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Dental health and need for non-operative treatment among 16-year-olds in Northern Norway

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This thesis is dedicated to my beloved parents, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

We do not know a truth without knowing its cause.

Aristotle, Nicomacheian Ethics, I.1.

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CONTENTS

LIST OF ABREVIATIONS

ANOVA, Analysis of variance

BMI, Body Mass Index

BW, Bite-wing radiographs

CAPP, Country / Area Profile Project

CPITN, Community Periodontal Index of Treatment Needs

DEW, Dental erosive wear

DMFT/S, Decayed Missing and Filled teeth / surfaces

DS, Decayed surfaces

DFS, Decayed and Filled surfaces

EUTRO, Tromsø Study Database

FDI, World Dental Federation

FS, Filled surfaces

ICDAS, International Caries Detection and Assessment System

LCD, Liquid-Crystal Display

NOCT, Non-operative caries treatment

NSD, Norwegian Social Science Data Services

OR, Odds ratio

PDS, Public Dental Service

PEL, Proximal enamel lesions

REK, Regional Committee for Medical Research Ethics

USPHS, United States Public Health Service

VEDE, Visual Erosion Dental Examination

WHO, World Health Organization

LIST OF PAPERS

This thesis consists of the following three papers, referred to in the text by the corresponding roman numerals.

I. **JACOBSEN, I.**, ERIKSEN, H., ESPELID, I., SCHMALFUSS, A., ULLBRO, C. & CROSSNER, C. (2016). Prevalence of dental caries among 16-year-olds in Troms County, Northern Norway. Swed Dent J, 40(2):191-201.

II. **JACOBSEN, I.,** CROSSNER, C., ERIKSEN, H., ESPELID, I. & ULLBRO, C. Need of non-operative caries treatment in 16-year-olds. Accepted for publication in Eur Arch Paediatr Dent (08.02.2017).

III. MULIC, A., FREDRIKSEN, Ø., **JACOBSEN, I.,** TVEIT, A., ESPELID, I. & CROSSNER, C. (2016). Dental erosion: Prevalence and severity among 16-year-old adolescents in Troms, Norway. Eur J Paediatr Dent, 17(3):197-201.

1. ABSTRACT

Epidemiological data have disclosed a considerable reduction in caries prevalence among children and adolescents in Western countries including Norway for over 40 years. Concomitantly, enamel caries has received increased focus in order to give a better picture of the complete need for dental treatment, non-operative as well as operative. More recently, dental erosive wear seems to be a growing problem among the same age group.

The aims of the present thesis were:

- to determine the prevalence of dentinal caries and the variation in caries prevalence related to selected independent variables (sociodemography, lifestyle) in a sample of 869 16-year-olds from Northern Norway.
- to estimate the prevalence of proximal enamel lesions and the need for non-operative caries treatment.
- to record the quality of dental restorations.
- to study the prevalence, distribution and severity of dental erosion.

The thesis is based on an oral- and general health cross-sectional study (Fit Futures), with an attendance rate of 90%.

The DMFT/S-values were 4.2 / 6.1. The final multivariate regression analysis indicated that use of smokeless tobacco, dental fear, self-rated dental health and proximal enamel caries showed a strong independent association with prevalence of dentinal caries. Only 6 % of the 16-year-olds were completely caries-free. Eighty-four per cent of the participants presented with proximal enamel lesions. A majority of them had either previously restored teeth (35%) or both restored teeth and untreated dentinal caries lesions (34%). Over one third (35%) of the participants with fillings presented with at least one restoration below acceptable quality level. More than one third (38%) of the adolescents showed erosive wear on at least one tooth surface, either limited to the enamel (18%), or extending into the dentine (20%).

Dental caries and erosive wear are challenging conditions among North Norwegian 16-year-olds. The high prevalence of early signs of disease (proximal enamel lesions and cuppings) entails a need for non-operative treatment interventions. The DMFS-score and the high number of 16-year-olds with restorations in need of repair or replacement further indicate the importance of a non-operative treatment strategy in order to reduce the need of traditional restorative care.

2. INTRODUCTION

Dental caries

Dental caries is a chronic disease involving the localized destruction of dental hard tissues (Fejerskov, 1997). Both the disease process and the resulting lesions are described by the term "caries" (Koch and Poulsen, 2009). Cariogenic bacteria produce organic acids during metabolism of fermentable carbohydrates in dental biofilm on the tooth surface. These acids dissolve enamel and dentine minerals by reducing pH values locally (demineralization) and this process may result in cavitation (Selwitz et al., 2007, Featherstone, 2008).
Demineralization can be arrested or reversed through precipitation of mineral ions (calcium, phosphate and fluoride) derived from oral fluids and deposited in the demineralized tooth structures. This process is called remineralization. Under healthy conditions, there is a dynamic balance between demineralization and remineralization, maintaining a status quo at the tooth surface. When demineralization outweighs remineralization, cavity formation is the end result (Selwitz et al., 2007, Featherstone, 2008). In case of caries progression, the process is usually slow, due to successive cycles of demineralization and remineralization (Takahashi and Nyvad, 2011). The currently prevailing theory about the role of biofilm bacteria in the etiology of dental caries and the demineralization-remineralization balance of the caries process, is the ecological caries hypothesis (Marsh, 2003, Marsh, 2006), as extended by Takahashi and Nyvad (Takahashi and Nyvad, 2008, Takahashi and Nyvad, 2011). According to the extended caries ecological hypothesis, the changes in the demineralization / remineralization status of caries lesions are associated with shifts in the composition of the microflora caused by bacterial acid production. Acid production causes changes in the composition of the oral microflora from a dynamic stability stage (dominated by non-mutans streptococci and actinomyces), via acid induced adaptation and selection (dominated by low pH non-mutans bacteria and actinomyces), to an aciduric stage (dominated by mutans streptococci and other mutans bacteria, including lactovacilli and bifidobacterium). Whithin this theory, a broad range of acidogenic / aciduric bacteria and not only the mutans streprococci are involved in the caries process. Mutans streptococci are not the causative factor per se, but the result of the microbial acid production.
Biofilm has a fundamental role in dental caries. Biofilm is structurally and metabolically organized communities of interacting species on the oral surfaces in a dynamic equilibrium with their environment (mutualistic symbiosis). The microbial homeostasis is very sensitive to changes in the environment of the mouth and the lifestyle of the individual. Shifts in the

balance of the normal resident microbiota lead to dysbiosis. The microbial acid production which has as result the carious process perturbs the mutualistic symbiosis in the microbial ecosystem (Takahashi and Nyvad, 2011). Disease can be prevented by influencing the factors that promote dysbiosis, such as saliva flow and buffering capacity, diet, oral hygiene, lifestyle and the immune system (Marsh et al., 2015a). It is possible to intervene in the caries process and arrest or reverse the progress of the caries lesion through environmental control of the microflora. Preventing acidification of the dental biofilm (through biofilm control, sugary diet control, pH-neutralization) may be more effective method than adopting antimicrobial strategies against mutans streptococci (Takahashi and Nyvad, 2011, Marsh et al., 2015b). The action of fluoride in the caries control is essential, as it both reduces demineralization and promotes remineralization (Fejerskov et al., 1981, Groeneveld, 1985, Groeneveld et al., 1990, Singh and Spencer, 2004).

The dental caries process is a continuum of disease states ranging from subclinical changes to dentinal involvement with or without cavitation (Selwitz et al., 2007). A large number of very early initial lesions in a dynamic state of progression-regression remain subclinical (Pitts, 2004b). The choice of diagnostic cut-off between sound and diseased tooth surfaces determines the number of carious lesions detected (Pitts, 2004b).

Risk factors

Dental caries is a multifactorial disease. Concerning the microbial factor, mutans streptococci have been considered as the main microbiological causative factor of caries. However, such a role has not been extensively verified (Bowden, 1997, Aas et al., 2008). Caries occurrence can neither be accurately anticipated in a person or at a tooth site, nor predicted following presence of a particular bacterium. Known risk factors are previous caries experience; sugar habits, amount of fluoride exposure, salivary flow, and socioeconomic status (Selwitz et al., 2007). Socioeconomic factors, knowledge, behavior and attitudes are more distant determinants of the carious process. Moreover, a social gradient has been shown in general and oral health, present and persistent in different countries and contexts, indicating the impact of broad social underlying factors in determining and shaping individual behaviors (Watt, 2012).

Dental caries is a “transmissible” disease. Cariogenic bacteria are transmitted early in life from mother / caregiver to child, and colonize teeth upon eruption (Featherstone, 2008, da Silva Bastos et al., 2015). Maternal factors seem to influence bacterial acquisition, while colonization may be mediated by oral health behaviors and practices and feeding habits (Leong et al., 2013).

International trends

Most epidemiological data about caries come from studies of children and adolescents or older people (Broadbent et al., 2013). Available data on caries prevalence at the international level concern the indicator group of 12-year-olds and are collected by the World Health Organization (WHO) within the Country / Area Profile Project (CAPP) (WHO, 2016). A number of studies from many developed countries confirm the declining trend in caries prevalence and in mean caries experience for permanent teeth in children and adolescents (Marthaler, 2004, Hugoson et al., 2005, Christensen et al., 2010, Widström et al., 2011), and also in adults (Norderyd et al., 2015a). This is a result of public health measures and well-organized prevention, better living conditions and improved oral hygiene practices (Petersen et al., 2005, Fontana et al., 2010). The change in the diagnostic and treatment criteria of caries may also have played a role in this decline (Nadanovsky and Sheiham, 1995). The widespread use of fluoride dentifrice may be the single most important reason for the decline (Bratthall et al., 1996). The role of sugar in the diet seems to be weaker in the era of widespread fluoride exposure (Burt and Szpunar, 1994, Burt and Pai, 2001, Mejàre et al., 2014).

However, not all share the positive changes in oral health. Despite the significant caries reduction observed in high-income countries, disparities remain and poor and disadvantaged population groups still present high levels of caries (Selwitz et al., 2007, WHO, 2012, Schwendicke et al., 2015). The WHO reports that worldwide, 60-90% of school children and nearly 100% of adults have experienced dental caries, while about 30% of people between 65 and 74 years old are edentulous (WHO, 2012). The prevalence of caries in later adult age remains substantial. Demography is changing, people live longer and number of older people retaining their teeth has increased. In USA, 91% of dentate adults older than 20 years have caries experience (Fontana et al., 2010). Marcenes et al. (2013) found a 35% global prevalence of untreated caries for all ages combined. In 2010, untreated caries in permanent teeth was the most prevalent medical condition affecting 2.4 billion people worldwide (Kassebaum et al., 2015). Bernabé and Sheiham (2014a) in their extensive analysis of age, period and cohort trends of caries in permanent teeth in four developed countries (USA, UK, Sweden and Japan) showed that there is still a gradual increase in DMFT/S-scores in the adult population due to untreated caries and neglect of oral health promotion in adult life. They generalized their findings to a larger set of developed and developing countries (Bernabé and

Sheiham, 2014b). Broadbent et al. (2013) also found (Dunedin study) that dental caries disease continues in adulthood, and that rates of dental caries remain relatively constant over time, with an average increase of 0.8 surfaces per year.

The comparison of international data about caries has many limitations. Diagnostic criteria vary from one study to another and researchers collecting data are not calibrated. In addition, caries lesion measurements in the various studies have variable diagnostic cut-offs, from including all forms of lesions to only dentinal cavitation. Dental caries prevalence is mostly measured at dentinal caries diagnostic threshold (Fontana et al., 2010) and the caries prevalence shown may be underestimated to a certain degree, due to non-inclusion of precavitated lesions and other factors inherent to the use of the DMFS index (Lagerweij and van Loveren, 2015). Additionally, the available data from the WHO database which concern the caries status of 12-year-olds in different countries and regions of the world cannot be used for comparisons, due to variation in the internal and external validity and in the year of their collection (WHO, 2012). Finally, the caries prevalence for this age group may be underestimated in most children as the second molars are not erupted and premolars and canines have been present only for a short period in the mouth (Meyer-Lueckel et al., 2013).

