On dental erosive wear among different groups in Norway

Scoring systems, prevalence and risk indicators

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Oslo, 2012

Aida Gacic Mulic

LIST OF PAPERS

The following Papers (I-V) are submitted in partial fulfilment of the requirements for the degree Philosophiae Doctor (Ph.D) at the Faculty of Dentistry, University of Oslo, Oslo, Norway.

Paper I Mulic A, Tveit AB, Wang NJ, Hove LH, Espelid I, Skaare AB.

Reliability of Two Clinical Scoring Systems for Dental Erosive Wear.

Caries Res **2010**; 44:294–299.

Paper II Mulic A, Tveit AB, Skaare AB.

Prevalence and severity of dental erosive wear among a group of Norwegian 18-year-olds.

Acta Odontologica Scandinavica, **2012**; 1-7.

Paper III Mulic A, Skudutyte-Rysstad R, Tveit AB, Skaare AB.

Risk indicators for dental erosive wear among 18-year-olds in Oslo, Norway. In manuscript.*

Paper IV Mulic A, Tveit AB, Songe D, Sivertsen H, Skaare AB.

Dental erosive wear and salivary flow rate in physically active young adults.

BMC Oral Health, **2012**; 12:8.

Paper V Mulic A, Tveit AB, Hove LH, Skaare AB.

Dental erosive wear among Norwegian wine tasters.

Acta Odontologica Scandinavica, **2011**; 69:21–26.

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INTRODUCTION

Dental health has experienced a stupendous change during the last decades. A substantial reduction in prevalence of dental caries in industrialized countries, especially among children and adolescents, has been confirmed [Hugoson et al., 2008a; Marthaler, 2004]. There has also been a decline in the prevalence and severity of periodontal diseases [Hugoson et al., 2008b; Skudutyte-Rysstad et al., 2007]. These substantial reductions of the most common dental diseases have caused a change in perception and focus on dental erosive wear, which is today an area of research undergoing growth. In a recent questionnaire-based study, Norwegian dentists reported that they registered more erosive lesions today compared with 10-15 years ago [Mulic et al., 2012]. This suggests that the diagnosis of the condition and identification of aetiological factors are becoming important.

Dental erosive wear

Dental erosion has been defined by Pindborg [1970] as progressive loss of dental hard tissue without involvement of bacteria, and a more extensive definition is given by ten Cate and Imfeld [1996]: "The clinical term dental erosion is used to describe the physical results of a pathologic, chronic, localized loss of dental hard tissue that is chemically etched away from the tooth surface by acid and/or chelation without bacterial involvement. The acids responsible for erosion are not products of the intraoral flora**."**

In recent studies emphasis has been made to distinguish the term *dental erosion* from *dental erosive wear* [El Aidi et al., 2011; Huysmans et al., 2011]. Although the terms have been considered as synonymous, dental erosion definition has been currently limited to a chemical process caused by acids, whereas erosive tooth wear has been extensively defined as a clinically manifest erosion-facilitated wear process. Since it is not easy to measure clinically erosion alone, as coexistence of other types of tooth wear (abrasion, attrition, abfraction) will

always be present, the term *dental erosive wear* is applied to mine results in this thesis when the clinical condition of dental erosion is described.

Dental erosive wear is becoming increasingly significant in the long term of the dental health since once the tooth surface is destroyed it may compromise the health of the dentition, and will require repeated maintenance throughout life.

Different diagnostic criteria for clinically recording dental erosive wear

The choice of method used to register erosive lesions will affect the recording of dental erosive wear. To increase comparability between epidemiological surveys, when designing a study, different diagnostic thresholds should be considered: number of examiners, selection of study population, age groups and teeth examined, and whether the dental examination should be carried out in a dental clinic or under field conditions. Another major factor which must be taken into account prior to the commencement of a study is selection and testing of a grading system used to assess tooth substance loss [Bardsley, 2008].

