänman, 2014; Schiffman *et al.*, 2014).

Women had both subjective symptoms and clinical signs of TMD more often than men, especially pain in the masticatory muscles and TMJs, which is in accordance with earlier studies (Slade *et al.*, 2013a). Estrogen hormone level has been suspected as one reason why TMD is more common in women than in men, especially during reproductive age (LeResche *et al.*, 1997). Estrogen receptors located in the TMJ are associated with metabolic changes by increasing the laxity of the ligament. In addition, condylar cartilage structure and metabolism has been found to be sensitive to estrogen level and aging, as found in experimental studies (Orajärvi *et al.*, 2018). Estrogen has also been suggested to increase pain sensitivity by having an influence on the limbic system, thereby affecting the psychosocial condition of females (Suvinen & Reade, 1995; LeResche *et al.*, 1997; Wang *et al.*, 2007; Wang *et al.*, 2008).

In the previous NFBC study, when the subjects were at the age of 31 years, the prevalence of facial pain was analyzed based on a questionnaire, and part of the study sample was clinically examined (Sipilä *et al.*, 2002). In the present study the prevalence of pain-related TMD symptoms (i.e. pain in areas of the face, jaws, temples, ears or behind the ears) was higher than 15 years before. The prevalence of TMD signs has been shown to be associated with age (Rutkiewicz *et al.*, 2006; Slade *et al.*, 2013a), although a decrease of TMD signs has been found in the oldest age groups (Hiltunen, Schmidt-Kaunisaho, Nevalainen, Närhi, & Ainamo, 1995;

Hiltunen, Peltola, Vehkalahti, Närhi, & Ainamo, 2003; Yekkalam & Wänman, 2014).

The most common TMD diagnosis was disc displacement with reduction. According to a systematic review by Manfredini *et al.* (2011), disc displacement with reduction is the most common diagnosis at the general population level, while in TMD patients myofascial pain with or without limited jaw opening has been found to be the most common diagnosis. It has been shown that a diagnosis based on the DC/TMD has good validity for diagnosing myalgia and arthralgia, but lower validity for diagnosing disc displacements (Schiffman *et al.*, 2014). Definitive diagnosis of intra-articular disorders of the TMJ needs, however, additional diagnostic methods such as magnetic resonance imaging (MRI) (Schiffman *et al.*, 2014), which were not used here.

6.2 Correlation of risk factors with TMD

6.2.1 Occlusal factors

The results here indicate that certain occlusal disturbances can be considered as potential risk factors in TMD, while earlier the role of occlusion in TMD has often been found to be controversial (Seligman & Pullinger, 1991; Okeson, 2013; Manfredini, Lombardo, & Siciliani, 2017). However, a more evident role of occlusal factors has been presented. In a 4-year controlled clinical trial, occlusal adjustment performed in children and adolescents significantly reduced the incidence of TMD (Kirveskari *et al.,* 1998). Le Bell *et al.*, (2002) noted that subjects without a TMD history indicated relatively good adaptation to artificial interferences, while those with a TMD history and true interferences showed a significant increase in clinical signs. A cross-sectional study design, as in the present study, allows surveying of associations between recorded findings and background factors, while causalities are missing. Occlusal disturbances and changes in occlusion may, however, alter muscular activity, as noted earlier (Santana-Mora *et al.*, 2009).

Although males had more malocclusions and occlusal interferences than women, female dominance was found in all the recorded TMD signs overall. TMJ diagnoses (e.g. arthralgia and degenerative joint disease), however, were found to be less frequent in men. TMD signs were associated here with unstable occlusion, especially the amount and lateral deviation in RCP-ICP slide and negative overjet.

An association was found between myalgia and lateral scissor bite, as well as between arthralgia and lateral deviation in RCP-ICP slide. Some evidence concerning the impact of occlusal disturbances on the configuration, position, and function of the disc has been reported earlier (Raustia *et al.*, 1995a, 1995b; Taskaya-Ylimaz *et al.*, 2004; Rusanen *et al.*, 2008). Even in mild cases of intra-articular disorders of the TMJ, inflammatory mediators have been shown to be released into the joint cavity and degenerative changes have been recorded (Srinivas *et al.*, 2001; Tiilikainen *et al.*, 2005).