Norwegian trends

In Norway, statistical data on caries experience recorded at dentin level (DMFT) for index age groups 5, 12 and 18 have been collected annually at county level since 1985 (Lyshol and Biehl, 2009, Wilberg, 2012). These data confirm the internationally reported decrease in caries prevalence. This positive development is, however, not shared by all. Dental health varies with socio-economic background and dental caries still remains high in risk groups (Norwegian Institute of Public Health, 2010). Parental migration and immigrant background are associated with higher risk for caries in children and adolescents (Skeie et al., 2005, Gimmestad et al., 2006, Wigen et al., 2011, Wigen and Wang, 2012). Furthermore, higher caries prevalence and severity of caries have been observed among children and adolescents in Northern Norway, in particular Finnmark, compared to the rest of the country (Helse- og omsorgsdepartementet, 2007, Lyshol and Biehl, 2009, Widström et al., 2010, Adekoya and Brustad, 2012, Skeie et al., 2012). Possible explanations for these findings are the high frequency of rural population in this area, the large proportion of indigenous Sami population living in Finnmark and the low dental service availability due to low dentist density (Adekoya and Brustad, 2012). Compiled national data on caries among adolescents with Sami background are, however, lacking.

Enamel caries

Lesions limited to the enamel constitute a considerable part of all carious lesions (Martignon et al., 2010, Skeie and Klock, 2014). Alm et al. (2007) claim that over 80% of proximal caries lesions diagnosed in adolescents are in the enamel only, indicating that the reduction in prevalence of caries is overestimated and that the burden and the need for treatment of the caries disease is underestimated (Amarante et al., 1998, Nyvad et al., 1999, Schwendicke et al., 2014). Hugoson and Koch (2008) found that 80-90% of the proximal lesion in age groups 20-50 years were limited to enamel. As a consequence, valid caries diagnosis in populations with low caries prevalence and slow caries progression may need more sensitive diagnostic criteria including enamel lesions (Nyvad et al., 1999, Pitts, 2004a). As the prevalence of dentinal caries has declined, enamel caries has received increased focus in order to give a more comprehensive picture of dental heath in children and adolescents and consequently a better picture of the complete need for dental treatment including non-operative as well as operative treatment (Isaksson et al., 2014). The choice of diagnostic cut-off between sound and diseased tooth substance determines the number of carious lesions detected and recorded, and by choosing a cut-off at the level of dentinal cavitation and recording only dentinal lesions, the caries disease is underestimated (Pitts, 2004b). Early detection and treatment of caries lesions preserves more dental tissues and is compatible with the principles of the minimally invasive dentistry (Araújo et al., 2014). Treatment objectives for enamel lesions are to slow down, arrest or reverse the progression of the lesions by non-operative treatment procedures and thereby reduce the need for restorative treatment (Ekstrand and Christiansen, 2005, Hausen et al., 2007). It seems that, if caries is controlled during childhood and adolescence, the benefits are maintained later in life, as most lesions develop before the age of 20 years, as shown by Crossner and Unell (2007) and Norderyd et al. (2015a). Enamel caries is not recorded and monitored in the Official Statistics of Norway (Skeie and Klock, 2014).

Treatment options

Caries treatment has traditionally been associated with restorations. The term “treatment” should be used with caution for caries, as “dental caries” is a dynamic process without a generally agreed start point. In the past, treatment of dental caries was symptomatic, aiming to relieve symptoms and restore function. The treatment included removal of the carious tissues and restoration of the deriving cavity. Modern dentistry has moved away from operative intervention, towards a causal, biologically grounded approach to caries management, based on prevention and preservation of the dental tissues (Selwitz et al., 2007). This shift happened following considerations of tooth integrity – avoidance of the retreatment spiral -, but also cost, and the fact that prevention proved effective (Tyas et al., 2000, Pitts, 2004a, Qvist, 2012, Schwendicke et al., 2014). Additionally, due to slow caries progression in most cases (Mejàre et al., 2004), unnecessary invasive treatment can be delayed considerably. Modern treatment philosophy focuses on caries control through elimination of the causes of the disease, by altering the unfavorable oral milieu and by restoring the ecological equilibrium in the oral cavity. Initiation and progression of the disease can thus be controlled lifelong for individual patients (Selwitz et al., 2007). The environmental control of the microflora involves mechanical biofilm control, control of sugary diet and pH-neutralizing techniques. This approach necessitates accurate diagnosis of any disease or lesions at individual (etiological risk factors) and tooth (location, severity, activity of lesion) level. Disease prevention, just-in-time restoration, choice of minimally invasive restorative procedures, and prevention of recurrence are essential measures and should be based on patient's compliance (Selwitz et al., 2007, Young and Featherstone, 2013).

Non-operative caries treatment (NOCT)

In non-operative treatment, hard tissues of the tooth are not removed. This approach is fully justified in the earlier stages of the disease. The clinician faces the challenge to detect caries lesions early, before progression into dentine and cavitation occurs, and also to monitor eventual changes in severity, extent or activity of the lesion (Selwitz et al., 2007, Pretty and Ekstrand, 2015). Generally, non-cavitated lesions may be treated with non-operative interventions (Meyer-Lueckel et al., 2013). Moreover, only active lesions need treatment (Nyvad et al., 1999), and in case of doubt concerning the activity of the lesion, it is suggested to consider it as active (Kidd, 2011). Additionally, caries risk assessment is necessary, in order to take measures for preventing new lesions in individuals at risk (Pretty and Ekstrand, 2015).

Components of caries control by non-operative treatment are efficient mechanical removal of dental biofilm, fluoride application, diet considerations, and considerations of social and behavioral factors for motivation and active compliance of the individual patient (Kidd, 2011). Fluoride acts at the point of acid attack, promotes remineralization, and inhibits further demineralization and progression of the lesion (Fejerskov et al., 1981). It seems that frequent, daily exposure of the teeth to fluoride is more effective against caries than incorporation of fluoride into the dental tissues, achieved in semiannual topical fluoride applications (Ten Cate, 2013). Daily use of fluoride toothpaste in the permanent dentition is reported to be effective with high quality of evidence for primary caries prevention (Marinho, 2014, Twetman, 2015, Kay et al., 2016). Twetman (2015), in a conference paper, rated the quality of evidence for primary prevention of caries concerning a number of interventions - other than fluoride toothpaste - from low or very low (fluoride supplements, xylitol, antibacterial preparations, interdental cleaning and oral health promotion) to moderate (fluoride varnish, fissure sealants), whereas the role of diet counseling was found unclear. In the same paper, the quality of evidence for secondary prevention of caries or caries control (re-mineralization or arrestment of existing early, non-cavitated lesions) was rated, as low (for fluoride interventions) or very low, based on few systematic reviews with few studies.

In most cases, the first clinical visually detected sign of caries activity is white spot lesions, a rather advanced stage of the disease (Twetman, 2015). Similarly, Kay et al. (2016) found no effect for dietary counseling, and only short term effect for changes in oral hygiene behavior. Although the preventive caries management has focus on children and adolescents, the caries process needs to be managed over a person's lifetime, and the components of the non-operative treatment can be used with benefits at any stage of the disease and at any age (Fejerskov et al., 2013).

The caries control concept has been applied successfully in three intervention studies: the Nexø study (Ekstrand and Christiansen, 2005), followed by more projects applying the Nexø method (Ekstrand and Qvist, 2014, Kuzmina and Ekstrand, 2015), the Pori clinical trial (Hausen et al., 2007, Hietasalo et al., 2009) and the Odder municipality dental health-care program (Fejerskov et al., 2013). These experiments had a non-operative treatment approach in common, frequent recall intervals, a whole population approach, concrete treatment protocol to follow, involvement of dental auxiliary personnel and active compliance of patients or caregivers.

For non-cavitated lesions extending to the outer third of dentin and seeming to progress despite the application of NOCT, often in the case of proximal lesions, the micro-invasive intervention, which does not depend on the patient's compliance, is reported to be more effective compared to NOCT in order to arrest these initial lesions or reduce their progression (Dorri et al., 2015, Meyer-Lueckel and Paris, 2016). The micro-invasive intervention concerns the creation of a diffusion barrier for acids produced by the cariogenic bacteria through sealing or resin infiltration of the lesion. A prior conditioning of the tooth surface is required, causing a few micrometers loss of enamel (Kugel et al., 2009).

Restorative treatment

A prerequisite for the successful use of NOCT is the accessibility of the lesion to cleaning, which is difficult in case of cavitation and depends on the cavitation level. In case of cavitation, restorative treatment might be the best choice, however with respect to the principles on minimally invasive therapy, which has evolved following progress in cariology, diagnostics and dental materials, and changes in the approach to manage dental caries (Murdoch-Kinch and McLean, 2003).

It is shown that restorations have limited longevity, and secondary caries may form at their margins. Secondary caries and restoration fracture are reported to be major reasons for failure of restorations (Mjör et al., 2000, Ástvaldsdóttir et al., 2015). Restorations may need replacement several times, and result in larger restorations (Brantley et al., 1995). This re-restoration circle places tooth survival at risk, may cause iatrogenic damages to the adjacent tooth surface and secondary caries due to restoration quality (i.e. poor anatomical form, poor marginal adaptation) and may necessitate costly interventions (Kuper et al., 2012, Kopperud et al., 2015, Skudutyte-Rysstad et al., 2016). Despite its limitations, restorative treatment is still the dominating treatment approach in dentistry (Selwitz et al., 2007). Staxrud et al. (2016) report that 57% of the working day in the Public Dental Service (PDS) settings in Norway are used in operative procedures and 45% among them are devoted to replacement/repair of previously placed restorations. It is suggested to consider the restorations in the management of caries as a mean to control biofilm, a complement to preventive and non-operative treatment. Fillings should be placed only following cavitation, in order to facilitate the removal of biofilm (Kidd, 2011).

Quality and longevity of fillings

The quality of dental fillings has been related to various aspects of restorative care and has often been correlated to the technical excellence (Jokstad et al., 2001). The traditional quality criteria were based to firm technical considerations, such as cavity design and accurate reproduction of tooth anatomy. Currently, dental restorations are evaluated for their clinical performance, based on specific criteria and considering tooth prognosis (Söderholm et al., 1998, Jokstad et al., 2001).

Various systems have been applied for evaluation of the quality of dental restorations. Most used are the United States Public Health Service (USPHS) and the World Dental Federation (FDI) criteria. The USPHS system (Ryge criteria), was developed by Cvar and Ryge (1971) for use in the United States Public Health Service. Five characteristics of restorations were assessed, color match, cavo-surface marginal discoloration, anatomic form, marginal adaptation and caries at margins (Cvar and Ryge, 2005). The USPHS guidelines have been used in various modified versions (Bayne and Schmalz, 2005). The Ryge criteria were not sensitive enough for the evaluation of various restorative materials used with various operative techniques, and have undergone many modifications making comparison between studies difficult (Demarco et al., 2015). Hickel et al. (2007) presented new clinical criteria, approved by the FDI. The new criteria were flexible and adjustable to the needs of the investigators, and comprised 3 groups, aesthetic, functional and biological, with 16 subgroups of criteria. These "FDI clinical criteria for the evaluation of direct and indirect restorations" were updated and instructions for training and calibration were given by Hickel et al. (2010). According to these criteria, restorations with poor quality ratings are considered as failures (or semi-failures) and should be repaired or replaced.