To be able to record presence and severity, as well as progression of an erosive lesion, use of a grading system is required [Ganss et al., 2011]. A range of different scoring systems for dental erosive wear have been proposed and used in epidemiological studies over recent decades. As pointed out in a review by Kreulen et al. [2010], nine scoring systems were applied in 29 studies. Mostly these are modifications of previously published indices [Eccles, 1979; Lussi, 1996; Smith and Knight, 1984], and are characterized by distinguishing between erosive tooth wear in enamel and dentine. Unfortunately, the indices developed all over the world vary considerably with respect to scale, grading, definitions, as well as information provided, giving limited ability to compare data between studies and different countries. Even though validating a scoring system prior to an epidemiological study may be an attempt to avoid diagnostic uncertainties, most studies have been carried out with measurement systems

of untested reliability. Bardsley [2008] defined an ideal index as simple to understand and use, clear in its scoring criteria and apparently reproducible. Its application should be useful for research into the aetiology, prevention and monitoring of a condition, being an epidemiological and clinical tool. With that in mind, Basic Erosive Wear Examination (BEWE) was recently introduced. The scoring system aims to increase awareness of dental erosion among clinicians and to establish a simple tool for scoring erosive wear both in general dental practice and for research purposes [Bartlett et al., 2008]. The system records dental erosive wear on a four-point scale from 0 to 3 without distinguishing between enamel loss and exposed dentine (Table 3). The scoring system gives a cumulative score which is matched to a risk level so the management of the condition can be proposed. Even though the intention of the system is important and valuable, there are still some limitations before it can reach the perfection it seeks [Milosevic, 2011].

In the student dental clinics at the University of Oslo, a modification of the dental erosion index proposed by Lussi [1996], has been used. The main intention with the grading system, Visual Erosion Dental Examination (VEDE), is to introduce a simple registration tool with clearly defined grades supported by a pictures-based classification. VEDE measures erosive wear at tooth surface level on a six-point scale from 0 to 5, and records enamel and dentine separately, like many previous indices. A novelty with the VEDE system is the written classification accompanied by a pictorial manual [Mulic et al., 2010] (Table 3).

It is clearly a challenge to try to develop a simple grading system that can be used clinically to assess presence, severity and progression of dental erosive wear. Perhaps it may be necessary to accept that *one* simple index does not meet all these requirements. There is obviously a need in future research to explore methods for validation of erosive wear systems so a correct registration of tooth substance loss could be accomplished. However, the main

goal should be to develop indices that are internationally accepted, standardized and validated in order to strengthen knowledge of dental erosive wear [Bartlett et al., 2008].

Prevalence of dental erosive wear

Despite the fact that the reported prevalence of dental erosive wear vary and cannot be directly compared, there are indications that it is relatively common among children and adolescents [Arnadottir et al., 2010; Bardolia et al., 2010; Caglar et al., 2011; El Aidi et al., 2010; Gurgel et al., 2011; Hasselkvist et al., 2010; Margaritis et al., 2011; Wang et al., 2010]. Several studies examining children aged 2-5 years (primary dentition) have shown a prevalence of dental erosion between 6% and 52% [Al-Malik et al., 2002; El Aidi et al., 2010; Luo et al., 2005; Murakami et al., 2011]. It has been suggested that, due to structural differences, primary teeth are more susceptible to erosive influence compared with permanent teeth [Johansson et al., 2001]. Johansson et al. [2001] reported a lower microhardness and a thinner enamel layer in deciduous teeth than in permanent teeth. Recently, Kreulen et al. [2010] have shown in a review paper that dentine lesions in primary teeth increase linearly with age. In the permanent teeth, this association could not be found: age and tooth wear into dentine were not related.