Crepitus in the TMJs and clinically diagnosed degenerative joint disease as well as arthralgia were more common among subjects who had received orthodontic treatment compared with untreated subjects. Here the data on orthodontic treatment experience was based on a questionnaire without specifying different treatment types, and information concerning the severity of each malocclusion before treatment was not available. Crepitus in the TMJs and degenerative joint disease have been found to be prevalent among subjects who have had orthognathic treatment (Rodrigues-Garcia *et al.*, 1998), and a possible reason for increased crepitation in these cases could be acute changes in condylar position, which may cause degenerative changes in the articular joint surfaces.

6.2.2 Background factors

Here 46-year-old subjects with self-reported poor or fair health condition had more pain-related TMD symptoms and clinical signs than subjects who reported good health condition. Diagnosed depression, migraine, FM, gastrointestinal diseases, rheumatic disease, and OA correlated with pain-related TMD symptoms. General pain conditions may also affect the masticatory system. It has been noted that neuromuscular and/or biomechanical factors as well as inflammatory mediators in the TMJs may have a role in orofacial pain symptoms (Srinivas *et al.*, 2001; Tiilikainen *et al.*, 2005; Wang *et al.*, 2007). Bair *et al.*, (2016) have identified three clusters of TMD subjects or chronic pain conditions, i.e. adaptive, pain-sensitive, and global clusters of subjects. Compared with the adaptive cluster, subjects in the other clusters have shown a higher response to experimental pain, pain sensitivity, and more psychological distress (Greenspan *et al.,* 2013). Among men, however, even widespread pain has not been found to predict the onset or continuation of TMD pain (John, Hirsch, Drangsholt, Mancl, & Setz, 2002; Bair *et al.*, 2016).

An association between diagnosed depression and pain on palpation in the masticatory muscles and pain in the TMJs was noted, which is in accordance with

earlier studies (Kindler *et al.*, 2012; Fillingim *et al.*, 2013; Chen *et al.*, 2013; Ohrbach & List, 2013). Neurotransmitters serotonin and norepinephrine are involved in nociception and depression. High levels of cortisol also have been reported to occur in both facial pain and depression, possibly due to cortisol dysregulation in the hypothalamic-pituitary-adrenal (HPA) axis (Dersh, Gatchel, Polatin, & Mayer, 2002; Korszun *et al.*, 2002). Here thyroid diseases were associated with pain on palpation in the masticatory muscles. Although the pathogenesis of hypothyroid myopathy is not clear, the occurrence of muscular weakness and muscular lesions in hypothyroidism has been found (Sindoni *et al.*, 2016).

Subjective well-being or impaired self-reported health condition can be seen as an individual's personal view of emotional and physical well-being, while they may differ from the subjects' objective well-being (Bäckman, 1987). Socioeconomic status (SES) (including education and employment) has an influence on an individual's health and well-being. Lifestyle—taking part in counterproductive and detrimental habits such as smoking, alcohol, and/or substance abuse—can to a certain extent be linked to the strenuousness of an individual's occupation and it may also be connected to poorer general health (Slade *et al.*, 2013b; Glymour *et al.*, 2014; Yekkalam & Wänman, 2014). In this study a majority of the subjects perceived their health as good. No correlation was shown between TMD and marital status, living conditions, education or socioeconomic groups. In an earlier study, TMD symptoms have been shown to be associated to some extent with a higher education level (Yekkalam and Wänman, 2014). The subjects here who were not working or were retired had more pain-related symptoms than those who were currently working, which might partly reflect differences in the use of health care services and differences in lifestyle and activities.

6.3 Material and methods

The NFBC 1966 is a population-based cohort of subjects who have been screened several times during its lifetime (Rantakallio, 1988), and the subjects may have become more aware of health issues. On the other hand, subjects with severe acute or chronic health problems may not have had equal physical capacity or possibilities to participate in a study compared with healthy subjects. A majority of the participants (n = 1 258) reported their health condition as good.