Fracture together with secondary caries, are the most common reasons for failure of dental restorations (Demarco et al., 2012, Opdam et al., 2014). Despite the excellent mechanical and physical properties of the existing restorative materials, their properties, as tested in laboratories, correlate poorly with their clinical performance. Despite the numerous relevant peer reviewed studies, factors influencing the clinical success of restorations are not identified due to high variability in the reported data. The clinical success of dental restorations is multifactorial and cannot be reliably predicted (Ferracane, 2013).

Longevity is a component of quality of products in general, but quality does not always imply longevity (Cooper, 2012) and this applies also to dental restorations (Jokstad et al., 2001). Longevity of dental restorations is desirable, as it prevents the vicious circle of retreatment and is considered as an indicator of quality of the dental care provided (Laske et al., 2016a). Longevity of restorations and reasons for their failure, including a large range of parameters related to restorations, operators and patients, have been frequent research objects. The length of survival of dental restorations is evaluated as a measure of their quality. Kaplan-Meier survival analysis is the statistical method of choice for the evaluation of longevity of restorations, allowing estimation of restoration survival over time. Despite the large amount of relevant studies, a reliable measurement of longevity by Kaplan–Meier statistics is often missing due to incomplete data. Many studies are cross-sectional or retrospective with inherent methodological weaknesses. Prospective studies may not have adequate length of observation time due to subjects' attrition, and "failure" of restorations is evaluated based on non-homogenous criteria (da Rosa Rodolpho et al., 2011, Loomans and Özcan, 2016). Due to improved properties of dental materials and better dental health, restorations have generally good survival with low annual failure rates (Laske et al., 2016b). Kubo (2011) suggest longevity more than 10 years for over 60% of composite restorations, “when proper materials are applied correctly”. Pallesen et al. (2013) found that posterior composite restorations placed in PDS clinical settings in Denmark had 15.7 % failure after 8 years, while Kopperud et al. (2012) reported 11% failure in the restorations placed in a large sample of adolescents in PDS in Norway, after an average follow up period of 4.6 years. The findings from general practice show high heterogeneity (Laske et al., 2016a, Laske et al., 2016b). Research carried out in university clinical settings, where many factors can be controlled, differs from that carried out in general dental practice. However research from the general dental practice is also needed, as it reflects the real-life situation (Wilson et al., 2002, da Rosa Rodolpho et al., 2006, Kopperud et al., 2012, Laske et al., 2016b). It seems that longevity of restorations is related to numerous factors depending on the patient, the tooth and the operator (Wilson et al., 2016). Operative treatment and re-restoration is an important part of general practice and criteria for placing, repairing and replacing restorations vary a lot among dentists and are not based on standardized criteria but on the clinical experience and attitude of the dentist (Laske et al., 2016a). It is not clear which quality factors are the most important contributors to longevity of restorations.

The prevailing philosophy is to maintain existing restorations as long as possible, through prevention of caries disease and by repairing them instead of replacing them, according to the principles of minimal intervention dentistry (Opdam et al., 2012, Hickel et al., 2013, Lynch et al., 2014, Wilson et al., 2016).

Considering the documented limitations in longevity of restorations, the most important aspect of caries treatment is to intervene early with non-operative treatment modalities thereby avoiding restorations. This aspect is considered in the present thesis.

Dental erosion

Dental erosion is the progressive dissolution of tooth mineral without the presence of biofilm (Imfeld, 1996, Ganss, 2006). The erosive process is multifactorial (Shellis and Addy, 2014). A multitude of factors related to the patient, his / her biology and nutrition, as well as his / her socioeconomic and behavioral level, interact over time with the tooth surface, in a way comparable to the complex interplay for caries disease (Lussi et al., 2012a, Lussi et al., 2012b). The result of these interactions is that the tooth surface is either exposed to erosive activity or protected from it, depending on a subtle balance (Lussi and Carvalho, 2014). Bartlett (2016) supports the combination of a lifetime slow cumulative effect of erosive tooth wear, with periods of higher erosive activity in case of exposure to risk factors. The erosive process involves not only the interface between solution and enamel ("surface demineralization"), but also the thin, partly demineralized softened enamel layer ("near – surface demineralization") (Shellis et al., 2013). The critical pH value for the erosive process is not fixed, but varies depending on the concentration of mineral components (calcium, fluoride, phosphate) in the erosive solution. Although the pH value of a solution can be below the critical pH level of 5.5 for dental caries, an erosive effect will not occur if this solution is supersaturated compared to biofilm fluid (Larsen and Nyvad, 1999, Lussi et al., 2012a, Lussi and Carvalho, 2014). In the erosive process, remineralization is limited to the surface and near-surface demineralized enamel layer, while remineralization in dental caries can occur in initial subsurface caries lesions in the presence of saliva (Lussi et al., 2011). Erosive action is much stronger compared to that of caries, as erosive lesions are not protected by surface layer and are exposed to frictional forces (Shellis, 2015). Saliva reduces demineralization and promotes remineralization of the tooth mineral (Hara et al., 2006). However, the remineralization process in erosive lesions, when compared with remineralization in caries, is different and limited, due to low degree of saturation of saliva and to the presence of salivary proteins (proline-rich proteins and statherin) which hinder mineral precipitation on enamel surface (Shellis, 2015). Lussi et al. (2014) found no measurable remineralization effect for eroded dental hard tissues after their exposure in human saliva for up to 4 hours.

Dental erosion involves interrelated processes (erosion, attrition, abrasion) and the result of this multifactorial activity can be loss of hard dental tissue (Nunn, 1996, El Aidi et al., 2011). This combined effect from chemical and mechanical action is termed erosive tooth wear (Huysmans et al., 2011), while erosion refers to the exclusively chemical process. It is suggested that tooth wear occurs rarely from the contribution of one condition only (Bartlett, 2016). It seems that erosion is the main cause of tooth wear because it demineralizes tooth structure, and facilitates the impact of attrition /abrasion on the demineralized surface (Meurman and ten Gate, 1996, Khan et al., 1998, Bartlett, 2005, Khan and Young, 2011). Enamel pre-softened by acid is very vulnerable to abrasive action of food, oral soft tissues (tongue, during speech and swallowing), toothbrush and toothpaste (Amaechi et al., 2003, Eisenburger et al., 2003, Hooper et al., 2003). The wear effect from attrition and abrasion without erosive pre-softening of the dental tissue is limited (Bartlett, 2005). Moreover, erosion and abrasion together may induce much larger tooth wear effect than erosion or abrasion alone (Davis and Winter, 1979, Shellis, 2015). Toothbrushing may be associated with tooth wear only in combination with an acidic diet, and it has been proposed to delay it, in order to allow remineralization (Addy, 2005). However, Bartlett et al. (2013) in their large study of over 3000 individuals, did not find indications that toothbrushing directly after breakfast increased tooth wear, but rather, the type of toothbrushing could have a such effect. West et al. (2013) found strong relationship between dentine hypersensitivity and erosive tooth wear, but not any effect of the time interval between breakfast and brushing. The contribution of attrition to tooth wear in bruxism cases may be overestimated (Johansson et al., 2012), as erosion is often the prevailing condition in bruxism cases (Khan et al., 1998). Despite equivocal findings in the literature, caries seems not to be associated with erosion (Auad et al., 2009, Mulic et al., 2013, Søvik et al., 2014).

International trends

Increased focus is set on dental erosion during the last decades as erosive wear is recognized as a problem of growing importance (Johansson et al., 2012, Skudutyte-Rysstad et al., 2013). Erosive tooth wear is a common condition in children and adults. Primary and permanent teeth can both be affected (Larsen, 1990). There is a tendency towards increase in prevalence of erosive wear, and possible explanations relate to changes in diet and oral hygiene habits (Meyer-Lueckel et al., 2013).

Available studies show large differences in reported prevalence of erosive wear. Universally accepted examination standards for evaluation of erosive condition is lacking, despite the attempts towards greater standardization (Johansson et al., 2012), Differences in age, geographical location, sample size and index used, can explain to a certain degree the differences in reported prevalence (Ganss et al., 2011, Ren, 2011, Jaeggi and Lussi, 2014, Salas et al., 2015). Research in many countries all over the world demonstrates increase in the prevalence of erosive wear, especially among children and adolescents as well as higher severity, shown as higher numbers and increase in depth of erosive lesions (Jaeggi and Lussi, 2014). Moreover, there are indications that the occurrence of erosive wear is increasing, and existing lesions progress more rapidly (Dugmore and Rock, 2003, Bartlett, 2005, El Aidi et al., 2008, Johansson et al., 2012, Lussi and Carvalho, 2014). However, according to Salas et al. (2015) the information about worldwide incidence of erosive tooth wear is unclear. Worldwide, the prevalence of erosive wear in permanent teeth of children and adolescents (8 to 19 years), calculated exclusively from population-based studies with representative sample, is reported to be from 7.2% to 74.0%, with estimated global prevalence 30.4% (Salas et al., 2015)

Soft drinks, carbonated drinks, energy drinks, and fruit juices are associated with erosion. Soft drinks is the main cause of erosion for children and adolescents and the teeth are exposed to citric, phosphoric and malic acid more often than before (Johansson et al., 2012). The consumption of soft drinks, carbonated drinks and energy drinks has increased internationally during the last decades due to changes in lifestyle. This increase concerns total amount, serving sizes and frequency of consumption (Cavadini et al., 2000, Gleason and Suitor, 2001). According to Lussi and Carvalho (2014), 16% of children are considered high chronic users and the prevalence of consumption is highest in the adolescent group (68%).

Norwegian trends

Studies about erosive wear among Norwegian adolescents show a prevalence of 38% (Mulic et al., 2013) and 59% (Søvik et al., 2014). At the same time, it is reported increase in household expenditure of acidic drinks in Norway between 1992 and 2013 (Statistics Norway, 2014). The official statistics show data on sugary soft drinks and, from 2012, on soft drinks with artificial sweeteners. However, the soft drinks market is evolving very quickly and numerous new products that can be of interest for their erosive potential may not be covered under the traditional categories. Asmyhr et al. (2012) indicate high consumption of soft drinks and juice, despite the widespread awareness and knowledge about the causes of erosion among young Norwegians adults. Skudutyte-Rysstad et al. (2013) reported good knowledge about the erosive condition among 18 years olds Norwegians, but low level of awareness of having the condition in their own dentition. Dental practitioners very often oversee or underestimate the erosive condition (Bartlett et al., 2008). Although Norwegian dentists reported confidence in recording erosive wear and identifying its causes (Mulic and Kopperud, 2013), many patients having the condition did not recall being informed about it by their dentist (Mulic et al., 2011, Mulic et al., 2012b). This indicates a communication problem between patient and dentist (Skudutyte-Rysstad et al., 2013).

Treatment options

Dental erosion results in irreversible loss of tooth substance. Restoration of a dentition with severe hard tissue loss due to erosion may necessitate complex prosthetic treatment for functional and esthetical rehabilitation (Dugmore and Rock, 2003, Johansson et al., 2008, Muts et al., 2014). Moreover, restorations may fail in case of persisting erosive activity, due to marginal deterioration (Ren et al., 2011). Early intervention and prevention of the erosive procedure is a more effective action than treatment of lost dental tooth substance. Early diagnosis of the erosive condition is difficult to achieve and diagnosis becomes possible only through clinical detection of the defects when erosive wear lesions are established (Bartlett, 2005, Lussi and Carvalho, 2014, Carvalho et al., 2015). As primary prevention, it is suggested the avoidance of erosive substances in the diet, as well as the management of eventual eating disorders, psychological counseling and lifestyle changes. Despite indications that preventive strategies focusing on increasing the resistance of hard dental tissues to acid by the use of fluoride, phosphates or calcium may be efficient (Ren, 2011), the results of a relevant recent review (Zini et al., 2014) are inconclusive. Twetman (2015) evaluated the quality of evidence for preventing dental erosion as very low based on the few available reviews dealing with prevention and management of dental erosion. It seems that fluoride products alone protect only minimally against erosive wear, while they show promising results together with other products (i.e. polyvalent metal ions, some polymers) (Lussi and Carvalho, 2015). It is further accepted that prevention is beneficial at any stage of the erosive wear condition, since risk factors and subsequent periods with higher erosive activity can occur at any moment of life (Bartlett, 2016).