The reported prevalence of dental erosion in permanent teeth in adolescents has varied from 20% to 58% in recent studies [Arnadottir et al., 2010; Bardolia et al., 2010; Caglar et al., 2011; El Aidi et al., 2010; Gurgel et al., 2011; Hasselkvist et al., 2010; Margaritis et al., 2011; Okunseri et al., 2011] (Table 1). The studies are difficult to compare due to different examination standards (reliability of examiner(s), various scoring systems, different marker teeth and surfaces) and subject selection (age, gender, number of examined individuals, socioeconomic status and geographical location) [Lussi and Jaeggi, 2011a].

Table 1. Recent epidemiological studies on prevalence of dental erosion in adolescents listed according to publication year (2010-2012).

Author	Year	Country	Sample		Grading system (modification)	Erosion prevalence
			Age	Subjects		
Mulic et al.	2012	Norway	18	1456	VEDE (Lussi)	38%
Gurgel et al.	2011	Brazil	12 & 16	414	O'Brien	20%
Margaritis et al.	2011	Greece	14-16	502	BEWE	58%
Okunseri et al.	2011	USA	13-19	1314	(Smith & Knight)	45%
Arnadottir et al.	2010	Iceland	12	2251	(Lussi)	16%
			15			31%
Bardolia et al.	2010	Great Britain	13-14	629	(Smith & Knight)	20%*
El Aidi et al.	2010	The Netherlands	11	622	(Lussi)	30%
			15			44%
Hasselkvist et al.	2010	Sweden	13-14	227	SEPRS (Johansson)	12%*
			18-19	247		22%*
Wang et al.	2010	South-China	12-13	1499	Eccles/O'Sullivan	27%

* with dentine exposure

Because it is easier to recruit schoolchildren and adolescents than adults, there are only a few prevalence studies on adult populations [Fares et al., 2009; Johansson et al., 1996; Lussi et al., 1991; Skaare et al., 2011]. Skaare et al. [2011] found that 54% of the examined 18- to 35-year-old university students in Oslo had at least one tooth with dental erosive wear, 24% in the enamel and 30% into dentine. Studies have shown that prevalence of dental erosive wear [El Aidi et al., 2008] and tooth wear in general [Van't Spijker et al., 2009] increases with age.

Interestingly, Rodriguez et al. [2012] found that tooth wear progression in 63 examined participants with a mean age of 39.1 years was relatively slow; 78% of the participants showed median wear <15µm over a 6-month period.

There are only a few studies that have investigated the incidence of dental erosion. Ganss et al. [2001] evaluated 1000 study models of children, mean age 11.4 years. After five years, new casts were made of 265 individuals and examined. The proportion of permanent teeth with moderate lesions increased from 5.3% to 23%, while teeth with more severe lesions increased from 0.4% to 1.5%. The same study revealed that individuals with erosive lesions in their deciduous dentition had a significantly increased risk (relative risk 3.9) of development of lesions in their permanent dentition. Harding et al. [2010] concluded, in a longitudinal study, following participants at age 5 and 12 years, that tooth wear is a lifelong cumulative process, and should be registered in both the primary and permanent teeth. A study from Netherlands [El Aidi et al., 2010] on 622 children with a mean age of 11.9 years showed a prevalence of 32% at baseline, and 42.3% after 3 years. Lussi and Schaffner [2000] examined 55 26-30- and 45-50-year-old individuals at baseline and after 6 years. They observed a rise in the proportion of teeth with dentine lesions from 7% to 25% (26-30 years) and from 8% to 26% (45-50 years). Even though longitudinal data remain sparse, the available studies suggest that with increased age, lesion progression increases.