The study sample here was large enough to be compared with other population-based studies concerning the prevalence of TMD (De Kanter *et al.*, 1993; Yekkalam & Wänman, 2014; Progiante *et al.*, 2015). The cross-sectional study design may be considered a weakness of this study, as the symptoms and signs of TMD were analyzed only once. Altogether 1 964 of 3 150 invited subjects (62%) attended the clinical examination. No information was available concerning TMD symptoms and signs of cohort subjects who did not attend the clinical examination. Concerning the number of subjects not attending (38%), e.g. possible selection bias should be taken into account when comparing the present results with other large cohort studies.

However, the strengths of the present study are the volume of material as a population cohort and the valid methods used in the study design, i.e. questionnaires concerning general health, socioeconomic variables, and TMD. The six examiners were calibrated before the beginning of the study and intra-examiner agreement was also determined regularly during the study by a senior dentist serving as a gold standard. Digital recording of the findings in the NFBC 1966 data system was done by trained dental nurses. In some case the data were invalid, missing or failed, and was excluded or left out of the analyses.

The results of this study confirm the previous associations between self-reported pain-related symptoms and TMD, especially in myalgia and arthralgia. Subjective TMD symptoms were inquired with both valid questions by Nilsson *et al.* (2006) and questions related to the DC/TMD diagnostic protocol (Schiffman *et al.*, 2014). Nilsson *et al.* (2006) used the questions for TMD screening in adolescents, but the results of this study indicate that these two questions seem to be reliable also in adults.

The stomatognathic examinations of the subjects were conducted according to a modified modern DC/TMD protocol presented in a symposium at IADR Conference in 2010 (Schiffman, 2010). The recently confirmed DC/TMD (Schiffman *et al.*, 2014) was not yet totally available in 2012–2013 when the present survey was formed. The protocol has been translated into Finnish in 2016 by Sipilä and Suvinen (Leskinen *et al.*, 2017; Ohrbach, Gonzalez, Michelotti, & Schiffman, 2018). Minor differences related to the clinical examination methods used here can be seen if compared with the confirmed DC/TMD. In addition, Axis II was not used in the present study, which may be considered and included in the future in the next follow-up study based on the NFBC 1966 material.

7 Summary and conclusions

The present results show that the prevalence of TMD is relatively high in the Northern Finnish adult population and awareness of TMD problems should be taken into account better in general health care. Related to the complex etiology of TMD, a holistic view of associated risk and background factors is needed. The association between impaired general health and TMD symptoms and signs confirms the widely integrated view of TMD. Anamnestic information combined with clinical findings based on systemically performed stomatognathic examinations are important for proper diagnoses. Pain as a biological disturbance affects the tissues of the masticatory system, and painful TMD symptoms and signs are common. Painful general health problems require appropriate pain-relieving methods, which should be considered to avoid a so-called "vicious circle" of pain and potential associated negative psychological symptoms. Biopsychosocial factors and pain mechanisms associated with TMD need more investigation.

Further investigations in follow-up studies of the cohort subjects and the role of hormonal status related to the age of the subjects are necessary. In addition, further studies concerning pain sensitivity, psycho-social stress or overload, lifestyle and genetic factors, SES, and general health problems are needed.

Conclusions

I The prevalence of TMD signs in the NFBC 1966 was in accordance with other population-based studies, and unequivocally predominant in females.

II TMD signs were associated with unstable occlusion, especially the amount and lateral deviation in RCP-ICP slide as well as negative overjet. The finding highlights the importance of examining the occlusion of TMD patients also from a functional point of view as well as to evaluate the need for occlusal treatment.

III Female gender and general health problems had a significant association with pain-related TMD symptoms and clinical signs of TMD. The associated risk factors of TMD should be taken into account when diagnosing and treating TMD patients.

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III Jussila, P., Knuutila, J.*, Salmela, S.*, Näpänkangas, R., Päkkilä, J., Pirttiniemi, P., Raustia, A. (2018). Association of risk factors with temporomandibular disorders in Northern Finland Birth Cohort 1966. *Acta Odontologica Scandinavica*, *76*(7), 525-529. https://doi.org/10.1080/00016357.2018.1479769

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