3. AIMS

The present thesis is based on a sample of 16-year-olds in Troms County, Northern Norway, and has the following aims:

- to record the prevalence of dentinal caries in this sample (Paper I)
- to examine the variation in dentinal caries prevalence related to selected, independent variables including ethnicity, lifestyle, oral health attitudes and perceptions, oral health parameters and general health (Paper I)
- to document the prevalence of proximal enamel lesions and to estimate the need for non-operative caries treatment (Paper II)
- to record the quality of dental restorations (Paper II)
- to study the prevalence, distribution and severity of dental erosion (Paper III).

4. MATERIALS AND METHODS

Study sample

The data of the present thesis were taken from a cross-sectional health study including oral health (“Fit Futures”). The study was carried out from September 2010 to May 2011, which was part of a larger epidemiological general health project in Northern Norway (“The Tromsø Study”) (Jacobsen et al., 2012, Winther et al., 2014). All first year upper-secondary school students in two neighboring municipalities in Northern Norway, Tromsø (urban, 7 schools) and Balsfjord (rural, 1 school), were invited to the Fit Futures project. Of a total of 1301

registered students, 184 were not attending the schools at the time of investigation for a variety of reasons (illness, moved, exchange students etc.), and were therefore excluded from the sample. Out of the remaining 1117, 1038 students volunteered to participate in the medical part and 1010 volunteered to participate in the oral part (90% attendance rate). Within this group all subjects born in 1994 (869) were included in the present study.
Recruitment took place at the schools and information was presented orally, electronically and by distributing a brochure for students and parents/guardians. Students interested in attending confirmed on internet by a link sent to their personal e-mail address and signed a written consent on arrival for the examination. In order to obtain a high participation rate, the survey was conducted during school hours. The participants were transported from the schools to the examination stations at the university by mini-buses, and a 200 NOK (35 $ US) bonus check was handed out.

Clinical examination

The oral health part of the study included a standard clinical examination and two bite-wing radiographs, eight intraoral clinical photographs and a questionnaire. The clinical examination was carried out by an experienced dentist (IDJ) assisted by dental assistants at the University Dental Clinic, UiT The Arctic University of Norway, Tromsø, and replaced the annual dental examination at the PDS. The collected clinical variables, not all of them used in the present thesis, were caries status, number of restorations, quality of restorations (a grade assigned to each participant), periodontal health, dental hard tissues mineralization disorders, signs of trauma to the dentition and dental erosive wear. As a part of the clinical examination, eight photographs (Canon EOS 60D; Canon 105 mm; Sigma EM-140 DG) were taken by one dental assistant in the following order: the buccal surfaces of the teeth in the first and fourth quadrant, the corresponding surfaces in the second and third quadrant, the buccal surfaces of the upper and lower anterior teeth, the occlusal surfaces of the upper teeth and lower teeth, and the palatal surfaces of the upper anterior teeth. All pictures were coded to ensure the anonymity of the participants.

Study design

Paper I

This paper presented an epidemiological study. Dental caries was the dependent variable and the independent variables covered sociodemography, lifestyle, dental-health related perceptions and attitudes, dental health and general health characteristics of the 869 16-years-old participants. The variables used in the present study are shown in Table 1.

Paper II

This paper presented the prevalence and distribution of proximal enamel lesions (PEL) among the 869 16-years-old participants, in relation to dentinal caries experience, according to DMFS-index. The distribution of participants according to the quality of the poorest dental restoration of each participant was also presented in this paper.

Paper III

This paper presented the prevalence, distribution and severity of dental erosive wear among 392 subjects, randomly selected out of the initial sample of the 869 16-years-old participants, according to gender, type and surface of tooth, as well as the distribution of cuppings.

Registration of variables

Paper I and II

Proximal lesions were assessed radiographically and scored according to a scale 1-5 for increasing depth of radiolucency. Occlusal lesions were diagnosed and scored in a similar 5-graded scale with a combination of clinical and radiographic criteria, while buccal and lingual caries were diagnosed and scored in a 5-graded scale based on clinical criteria only. Grade 3-5 lesions reaching into dentine (corresponding to International Caries Detection and Assessment System (ICDAS) (Pitts, 2004a) level 4-6) were included in the DMF-scores, while grade 1-2 were assigned to enamel lesions (corresponding to ICDAS level 1-3) and were not included in the DMF-scores (Topping and Pitts, 2009). The DMF index values were calculated by adding all "decayed", "missing" and "filled" (due to caries) permanent teeth/surfaces. For enamel caries, only proximal lesions registered from bitewing radiographs were used as an independent variable in the present analyses.

Restorations were registered for each participant and the quality was evaluated clinically and, when applicable, radiographically for each participant by the principal examiner (IDJ) according to a modified version of the clinical and radiographic criteria described by Hickel et al. (2010). Scores from 1 to 4 were used, 1 – good, 2 – acceptable (with minor defects), 3 – poor (filling with defects in need for repair/replacement but not immediately), 4 – unacceptable (filling needing immediate repair/replacement). A score was assigned to each participant corresponding to the assessed quality of the poorest filling.

Periodontal status was measured according to the Community Periodontal Index for Treatment Needs (CPITN) index system. Due to low age of the participants, a simplified version including only six index teeth (16, 11, 26, 36, 31 and 46) was used. The scores registered were number of teeth with presence of gingival bleeding and number of teeth with periodontal pockets 4-5mm or >5mm.

Body mass index (BMI) was calculated by the formula weight ⁄ height^2. The adolescents were classified into four groups (underweight / normal weight / overweight / obese), according to the Extended International Body Mass Index by Cole and Lobstein (2012).

The participants answered two closed questionnaires. One included questions concerning oral hygiene habits and oral health knowledge and attitudes as well as how they perceived parents (or guardians) dental health-related attitudes. Only information concerning parental supervision of tooth brushing during young age, missing dental appointments due to dental fear and self-rated dental health were used in the present analyses from the oral health questionnaire. The other questionnaire was web-based and included self-reported answers about family demographics, current psychological and physical health status, pain, medication, dietary habits and information on lifestyle.

Ethnicity information included country of birth of the participant and his / her parents, and self-perceived ethnicity. For self-perceived ethnicity, more than one answer were allowed. Based on a combination of the available information, the individuals were classified as Norwegian, Sami or immigrants. Parents' educational level was stratified according to years of schooling as: low (0-9 years), medium (high school or equal) and high (college or university). Family structure was identified based on living with both, one or none of the biological parents. Lifestyle habits covered use of snuff, smoking, sugar consumption, physical activity and time in front of the TV/computer screen. Sugar consumption was based on intake frequency of sweets and soft drinks with sugar. Scores were recorded for the two items in a scale from 1 (minimal - no consumption) to 5 (maximal consumption). The 9 resulting groups based on a combined score for sugar intake were further merged into 2 groups: score 2-6 (low)/score 7-10 (high).

Physical activity (frequency and intensity), based on participants' leisure activities, was registered and graded as sedentary, low, moderate or high. Frequency of actively doing sports or physical activities outside school hours was recorded in a 6-interval scale from "never" to "almost every day". The 6 categories were further converted into three (≤ 1 day a week, 2-3 days a week or ≥ 4 days a week). Time in front of a TV/computer screen was recorded for weekdays and weekends in a 7-graded scale from "none" to ≥ "10 hours /day" and dichotomized in <4 hours/day or ≥4 hours/day.

Information on dental health-related variables such as toothbrushing frequency, parentally controlled oral hygiene and self-rated oral health were also recorded. The students reported whether their parents/caregivers supervised their toothbrushing in young age recorded in "yes" or "no". Toothbrushing frequency was given in a 6-graded scale from less than once a week to ≥ 2 times a day. Dental fear was measured based on missed dental appointments due to fear and recorded as "yes" or "no".

Self-rating of dental and general health were classified as "good" or "neither good nor bad" or "bad". In addition, presence of allergy comorbidities was registered, if reported medical diagnosis of at least one condition among allergic rhinitis, atopic eczema and asthma.

Paper III

Out of the 869 16-years-old participants, 45% (n = 392) were randomly selected for scoring of dental erosive wear. The intraoral photographs, 8 for each participant, taken during the clinical examination were used to score the erosive lesions. The clinical photographs of the 392 adolescents were shown on a flat screen in a room with indirect, standardized lighting and examined independently by three experienced dentists. Out of 4704 surfaces of 392 participants, 240 surfaces (5.1%) were found to be illegible and excluded due to orthodontic treatment (brackets, 220 surfaces) and fillings or comprehensive deformities in the enamel, covering most of the surface (20 surfaces). Buccal and palatal surfaces on all upper incisors and occlusal surfaces on all first permanent molars were included in the examination. Dental erosive wear was scored according to the Visual Erosion Dental Examination (VEDE) system (Mulic et al., 2010) with the following criteria: grade 0 = no erosion; grade 1 = initial loss of enamel, no dentine exposed; grade 2 = pronounced loss of enamel, no dentine exposed; grade 3 = dentine exposed, < 1/3 of the surface involved; grade 4 = dentine exposed, 1/3 – 2/3 of the surface involved; grade 5 = dentine exposed, > 2/3 of the surface involved. The reliability of this scoring system has been tested and found to be sufficient (Mulic et al., 2010).

Calibration

Paper I and II

The principal examiner (IDJ) was calibrated with two experienced dentists. For calculation of inter-observer agreement regarding radiographic examination, BW-radiographs from 88 patients (10% of the study sample) were randomly selected. The three dentists independently examined the proximal surfaces from mesial surface of second molar to the mesial surface of first premolar in each quadrant, altogether 28 surfaces per patient, making a total of 2464 surfaces and scored them in a scale of 0 (no finding) 1, 2 (enamel caries) 3, 4, 5 (dentinal caries). On average, the calculated Kappa value between recordings of the three examiners, was 0.61 (0.71). The linear weighted Kappa score is given in parenthesis. Weighted Kappa values are higher because some credit is given for differences in recordings when scores are close to each other. Kappa values were calculated by the statistical software MedCalc® version 12.4.0.0 (Ostend, Belgium). Intra-examiner agreement was also calculated between the two registrations of the principal examiner. Kappa value was 0.58 (0.63) comparing all grades and increased to 0.70 when all positive caries scored were pooled into one category (dichotomized). Corresponding calculation based on dichotomized scores for the BW examinations of 88 patients by three observers, showed a Kappa value of 0.69.

Paper III

Three experienced dentists examined the clinical images from Fit Futures and scored the dental erosive wear according to the VEDE system (Mulic et al., 2010). Prior to the study, the observers were calibrated using 74 intra-oral photographs. Both the calibration and the subsequent scoring of dental erosions were carried out in the same room, using the same liquid-crystal display (LCD) screen and identical lighting. In order to calculate the intra-observer agreement, the same calibration material was scored a second time after 21 days. The average inter-observer agreement expressed by weighted Kappa on the photographs was calculated to be 0.84 for the three dentists, and the intra-observer agreement was 0.71 (observer 1), 0.73 (observer 2) and 0.89 (observer 3), which indicated good agreement (Landis and Koch, 1977).