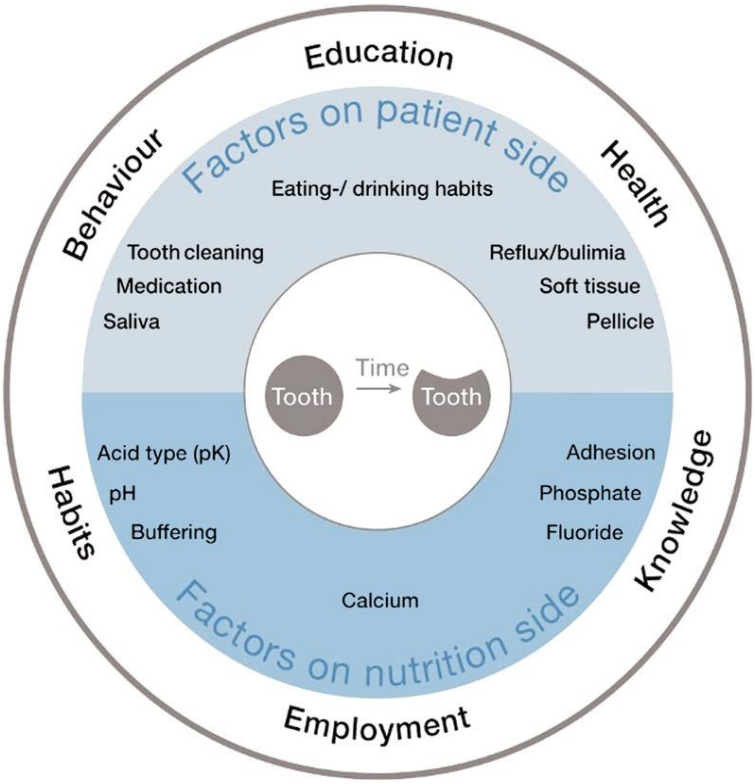
Localities of erosive lesions have been reported both in deciduous and permanent dentition. There is general agreement that erosive lesions can be found on all surfaces, but are most common on occlusal and facial surfaces of maxillary and mandibular teeth, and on palatal surfaces of the maxillary anterior teeth. Studies have indicated that first permanent molars are affected most frequently and severely [El Aidi et al., 2008; Ganss et al., 2001; Lussi et al., 1991; Milosevic et al., 1994; Rodriguez et al., 2012], and are considered as indicators of the

onset and severity of erosive lesions. Cuppings on molars, as one of the first signs of erosive wear, are described in some studies [Hasselkvist et al., 2010; Johansson et al., 2002; Khan et al., 2001]. Johansson et al. [2002] found that the number of cuppings was associated with the severity of erosions, while Khan et al. [2001] found a linear increase in lesion number and size with age in adults less than 30 years. They concluded that cuppings may indicate early onset of active erosive lesions.

Aetiology of dental erosive wear

Dental erosive wear is a multifactorial condition, and to be able to prevent occurrence or further development it is important to identify its aetiology. Lussi & Jaeggi [2011b] have structured various factors which may influence the occurrence of dental erosive wear into patient- and nutrition-related factors which can be modified when an interaction with other general factors occurs (Figure 1). Another way of classifying the aetiology of erosive lesions is into “extrinsic” or “intrinsic” factors, related to the origin acids involved [ten Cate and Imfeld, 1996].

Figure 1. Factors affecting the development of dental erosion [Lussi and Jaeggi, 2011b].



Patient-related factors

Diet and dietary habits

Acidic drinks are thought to be one of the most important factors leading to dental erosive wear, especially considering that the consumption of such drinks (mineral water, juice and soft drinks) has increased greatly over past decades [Lussi et al., 2004]. Norway is no exception, with a yearly mean consumption of well over 100 litres per person; the country is in the top five European countries [Bryggeri- og drikkevareforeningen, Norway 2012]. Fruit juices are also commonly believed to be causal factors for dental erosive lesions, as well as fruit itself [Jarvinen et al., 1991; Margaritis et al., 2011; Okunseri et al., 2011]. An intake of citrus fruits more than twice a day has also been shown to be a great challenge for the dental

enamel, and the risk of developing erosive tooth wear was found to be 37 times higher in people with a high intake of fruit than in persons eating fruit less often [Jarvinen et al., 1991]. Consumption of alcoholic mixed drinks [El Aidi et al., 2011] and wine [Chikte et al., 2005; Ferguson et al., 1996; Wiktorsson et al., 1997] has also been shown to increase the risk for dental erosive wear. Furthermore, the frequency and duration of acid attacks, as well as the manner of consumption of erosive foods and beverages, influences the severity of the erosive lesions [Jarvinen et al., 1991; Johansson et al., 2002; Johansson et al., 2004;Moazzez et al., 2000].