Data Analysis

For Paper I, statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Student t-test and ANOVA were applied to test differences between groups using DMFS-scores as a continuous dependent variable. The DMFS-scores were then dichotomized at the mean and all independent variables with p-value ≤ 0.05 in the bivariate test (Table 1) were selected to be included in a multivariate regression model (parental education level was used instead of father`s and mother`s separately). A p-value ≤ 0.05 was considered statistically significant.

For Paper II, descriptive analyses and cross-tabulations were performed using IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

For Paper III, descriptive statistics and frequencies distribution were performed using IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.
The significance level was set to $\alpha = 0.05$. Inter- and intra-observer agreement was expressed by the weighted Kappa (Landis and Koch, 1977), and calculated using Microsoft Excel.

Ethical approval

The project was approved by the Regional Committee for Medical Research Ethics (2012/1197 REK Nord) and the Norwegian Data Protection Authority (07/00886-11). All the participants gave written informed consent signed at the study site.

5. RESULTS

Paper I

Dependent variable - dentinal caries

The prevalence of dental caries according to the DMF-index was 82.7% in this sample of 16-year-olds. The distribution was highly skewed (skewness =2.036). Mean DMFT of the sample was 4.16 (± 3.78), range 0-19, while DMFT > 9 was recorded for 9.8%. Mean DMFS was 6.09 ± 6.88, (range 0-48).

Independent variables - Bivariate model

The results of the bivariate analysis including all the independent variables are shown in Table 1.

Table 1. Characteristics of the study population with regard to DMFS index values used as a continuous variable. Bivariate analysis of variance (ANOVA)

Study population: n = 869, mean DMFT/S = 4.16/6.09 (SD = 6.88))

Independent variables		N (%)	DMFS mean	SD	P value
Socio-demographic					
gender	male	449 (51.7)	5.79	6.93	0.189
	female	420 (48.3)	6.40	6.82	
ethnicity	Norwegian	715 (82.3)	6.12	6.96	
	Sami	31 (3.6)	5.52	4.76	0.892
	immigrants	114 (13.1)	6.13	6.79	
father's education	college	287 (33.0)	4.90	5.98	
	high school	247 (28.4)	6.61	6.89	0.004
	9 years or less	70 (8.1)	7.16	7.55	
	don't know	237 (27.3)	6.64	7.52	
mother's education	college	363 (41.8)	5.32	6.07	
	high school	231 (26.6)	6.49	6.80	0.040
	9 years or less	47 (5.4)	7.21	7.87	
	don't know	213 (24.5)	6.7	7.90	
parents attended college/university	both	208 (23.9)	4.54	5.50	
	one	234 (26.9)	6.19	6.77	0.001
	none	239 (27.5)	7.23	7.51	
	don't know	188 (21.6)	6.21	7.29	
family parental status	both parents	463 (53.3)	5.33	5.90	
	one parent	235 (27.0)	6.81	8.25	0.002
	none of parents	162 (18.6)	7.25	7.00	
Lifestyle					
smoking	no	772 (88.8)	5.88	6.72	0.009
	yes	86 (9.9)	7.92	7.79	
snuff use	no	617 (71.0)	5.37	6.45	0.001
	yes	241 (27.7)	7.91	7.52	
sugar consumption	low	744 (85.6)	5.77	6.69	0.002
	high	107 (12.3)	7.95	7.06	
physical activity (intensity)	high	176 (20.3)	5.72	6.96	
	moderate	234 (26.9)	5.97	6.85	0.225
	low	272 (31.3)	5.84	6.01	
	sedentary	178 (20.5)	7.04	7.93	
physical activity (frequency)	≥ 4 days/week	224 (25.8)	5.50	6.60	
	2-3 days/week	293 (33.7)	6.19	6.95	0.298
	≤ 1 day/week	341 (39.2)	6.41	6.99	
leisure screen time (weekdays)	<4 hours/day	514 (59.1)	5.99	6.88	0.584
	≥4 hours/day	344 (39.6)	6.25	6.88	
leisure screen time (weekends)	<4 hours/day	353 (40.6)	5.63	6.54	
	≥4 hours/day	503 (57.9)	6.44	7.09	0.090

Dental health related perceptions and attitudes					
tooth-brushing frequency	twice or more daily once daily less than once daily	555 (63.9) 198 (22.8) 103 (11.9)	5.28 6.64 9.18	6.12 7.57 7.91	0.001
parental control of oral hygiene	yes no	698 (80.3) 164 (18.9)	5.70 7.65	6.61 7.51	0.001
dental fear	no yes	801 (92.2) 56 (6.4)	5.71 11.02	6.63 7.73	0.001
self-rated dental health	very good, good neither good nor bad bad, very bad	493 (56.7) 292 (33.6) 77 (8.9)	4.44 7.29 11.90	5.69 6.81 9.17	0.001
Dental health parameters					
proximal enamel lesions	<6 ≥6	482 (55.5) 387 (44.5)	3.81 8.92	5.14 7.68	0.001
number of teeth with gingival bleeding	<4 ≥4	148 (17.1) 718 (82.6)	5.05 6.28	5.30 7.15	0.017
General health status					
BMI	normal weight underweight overweight obese	620 (71.3) 50 (5.8) 139 (16.0) 59 (6.8)	5.63 5.02 7.55 8.44	6.56 5.21 7.94 7.88	0.001
chronic diseases/allergy	no yes	621 (71.5) 245 (28.2)	5.92 6.51	6.84 7.00	0.255
self-rated general health	very good, good neither good nor bad bad, very bad	635 (73.1) 180 (20.7) 41 (4.7)	5.51 7.43 9.56	6.39 7.47 9.40	0.001

Socio-demographic factors

Boys had lower DMFS scores than girls but the difference was not statistically significant (Table 1). Norwegian adolescents constituted a majority of our sample (82.3%) with adolescents of immigrant or Sami background representing 13.1% and 3.6% respectively. There was no statistically significant difference in DMFS score between Norwegian and adolescents with immigrant or Sami background. Adolescents where both parents had either college or university education had lower caries score compared to those having one or none of the parents with high education. Adolescents living with both parents had lower DMFS-score compared to those living with one or none of their biological parents. Recordings regarding these two parameters showed statistically significant different values (Table 1).

Lifestyle

About 10 % of the adolescents reported to smoke while 28 % reported regular use of snuff. Both groups of tobacco users had significantly higher caries score than non-users (Table 1). More boys than girls reported regular use of tobacco (12.4% vs 7.5% for smoking and 34% vs

21.8% for use of snuff). Regarding sugar intake, 12.5% of the adolescents reported frequent consumption. This was significantly associated with higher caries prevalence (Table 1). Frequent sugar consumption was more than twice as common in boys as in girls (17% vs 8%). Intensity and frequency of physical activity and time spent daily in front of the TV/computer screen during weekdays or weekends were not associated with differences in caries scores (Table 1).

Dental health-related perceptions and attitudes

A majority of girls (80%) were brushing their teeth at least twice a day compared to 50% of the boys. There was a considerable difference in mean DMFS score between the three toothbrushing frequency groups ($p< 0.001$) (Table 1). Over 80% of the parents used to control oral hygiene of their children. These adolescents had significantly lower DMFS scores than adolescents without parental control of oral hygiene ($p=0.001$) (Table 1).
Dental fear was highly significantly associated with higher mean DMFS scores and adolescents who rated their oral health as bad had almost 3 times higher mean DMFS scores than those who rated their oral health as good ($p< 0.001$) (Table 1).

Dental health parameters

Only 5.6% (49) of the adolescents were recorded completely caries free (DMFS = 0, PEL=0), and 11.6 % (101) had only PEL. About 23% (196) had more than 9 surfaces with PEL. The prevalence of dentinal caries was statistically significantly associated with PEL scores (Table 1). Number of teeth with gingival bleeding showed an association with caries prevalence in the bivariate analysis ($p=0.017$) (Table 1) that disappeared in the multivariate model. Only 2.3% (20) of the participants had periodontal pockets ≥4mm and only one presented with a pocket >5mm.

General health

Over 70% (620) of the students had normal weight, while 6.8 % (59) where obese. There was a statistically significant association between BMI and DMFS score ($p=0.001$), with higher caries prevalence linked to overweight/obesity (Table 1).
Most of the recorded chronic diseases were allergy-related conditions. No association between DMFS scores and chronic diseases was detected. Adolescents who rated their general health as bad had almost 2 times higher mean DMFS scores than those who rated their general health as good ($p< 0.001$).

Independent variables - Multivariate model

The final multivariate regression model comprised only the variables snuff use, dental fear, self-rated dental health and PEL, while the impact of the other selected disappeared (Table 2) indicating substantial co-variance among the parameters included. However, parents' education level and sugar consumption were close to statistical significance. Having ≥6 dental surfaces with PEL increased the chances to have high DMFS scores by O.R. 3.28.

Table 2. Multivariate logistic regression analysis including factors with p-values ≤ 0.05 from the bivariate analysis (Table 1) included in the final model. DMFS-scores are dichotomized with cut-off point DMFS = 6.

Independent variables		**Bivariate p value**	**Multivariate OR (95% CI)**	**Multivariate p value**
parents attended college/university	both one none don't know	P = 0.001		P = 0.092
parental family status	both parents one parent none of parents	P = 0.002		P = 0.133
smoking	no yes	P = 0.009		P = 0.962
snuff use	no yes	P = 0.001	1 1.57 (1.12-2.21)	P = 0.010
sugar consumption	low high	P = 0.002		P = 0.084
tooth-brushing frequency	twice or more daily once daily less than once daily	P = 0.001		P = 0.798
parental control of oral hygiene	yes no	P = 0.001		P = 0.222
dental fear	no yes	P = 0.001	1 3.26 (1.64-6.49)	P = 0.001
self-rated dental health	very good, good average bad, very bad	P = 0.001	1 1.99 (1.43-2.77) 4.51 (2.49-8.16)	P = 0.001
initial approximal caries	<6 ≥6	P = 0.001	1 3.25 (2.39-4.43)	P = 0.001
teeth with gingival bleeding	<4 ≥4	P = 0.017		P = 0.553
BMI	normal weight underweight overweight obese	P = 0.001		P = 0.623

self-rated general health	very good, good average bad, very bad	P = 0.001		P = 0.734

Paper II

Proximal enamel lesions

In the present sample of 16-year-olds, the prevalence of proximal enamel lesions was 83.9%, with a mean of 5.8 ± 5.0 (range 0 – 24). The distribution of subjects with or without proximal enamel lesions in relation to sound (DFS = 0), decayed (DS > 0) and filled (FS> 0) surfaces is presented in Table 3.

Table 3. Distribution of subjects with or without proximal enamel lesions (PEL), in relation to dentinal caries experience, based on DMFS-values. DS, FS, DFS are correspondingly decayed, filled and decayed-and-filled surfaces.

Proximal enamel lesions (PEL) = 0		**140 (16.1%)**
PEL = 0, DFS = 0		50 (5.8%)
PEL = 0, DFS> 0	DS = 0, FS> 0	79 (9.1%)
	DS > 0, FS = 0	3 (0.3%)
	DS> 0, FS> 0	8 (0.9%)
Proximal enamel lesions (PEL) > 0		**729 (83.9%)**
PEL> 0, DFS = 0		101 (11.6%)
PEL> 0, DFS> 0	DS= 0, FS> 0	301 (34.6%)
	DS> 0, FS = 0	28 (3.2%)
	DS> 0, FS> 0	299(34.4%)

In this sample, 16.1% did not have any proximal enamel lesions. However, a majority of these subjects (9.1%) had previously placed restorations and only 5.8% were totally caries-free. A major part of the participants with proximal enamel lesions had either previously restored teeth (34.6%) or both restored teeth and untreated dentinal caries lesions (34.4%). A number of subjects (11.6%) presented with proximal enamel lesions without any caries experience according to the DMFS-scores (Table 3). The estimated odds not to have any proximal enamel lesions (PEL=0) was 0.16 for a student with previous caries experience (DFS>0), compared to 0.56 for a student without previous experience (DFS=0), (OR = 3.45; 95% CI 2.31 - 5.18).