Reflux and eating disorders

Gastroesophageal reflux (GER) is a condition characterized by the involuntary movement of stomach acid into the mouth as a consequence of reflux, and when it becomes chronicle it is designated gastroesophageal reflux disease (GERD). Studies have indicated that there are patients with reflux esophagitis who do not show reflux discomfort [Rai and Orlando, 2001], known as “silent reflux”. The pH of stomach contents varies with the type of food and drink consumed, but the fasting pH has been reported to be between 0.8 and 2.0 [DeMeester et al., 1976]. There is emerging evidence that the prevalence of GERD is rising and may have links to adult obesity and other morbidities [Rai and Orlando, 2001; Sifrim and Zerbib, 2002].

While no difference was reported in the prevalence of dental erosion between young Icelandic adults and patients with GERD [Jensdottir et al., 2004], a more recent study found a significant association in 249 children and adults [Holbrook et al., 2009]. A systematic review including 17 studies on GERD and dental erosion also showed a strong association between the two conditions with a median prevalence of erosive lesions in GERD patients of 24% and the median prevalence of GERD in adults with dental erosion of 32.5% [Pace et al., 2008].

It is well known that eating disorders can be a problem among children and adolescents [Rome, 2012] and Norway is no exception [Kjelsas et al., 2004]. Among 45 patients (mean age 27.9) with diagnosed bulimia nervosa 23 were registered with erosive lesions (Mulic et al., unpublished observations). Dental personnel may in many cases be the first health workers to observe signs of such problems. Johansson et al. [2012] examined the oral health of patients with eating disorders and compared them to gender- and age-matched controls. In the group they studied, with a mean age of 21 years, patients with eating disorders were at 8.5 time higher risk of having dental erosion. Those patients with a longer history of eating disorder more commonly had dental erosive lesions. Patients with bulimia nervosa are also shown to have more acidic oral mucosa than age-matched controls [Aframian et al., 2010], as well as a decreased salivary flow rate [Ohrn and Angmar-Mansson, 2000; Rytomaa et al., 1998].

Saliva and pellicle

A high salivary flow rate favours the prevention or minimization of initial acid attack due to the increase in the organic and inorganic constituents of saliva [Hara et al., 2006]. These components function as buffers and help to maintain the integrity of the teeth [Dawes and Kubieniec, 2004]. The buffering capacity of saliva is important for prevention and reduction of acidic influence [Jensdottir et al., 2005], and it was demonstrated that buffering capacity of the saliva is positively correlated with the secretion rate [Bardow et al., 2000]. Järvinen et al. [1991] found that a low unstimulated salivary flow rate of $\leq$ 1 ml/min gave a five times higher risk of dental erosions. Several salivary mechanisms are important during an erosive challenge: dilution and clearance of an erosive agent, neutralization and buffering, and involvement of pellicle formation [Dawes and Kubieniec, 2004]. The acquired pellicle, an organic film free of bacteria, composed of mucins, glucoproteins, proteins and enzymes, acts as a diffusion barrier preventing direct contact between the acids and the tooth surface, thus

protecting against erosive exposure [Amaechi et al., 1999; Hannig et al., 2004; Johansson et al., 2002; Meurman and Frank, 1991].

Amaechi et al. [1999] have shown that the thickness of the pellicle may influence the level of protection; the thinnest pellicle was formed on the palatal surface of upper teeth and was less resistant to acid than the pellicle on the lingual surfaces of lower teeth. These observations could be one explanation for the high prevalence of dental erosive wear on the palatal surfaces of upper teeth.