Need for non-operative caries treatment

According to the distribution of proximal enamel lesions, 83.9% of the participants (729) were in need of non-operative caries treatment, either as the only treatment modality (46.2%) or in combination with restorative treatment (37.6%) (Table 3). When using the D-value of the DMFS-index as diagnostic criterion, 38.8% (338) of the participants were in need of operative dental treatment. When proximal enamel lesions were included in the diagnosis, the number of participants in need of individual operative and/or non-operative caries treatment was 85.1% (740) (Table 3).

Quality of dental restorations

In this material, 81.2% (706) of the 16-year-olds had experienced restorative care (Table 4). The distribution of individuals in accordance with the score of their poorest restoration is presented in Table 4. More than one-third of the participants with fillings (35.0%) had at least one restoration below acceptable quality levels (poor/unacceptable).

Table 4. Distribution of subjects according to the quality of the poorest dental restoration.

Individuals with restorations	706[1] (81.2%)
Quality of poorest filling	
Good	37 (5.3%)
Acceptable	421 (59.8%)
Poor	159 (22.6%)
Unacceptable	87 (12.4%)

[1]The quality of restorations in two subjects was not possible to assess due to orthodontic braces.

Paper III

Prevalence, distribution and severity of dental erosive wear

In the randomly selected sample of 392 adolescents, 38% (148) showed dental erosive wear. Looking at the severity of the erosive wear, approximately equal numbers of participants with erosive wear limited to enamel or extending into dentine were found. Figure 1 shows the distribution of participants who had healthy surfaces (grade 0), surfaces with lesions limited to enamel (grade 1-2) and surfaces with lesions extending into dentine (grade 3-5). In the group of participants with erosive wear extending into dentine (20%), half of the participants had both, lesions limited to enamel and lesions extending into dentine, and half showed only lesions extending into dentine. Of the group with erosive wear localized to the enamel (18%), 76% had ≤ 2 affected surfaces while the rest (24%) had 3 or more. The gender distribution of the participants studied was almost equal, 51% (199) were male and 49% (193) were female. A significantly higher share of males (65%) exhibited erosive wear ($p < 0.001$), and lesions extending into the dentine were also more common in male adolescents ($p < 0.001$) (Figure 2).

When assessing the severity of erosive wear based on the type of tooth, more erosive wear was found on molars (18%) compared to both the central incisors (11%) and lateral incisors (10%). On the upper central incisors, erosive wear limited to the enamel was most common, while about the same amounts of enamel and dentine lesions were found on the molars. When comparing the level of erosive wear on the first permanent molars, significantly more lesions were found in the lower jaw in comparison to upper jaw, 8% in the upper and 29% in the lower jaw, respectively (Table 5).

Figure 1. Prevalence of dental erosive wear in the examined population (n=392), divided into individuals without erosive wear, with erosive wear limited to enamel, or erosive wear extending into dentine.

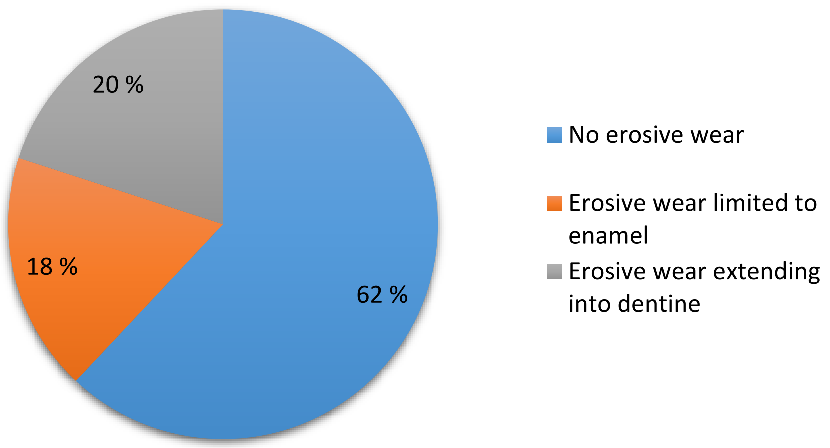

Figure 2. Distribution of gender among subjects with dental erosive wear, erosive wear limited only to enamel or extending into dentine (n=148) (Figure changed from the original one in Paper III).

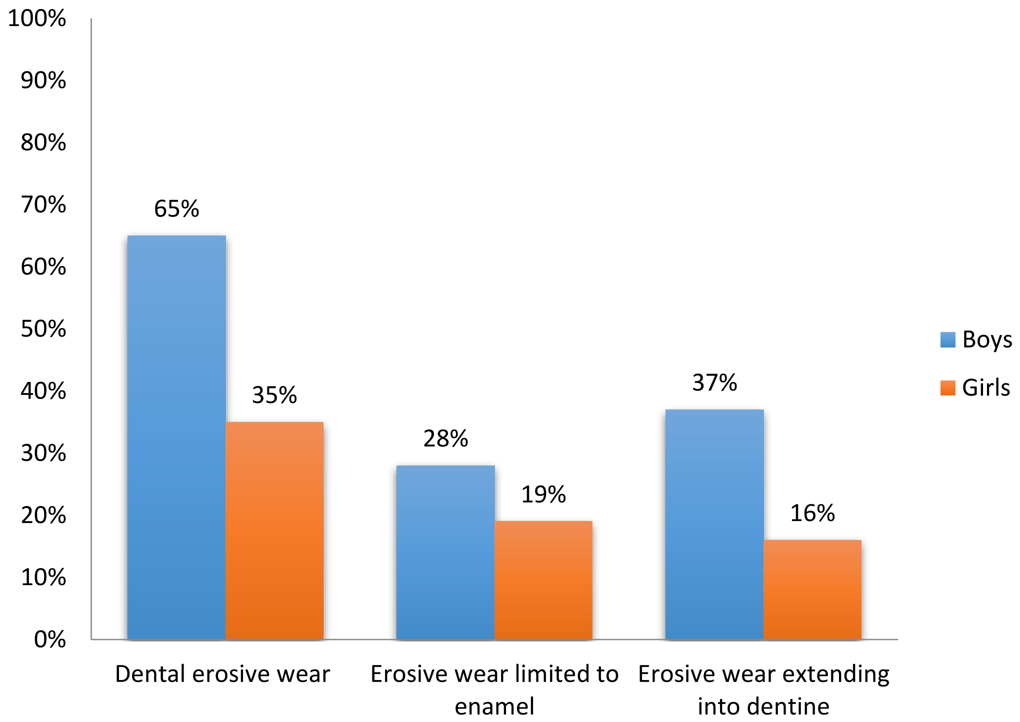

Figure 3. Localization of "cuppings" on 1st permanent molars. Percentage calculated from the sum of "cuppings" (n=309) in the upper and lower jaw of the 136 participants with cuppings.

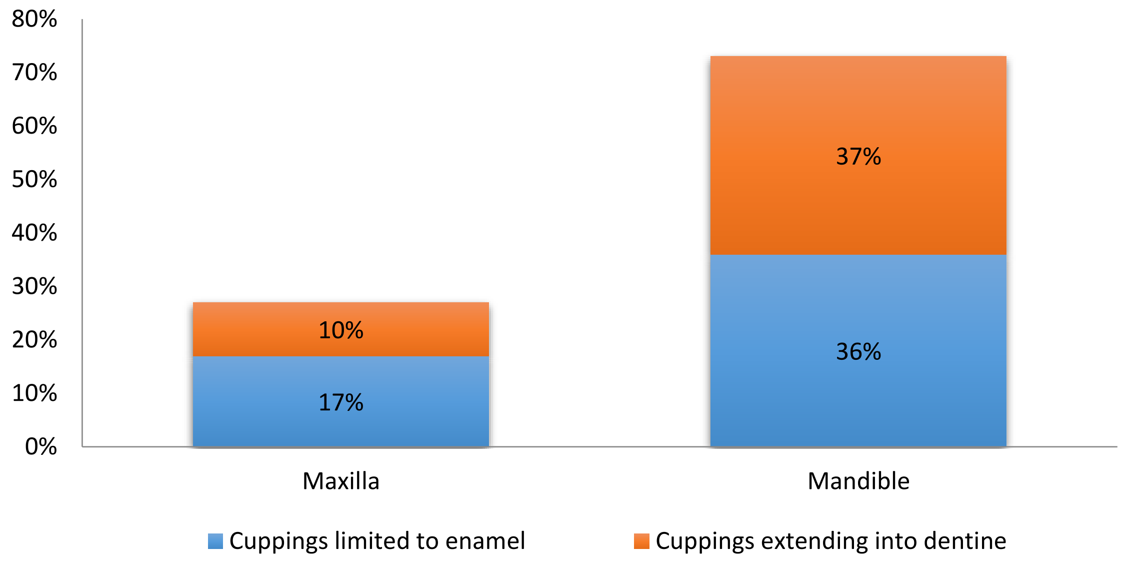

Table 5. Prevalence and severity of erosive wear based on the type of tooth surface (Table changed from the original one in Paper III).

	DEW	Enamel lesions	Dentine lesions	Total
	% (n)	% (n)	% (n)	% (n)
UJ central incisors (B and P)	5 (68)	4 (64)	0 (4)	100 (1462)
UJ lateral incisors (B and P)	3 (43)	3 (43)	0 (0)	100 (1466)
1st permanent molars in total (O)	17 (270)	9 (139)	8 (131)	100 (1556)
UJ 1st permanent molars (O)	7 (54)	5 (40)	2 (14)	100 (782)
LJ 1st permanent molars (O)	28 (216)	13 (99)	15 (117)	100 (774)

DEW: Dental erosive wear, UJ: upper jaw, LJ: lower jaw, B: buccal surfaces, P: palatal surfaces, O: occlusal surfaces

Table 6. Prevalence and number of cuppings.

Lesion extension	Individuals with DEW	Individuals with DEW and cuppings	1 cupping	2 cuppings	≥3 cuppings
	% (n)	% (n)	% (n)	% (n)	% (n)
Enamel	48 (71)	48 (65)	62 (40)	26 (17)	12 (8)
Dentine	52 (77)	52 (71)	18 (13)	37 (26)	45 (32)
Total	100 (148)	100 (136)			

“Cupping” on the molars was found in 92% (136 out of the 148) of the participants with dental erosive wear. They were equally distributed between individuals with erosive wear lesions limited to enamel (48%) and those with erosive wear extending into dentine (52%). Of the participants with lesions limited to enamel, 62% had 1 “cupping” and 12% had 3 or more. In the group of participants with lesions extending into dentine only 18% had 1 “cupping”, while 45% had 3 or more (Table 6). In total, 309 “cuppings” on the first permanent molars were registered, 27% (85) in the upper jaw and 73% (224) in the lower jaw (Figure 3). In the upper jaw the “cuppings” were localized mostly in the enamel, while in the lower jaw they were equally common in the enamel and dentine. The mesiobuccal cusp was most often affected (75%, n = 231).

6. GENERAL DISCUSSION

The main focus of the present study was the dental health conditions among a group of adolescents in northern Norway and specifically, dental caries and erosive lesions. Particular emphasis is placed on proximal enamel lesions and non-operative treatment intervention. The study has a cross-sectional design and, since the sequence of events (exposure to variables and onset of disease) is uncertain, the detection of definite causal relations is not possible and only indications for associations are disclosed (Levin, 2006).

Methodological considerations (Paper I)

Representativity

The present thesis was based on a cross-sectional oral and general health study, the Fit Futures, which is a population-based youth study (Winther et al., 2014).
The attendance rate (90%) was high, compared with similar studies (Mulic et al., 2013, Norderyd et al., 2015b), and male and female genders were equally represented (50.7% males, 49.3% females). Among the 1010 participants in the oral part of Fit Futures study, 95 % were born in 1992 or later, and within this group, all subjects born in 1994 (869, 51.7% males versus 48.3% females) were included in the present study.
Lower secondary education is compulsory in Norway, and in 2010-2011, more than 95% of students in Troms county had moved on from lower secondary school to first year of upper secondary school, usually as 16-year-olds (Statistics Norway, 2014).
In Troms County, 86% of the population lives in urban or densely populated, urban-like areas (Statistics Norway, 2014). The number of participants from the two municipalities (92% from

Tromsø municipality (urban) against 8% from Balsfjord municipality (rural)) corresponds to the demographic structure between urban / rural areas in Troms county.

On the basis of the above information, the results of the study can be considered representative for the county and valid indicators for oral health conditions in the age group examined in this part of Northern Norway. The combination of oral and general health part in the study provided an opportunity to monitor oral health among adolescents in the region and correlate dental caries and a multitude of determinants (sociodemographic characteristics, oral health attitudes, general health, lifestyle). However, the possibilities for direct comparison with national oral health statistics in Norway are limited, as the reference groups used nationally are 12 and 18 year-olds (Statistics Norway, 2014).

Non-participation in a study may result in bias if the reasons for non-participation are associated with either the exposure or the outcome studied affecting the representativity of the sample (Galea and Tracy, 2007). Non-participants have often low socioeconomic status, which is related to poor health conditions and, among adolescents, non-attendance to dental examination is associated with poor oral health (Galea and Tracy, 2007, Fägerstad et al., 2016). Analysis of non-participation in this study was not performed, but the overall high attendance rate might have reduced the risk for non-response bias (Galea and Tracy, 2007, Mindell et al., 2015).

The questionnaires

Questionnaires are prone to various forms of response bias in health research. Risk of bias might be reduced in the present study, as the questionnaires used were previously validated, pretested and used in studies of comparable age cohorts (Choi and Pak, 2005, Cook, 2010, Furberg, 2010). The use of self-administered electronic questionnaire for information about dietary habits and lifestyle might have facilitated reporting of some sensitive behaviors compared to paper and pencil or face to face interview methods (Hallfors et al., 2000).

Ethnicity

Ethnicity in the present study was registered based on self-perceived ethnicity, since ethnicity information for residents in Norway is not recorded. Presently, self-perceived ethnicity is prevailing over geographic or language indicators of ethnicity in health research (Bhopal, 2004). Additional questions on student's country of birth, mother's country of birth and father's country of birth provided supplementary, objective information on ethnic origin, and could secure identification of second generation of immigrants (Stronks et al., 2009).

Concerning validity of self-reported information, Nordahl et al. (2011) showed that students as young as 11 years can give valid answers about own and parents ethnicity background.

Sami participants

Among the 869 participants in the present study, 3.6% individuals considered themselves as Sami (self-perceived ethnicity). The Sami Parliament electoral register is a register of Sami people in Norway. For 2011, 1.5% of the total number of inhabitants in both participating municipalities was registered in the Sami Parliament electoral register. However, the Sami electoral register is not based on self-perceived ethnicity. It includes only people over 18 years who vote for the Sami Parliament and fulfill some language criteria. Consequently, it is not possible to assess whether the percentage of Sami participants in the present study corresponds to the percentage of Sami people in the total population of the included municipalities, a challenge discussed by Pettersen (2015).

Moreover, the low number of identified Sami participants may have resulted in an unreliable estimation of dental health in this group of adolescents.

Participants with immigrant background

The percentage of students with immigrant background in the sample of 869 participants (13.1%) was higher than that reported from Statistics Norway in 2010 (8.4% in Tromsø and 3.3% in Balsfjord municipalities) (Statistics Norway, 2014). The official statistical data are supplied from various sources (the local population registry offices, tax administration etc.), since an ethnicity registry at an individual level is lacking in Norway, and may not be as accurate as an ethnicity registry would be. The higher percentage of students with immigrant background in the assessed sample may be explained by the younger average age of individuals with immigrant background in Norway the last years (Statistics Norway, 2014). In that way, immigrants may be overrepresented in school ages.

The estimate of number of participants with immigrant background identified may have resulted in a reliable estimate of dental health in this group of adolescents.

Caries registration

The registration of proximal lesions was based on intraoral radiographs (bite-wings) which is a common method for assessing prevalence of caries in proximal surfaces. The intraoral radiographic examination has low sensitivity for the diagnosis of proximal initial lesions (The Swedish Council on Technology Assessment in Health Care, 2007) and the quality of evidence for radiographic detection of non-cavitated lesions is poor (Gomez et al., 2013, Mejare et al., 2015). Although bitewings are not necessary for assessing epidemiological trends (Poorterman et al., 1999, Bloemendal et al., 2004, Baelum et al., 2006, Agustsdottir et al., 2010, Nørrisgaard et al., 2016), they are necessary for calculating the prevalence of disease.

Calibration

The oral investigation was performed in a clinical setting and the principal investigator (IDJ) was thoroughly calibrated with experienced clinicians reaching substantial intra- and inter-observer agreement (Kappa=0.70 and 0.71 respectively) securing reliability. Calibration is extensively dealt with in Materials and Methods.

Statistics

Parametric statistical tests (Students t-test and ANOVA) were applied for descriptive purposes (Table 1) using DMFS scores as a continuous variable. Although the caries data were skewed, these parametric tests are robust and acceptable considering the large number of observations (Fagerland, 2012). In the present study, a number of variables in the initial bivariate analyses showed a significant bivariate association, but this number of variables decreased substantially in multivariate analysis, indicating substantial covariance. Simple bivariate correlations can be severely biased and lead to false conclusions due to the ignorance of possible correlations and covariance with other background characteristics, while the multivariate analysis may disclose underlying relationships by accounting for the influence of other observable variables (Fuchs and Woessmann, 2004).

Methodological considerations (Paper II)

Proximal enamel lesions

In Paper II only proximal enamel lesions were included, as proximal surfaces of the young adolescents contribute mostly to the caries burden in later age (Mejàre et al., 2004, Crossner and Unell, 2007, Sköld, 2016). Smooth and occlusal surfaces were not included, as buccal and lingual decay is a minor problem among Nordic teenagers and in order to eliminate uncertainties in visual discrimination between hypomineralizations and enamel lesions (Crossner and Unell, 2007, Norderyd et al., 2015a).

Active – arrested lesions

Activity assessment of the lesions was not performed in the present study due to the cross-sectional study design. Assessment of lesion activity at one single visit is shown to result in poor accuracy and reliability (Ekstrand et al., 2009, Ismail et al., 2015). Activity assessment at one examination is possible only based on a combination of clinical indicators including visual appearance, tactile feeling, potential for biofilm accumulation and gingival status and necessitates additional resources, such as trained/calibrated examiners and previously cleaned teeth (Ismail et al., 2015).

The non-discrimination of active and arrested caries in this study might have resulted in some over-estimation of the need for non-operative treatment. Agustsdottir et al. (2010), in the Icelandic Oral Health Survey (data collected in 2004-2005), reported activity in the majority of lesions in all age groups of young people examined. In their study, 70% of initial precavitated lesions among the 15-year-olds were active.

A possible over-estimation of the need for non-operative treatment in the present study entails the use of non-operative treatment in all non-cavitated initial lesions, also in those non-actives. However, due to the nature of non-operative procedures, these measures are not harmful.

Quality of fillings

The quality of restorations in this cross-sectional study was evaluated exclusively based on the assessment of their current performance and considering tooth prognosis since information about accurate dates, history and clinical parameters of placement of restorations were missing. Moreover, since the unit for analysis was the individual and not the restoration, the comparison with other studies is difficult.

The inclusion of radiographic criteria, in addition to the clinical ones, for the evaluation of restorations, might have increased the number of participants identified with at least one defective filling. This finding has been reported previously by Sonbul and Birkhed (2010). The use of exclusively clinical criteria would have left a number of defect restorations undetected (anatomical form, marginal adaptation etc.).

Methodological considerations (Paper III)

Erosive wear registration

Due to the extensive workload for three examiners to evaluate eight intraoral photos of 869 students, the assessment of dental erosive wear was not performed in the total group of 16-year-olds but in a representative randomly selected subgroup of 392 students. The subgroup had almost equal gender distribution (50.8% males, 49.2% females).

Furthermore, partial mouth scoring was decided for efficient use of available resources (time and finances), in order not to increase the number of false positive lesions detected, and not to reduce accuracy (Young et al., 2008). Erosive wear in the present study was scored on

selected teeth / surfaces, which were consistently more affected by dental erosion based on a number of earlier relevant studies (Mulic et al., 2010). The first molars and the palatal and buccal surfaces of maxillary incisors may be particularly exposed to erosive wear action, due to earlier eruption of these teeth (Isaksson et al., 2013, Mulic et al., 2013). Mandibular front-teeth were excluded from scoring due to difficulties in distinguishing wear due to erosion from wear supposed to be caused by attrition/abrasion, although presence of the last mentioned conditions is low in young age (Al-Dlaigan et al., 2001).
Identical study methods, i.e. same sample size, use of the same grading system, calibrated clinicians, choice of the index teeth and the age of the participants allow for the comparison of prevalence of dental erosion in this study with two other studies from Norway (Mulic et al., 2013, Søvik et al., 2014).

The use of clinical photos

Erosive wear in the present study was recorded from clinical intraoral photographs of high quality, eight for each participant, taken by a specially trained dental assistant following a standardized procedure (see Materials and Methods). The observer could spend an unlimited amount of time examining the photos and the scoring could easily be repeated.
Concerning the validity of this method, Al-Malik et al. (2001a) compared scoring of erosions in children (primary maxillary incisors) by using clinical and photographic examination, and found substantial agreement, although the extent of wear in dentin might be underestimated in photographs (Al-Malik et al., 2001b). Furthermore, the findings of Mulic et al. (2010) suggested that both methods, clinical examination and use of clinical photos could be acceptable for measuring dental erosive wear. Hove et al. (2013) also used photographs and clinical examination for scoring of dental erosions and found no significant difference between these methods. This documentation indicates that the present erosion data are reliable.

Calibration

In the present study, the average inter-observer agreement expressed by weighted Kappa based on the photographs was calculated to be 0.84 for the three dentists, and the intra-observer agreement was 0.71 (observer 1), 0.73 (observer 2) and 0.89 (observer 3), indicating substantial agreement. This was advantageous, as, in a range of relevant studies, low inter-examiner agreement was reported (Larsen et al., 2005, Mulic et al., 2010, Søvik et al., 2014). The low inter-examiner agreement was attributed to the difficulty for examiners to detect initial erosive lesions and the increased variability among the many examiners involved in the studies. In the present study, the thorough calibration of the examiners, the lower number of examiners than in the studies mentioned, and the relatively lower percentage of erosive wear in enamel found may explain the higher agreement levels.