Oral hygiene habits

Davis and Winter [1980] demonstrated in an *in vitro* study that the action of tooth brushing on already softened enamel is a factor that may accelerate tooth wear in general, and Kuroiwa et al. [1993;1994] showed that abrasives in dentifrices may reduce the thickness of or remove the pellicle, thus reducing the protection against erosive exposure. Therefore, Lussi et al. [2006] have suggested that preventive strategies against erosive challenge should include encouragement of non-destructive tooth brushing habits. Furthermore, tooth brushing should be postponed at least an hour after acid exposure as it has been suggested that softened tooth surface needs about an hour in presence of saliva to remineralize [Jaeggi and Lussi, 1999].

Medications, occupation and sport

Low pH medications [Zero, 1996] and daily occupational exposure to acids may also be classified as risk factors for erosive tooth wear [Wiegand and Attin, 2007; Zero, 1996]. In the review paper from 1996 [Zero], the author described iron tonics, liquid hydrochloric acid, vitamin C, aspirin, acidic salivary substitutes and salivary flow stimulants as potential erosive products. Recent studies [El Aidi et al., 2011; Ratnayake and Ekanayake, 2010] have shown that different supplemental vitamins were positively associated with progression of erosive lesions. Conflicting results regarding dental erosive wear and asthma are published [Al-

Dlaigan et al., 2002; Dugmore and Rock, 2003a; Sivasithamparam et al., 2002], and therefore it is difficult to support an association between asthmatic medications and erosive wear.

Some of the studies on occupational causes of dental erosion have been performed on workers exposed to sulphuric acids in battery manufacturing factories [Petersen and Gormsen, 1991], wine tasters [Chikte et al., 2005; Wiktorsson et al., 1997] and on competitive swimmers exposed to high levels of hydrochloric acid in chlorinated swimming pools [Centerwall et al., 1986; Geurtsen, 2000]. All these studies found a higher prevalence and more severe lesions among the exposed group compared with the controls. They concluded that severe erosion among such participants should be recognized as an occupational disease.

An increased interest in "healthy" lifestyle involving regular exercise and healthy diet can lead to dental problems such as erosive wear [Jaeggi and Lussi, 2006]. It is well-known that salivary flow rate and saliva's composition may be influenced by exercise [MacKinnon and Jenkins, 1993; Walsh et al., 2004] caused by rapid breathing and sweat-induced dehydration. Furthermore, athletic activity often requires consumption of sports drinks which have been proven to be acidic [Lussi et al., 2012]. Some studies have demonstrated that sports drinks, used during exercise are not associated with erosive lesions in athletes [Coombes, 2005; Mathew et al., 2002; Milosevic et al., 1997; Sirimaharaj et al., 2002], whereas Järvinen et al. [1991] found a four-fold increase in risk of lesions when sports drinks were consumed. In a review paper, Coombes [2005] concluded that for most individuals, the sports drinks offer no more benefits than water.

For dental health personnel, it is essential to identify individuals at risk so adequate preventive measures may be implemented.

Nutritional factors

The erosive potential of drinks and foods is determinate by various chemical properties, such as type of acid, pH, buffering capacity, as well as concentrations of calcium (Ca), phosphate (P) and fluoride (F).

Common dietary drinks include different type of acids, usually citric acid, phosphoric acid, ascorbic acid, malic acid and carbonic acid. Citric acid has a greater erosive potential than the other acids, which may be related to its ability to form chelating complexes with Ca and/or high buffering capacity. By modifying the amount and the type of acid used in e.g. beverages, Grenby [1996] have shown that it is possible to reduce the erosive potential of drinks.

The pH value of a drink is an important, but not the only variable influencing its erosive potential, and foods and beverages can show different potentials despite having similar pH values. The ability of an acid to dissolve enamel or dentine depends also on its buffering capacity, which is a good indicator of the erosive potential [Edwards et al., 1999]. The greater the buffering capacity, the longer the time for saliva to neutralize the acid and the more apatite may be dissolved before a higher pH value is reached.