Ethical considerations

The project concerned research on personal and health data and was approved by the Regional Committee for Medical Research Ethics (2012/1197 REK Nord) and the Norwegian Social Science Data Services (NSD) (07/00886-11). The study complies with the Declaration of Helsinki, International Ethical Guidelines for Biomedical Research Involving Human Subjects and the International Guidelines for Ethical Review of Epidemiological Studies. Participants gave a written informed consent prior to the study. Participation was voluntary and the participants retained the right to withdraw their consent at any moment from the study. As the study concerned students in first year of upper secondary school and some among them were younger than 16 years of age by the day of the study, additional written consent was obtained for these subjects from their parents/guardians. Participants were informed in detail orally, electronically and a brochure was distributed to students and parents/guardians. The information given to participants concerned the objectives of the study, a description of examinations and measurements included, the type of data collected for each participant, and the future use of data collected in research.

The oral part of Fit Futures included clinical procedures (dental examination, taking of intra-oral radiographs) well known and used regularly during the annual clinical examination in the PDS. The clinical examination was performed by experienced personnel and did replace the annual clinical examination. In case that the participants already had completed annual oral examination, they were excluded from radiographic examination. Clinical and radiographic data were recorded in patient files for treatment or for follow up. Clinical intraoral pictures did not display individual identification.

Upon completion of data collection, the data was stored de-identified in the Tromsø Study database (EUTRO), a data storage and management system, designed and administrated by the Department of Community Medicine, UiT The Arctic University of Norway, Tromsø (The Department of Community Medicine, 2010).

Main findings

Caries prevalence (Paper I)

The prevalence of dental caries and the mean DMFT/S in the present sample correspond with the figures reported at the Norwegian national level and with the figures for Troms county (Statistics Norway, 2014). This indicates that the caries status among 16-year-olds in Northern Norway has improved and that the previously documented regional difference between the North and South of Norway is diminishing (Mulic et al., 2013). However, data from epidemiological studies facilitating direct comparison with the age group studied are lacking. Results from Scandinavian studies indicate, however, that the caries prevalence among adolescents in Norway is higher than in Sweden, Denmark and Finland (Table 5).

Table 7. Mean caries score and prevalence of caries in the present study (Jacobsen et al, 2016) compared with results from similar Scandinavian studies.
(Di+mMFT/S is including both initial (i) and manifest (m) caries).

Study / country	Age / year of examination	Sample (N)	Caries score	Prevalence of caries
Jacobsen et al. (2016) Norway	16-year-olds 2010-11	869	6.1 (DMFS) 4.2 (DMFT)	82.7% (DMFT)
Mulic et al. (2013) Oslo	18-year-olds 2008-2009	1426	4.0 (DMFT)	76.0% (DMFT)
Nørrisgaard et al. (2016) Denmark	15-year-olds 18-year-olds 2012	1509 1168	2.06 (DMFS) 3.92 (DMFS)	45.3% (DMFT) 66.0% (DMFT)
Kämppi et al. (2013) Finland	19-21-year-olds	13504	4.11 (DMFT)	78.7% (DMFT)
Norderyd et al. (2015a) Sweden	15-year-olds 2013	101	2.9 (Di+mMFS)	57% (Di+mMFT)

The documented inferior caries status among adolescents in Norway is surprising, since the Scandinavian societies and their dental care systems are quite similar. They have health priorities based on a social welfare model and public dental health services for children and adolescents are based on prevention and are free of charge. There are, however, minor differences in the structure and provision of dental care in the various Scandinavian countries (number of work force and their tasks, risk strategy including definition of risk individuals, recall routines, prevention at group level and time allocated to prevention) (Wang and Aspelund, 2010). Nadanovsky and Sheiham (1995) have argued that the contribution to the caries decline from chair-side dentistry is of minor importance in comparison with the role of larger scale measures on society level like fluoridated toothpaste, oral health education at schools and availability of non-cariogenic snacks. Both clinical and chair-side activities and more general factors might explain the observed difference in caries prevalence (Table 7). However, our data do not offer any clue regarding reasons for the observed difference and it is beyond the scope of the present investigation to analyze these aspects.

Ethnicity and caries (Paper I)

Sami ethnicity was not associated with higher caries prevalence in the present study. However, the low number of identified Sami participants may have resulted in an unreliable estimate of dental health in this group of adolescents.

According to Pettersen (2015), most of the Sami population are well integrated in the modern Norwegian society and only a few are still pursuing traditional reindeer herding and a nomadic lifestyle. Thus, the finding of no difference in oral health between ethnic Norwegians and individuals with Sami background in the present sample may be explained by a high degree of social integration of Sami people within the Norwegian society. The dual self-perceived ethnicity (Norwegian and Sami) stated by a majority of the Sami participants supports this argument, indicating a weak relationship with Sami ethnicity (Lund et al., 2007).

Immigrant ethnicity was not associated with inferior oral health among 16-year-olds in the present study. This is contrary to the results from comparable Scandinavian studies documenting higher levels of caries among children with immigrant background, stating that the reported trends of caries reduction may concern only non-immigrants (Sundby and Petersen, 2003, Wigen and Wang, 2010, Stecksén-Blicks et al., 2014, Östberg et al., 2016). Julihn et al. (2010) and Jacobsson et al. (2011) found that immigrant adolescents had higher caries prevalence, irrespective of whether or not they were born abroad and despite their enrollment in regular dental public health care programs. In the present study, the adolescents of immigrant background were included in regular public dental care and were well integrated in the Norwegian society. This might explain the registration of no difference in their dental health condition. Investigation of immigrants' dental health according to country/region of birth and to immigration status (immigrants or descendants) might have disclosed further differences in dental status (Nordahl et al., 2011), Bast et al. (2015). However, such analyses were not performed in the present study due to too few participants giving insufficient statistical power.

Lifestyle factors and dental caries (Paper I)

Findings in the present study confirm the already shown association of lifestyle factors with dental caries (Sakki et al., 1994, Caufield and Griffen, 2000, Christensen et al., 2015). Among lifestyle factors tested in the present study, cigarette smoking, use of snuff and consumption of sugar were found to be statistically significantly associated with dentinal caries in a bivariate model. However, only use of snuff was still significant in the final multivariate model. This indicates covariance among lifestyle factors and is in agreement with a number of previous studies (Burt and Pai, 2001, Hugoson et al., 2012, Benedetti et al., 2013, Holmen et al., 2013).

Proximal enamel lesions (Paper II)

The high prevalence of PEL recorded in the present study is in agreement with results from other similar studies in low caries prevalence populations (Alm et al., 2007, Norderyd et al., 2015a). This finding is important since early proximal lesions in adolescents contribute substantially to the caries burden in later age (Mejàre et al., 2004, Crossner and Unell, 2007, Sköld, 2016). Most lesions develop before the age of 20 years, as shown by Crossner and Unell (2007) and Norderyd et al. (2015a).

Quality of restorations (Paper II)

The present study disclosed a high number of 16-year-olds (28%) with at least one filling of poor / unacceptable quality. This high prevalence might in part be due to the radiographic evaluation of quality of fillings which increases the number of participants identified with defective fillings while only clinical evaluation may leave a number of defects undetected (Sonbul and Birkhed (2010). It is surprising that over one third of the present young participants were in need of repair / replacement of defective filling(s), since these fillings must be rather new. Defective fillings contribute substantially to the high restorative burden in everyday dental practice (Qvist, 2012). As restorative dental materials currently used are of good quality, patient and dentist factors might explain the failure of restorations (Kopperud et al., 2016). Concerning dentist factors, the quality of clinical restorative work in the PDS in

Norway is good and homogenous according to Dobloug and Grytten (2015). It was therefore surprising to detect high prevalence of defective fillings in the present study.

Dental erosions (Paper III)

In the present study, 38% of the sample presented with erosive wear and almost equal numbers had erosive enamel lesions or lesions extending into dentine (Figure 1). These findings correspond well with the results of a study on 18-year-olds in Oslo using the same index (Mulic et al., 2013). Studies from other Nordic countries (Arnadottir et al., 2010, Hasselkvist et al., 2010, Isaksson et al., 2014) have reported varying prevalence of dental erosive wear in adolescents. The difference in prevalence may be explained by several factors, such as differences in number and group of teeth examined, index used, age group and timespan of the examination. Furthermore, variation in dietary habits and lifestyle among participants from different countries may also influence the results. In their systematic review, Salas et al. (2015) found high variation in prevalence of erosive conditions among children and adolescents worldwide and indicate the importance of choosing an index detecting specifically the erosive condition and not tooth wear with combined etiology.

Concerning gender distribution, the prevalence and severity of dental erosions were significantly higher in males than females in the present study. This corresponds well with previous research (Hasselkvist et al., 2010, Mulic et al., 2012a, Mulic et al., 2013, Søvik et al., 2014, Hasselkvist et al., 2016) although there are some studies indicating the opposite or no gender difference (Bartlett et al., 1998, Isaksson et al., 2014).

In the present study, 93% of adolescents with erosive wear also presented with cuppings on first molars, mostly in lower jaw. Cuppings on molars are considered as an initial sign of erosive wear (El Aidi et al., 2010, Isaksson et al., 2014, Søvik et al., 2014) and their presence is pointing to the need for accurate examination of the patient’s erosive status.

It is shown that erosive wear is increasing with age (El Aidi et al., 2010, Hasselkvist et al., 2016). Hasselkvist et al. (2016) reported 35% progression of erosive wear from 13-14 to 17-19 years of age. Øvrebø (2011)) found that drinking habits of young adolescents from Northern Norway changed during adolescence and especially boys adopted poorer drinking habits related to sugary drinks. Norwegian youth from 10 to 24 years of age represent the highest proportion of consumers of this category of drinks (Statistics Norway, 2014). The official statistics of Norway do not cover the consumption of the full range of drinks with erosive action among adolescents. They provide information on the consumption of traditional sugary soft drinks only. Despite a decline in the consumption of drinks belonging to the last mentioned category (carbonated beverages, juices), other beverages with erosive potential have recently been introduced on the market (energy drinks, zero drinks, drinks with artificial sweeteners) and the market is constantly supplied with drinks with erosive potential. The majority of 16-year-olds who present with erosive wear today will likely need treatment in the future.

7. CONCLUDING REMARKS

According to the findings in the present study, dental caries and erosive wear are challenging conditions among North Norwegian 16-year-olds. These North Norwegian 16-year-olds were in need of restorative treatment related to untreated caries (39%) and compromised restorations (28%), and 10% had DMFT>9. Their caries status was inferior to adolescents from other Scandinavian countries, but comparable to the prevalence reported from the South of Norway.

The prevalence of proximal enamel lesions was high, entailing a need for non-operative treatment interventions. In spite of being enrolled in a public dental health care system free of charge, of good quality and characterized by high financial and human resource allocations, over 85% of the examined 16-year-olds were in need of individual operative and/or non-operative treatment.

The prevalence and severity of erosive wear were high among the North Norwegian 16-year-olds. Increasing consumption of erosive drinks among Norwegian youths and the absence of strategies for preventing erosive conditions are matters of concern as they may result in complicated future treatments.

The present study is, to our knowledge, the first study assessing the treatment need of adolescents in Norway with focus on non-operative treatment and documents that the caries disease and erosive conditions are widespread within this teenage population. These findings further indicate reasons for considering a change in the PDS treatment strategy. Instead of trying to identify risk-groups and to prolong recall intervals, a relevant and successful treatment strategy for teenagers might be general prevention and shorter recall intervals in order to diagnose any active disease (caries or erosion) in time for non-operative treatment. This implies an individually adjusted treatment, cost effectually performed by auxiliary dental personnel, during a period when many permanent tooth surfaces are newly erupted. The teen years is a vulnerable time in life. Adolescents leave parental guidance, family routines and food habits, and need support on the way to an adult life. The DMFS-score and the high number of 16-year-olds with restorations in need of repair or replacement further indicate the importance of a “non-operative” treatment strategy in order to reduce the need of traditional restorative care aiming at minimizing the vicious operative re-treatment circle throughout life.

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