The concentrations of calcium (Ca), phosphate (P) and fluoride (F) ions added in a drink or food determine the degree of saturation with respect to enamel and dentine. Studies have shown that products modified with minerals have reduced erosive capacity, and are recommended for patients at risk of erosive lesions [Hooper et al., 2004; West et al., 2003].

AIMS OF THE STUDY

The overall aim of this thesis was to gain knowledge on the prevalence and distribution of dental erosive wear in different population groups in Norway, particularly in those who may be at risk. Furthermore, the research sought to identify related risk indicators which could be useful for planning preventive strategies among individuals at risk.

Specifically, the aims were:

- To evaluate and compare two clinical **measuring systems** for erosive dental wear, the Visual Erosion Dental Examination (VEDE) and Basic Erosive Wear Examination (BEWE) before initiating a prevalence study on dental erosive wear (PAPER I)
- To assess the prevalence of dental erosive wear among a group of **18-year-olds** and to describe the distribution and severity of the erosive lesions (PAPER II)
    - To study possible associations between dental erosive wear and caries experience, socio-economic status and national background factors
- To investigate risk indicators associated with dental erosive wear among **18-year-olds** (PAPER III)
    - To assess risk indicators separately for males and females
- To describe dental erosive wear among a group of **physically active young adults** compared with a non-exercising group of adolescents (PAPER IV)
    - To describe the patterns of dietary consumption and lifestyle among physically active young adults
    - To explore a possible association between exercise, salivary flow and erosive lesions

- To assess the prevalence and severity of dental erosive wear among **wine tasters** (PAPER V)

MATERIAL & METHODS

Study area

The present study was conducted from 2008 to 2009 in the city of Oslo, Norway, with a population, according to Statistics Norway, of 599.230 inhabitants in 2011. Only 20% are under the age of 18, while 10% are 67 years or older.

Study sample and design

The present thesis consists of a methodological part testing two scoring systems for erosive lesions (Paper I) and epidemiological surveys studying potential risk groups for dental erosive wear (Papers II-V) (Table 2).

Table 2. Overview of the studies.

Paper	Focus of interest	No of respondents (n=)	Age	Year of examination
I	Evaluation of measuring systems			2008
II	Prevalence, distribution and severity of dental erosive wear among a group of **18-year-olds**	1456	18 yr	2008-2009
III	Risk indicator for dental erosive wear among a group of **18-year-olds**	1456	18 yr	2008-2009
IV	Prevalence, distribution and severity of dental erosive wear among a group of **physically active young adults** related to salivary flow, dietary consumption and lifestyle	220	18-32 yr (mean 21 yr)	2009
V	Prevalence and severity of dental erosive wear among **wine tasters**	48	24-56 yr (mean 39 yr)	2008

Paper I Clinical scoring systems for dental erosive wear

This methodological Paper I, which aimed to test and compare two different scoring systems for erosive lesions, was based on 74 intraoral close-up photographs and clinical examination of 30 18-year-old adolescents. The scoring systems to be tested, Visual Erosion Dental Examination (VEDE) and Basic Erosive Wear Examination (BEWE) were developed to increase awareness of erosive wear among clinicians and to establish simple tools for scoring erosive lesions both in general dental practice and for research purposes. The VEDE has been used in the student clinics at the University of Oslo for seven years, and is a modification of the Lussi's dental erosion index [Lussi, 1996], while the BEWE was proposed during a workshop in 2007 [Bartlett et al., 2008; Young et al., 2008] (Table 3).

Table 3. Comparison of features: Visual Erosion Dental Examination (VEDE) system and Basic Erosive Wear Examination (BEWE) system.

VEDE		**BEWE**	
Score	Definition	Score	Definition
0	No erosive wear	0	No erosive wear
1	Initial loss of enamel, no dentine exposed	1	Initial loss of surface texture
2	Pronounced loss of enamel, no dentine exposed	2*	Distinct defect, hard tissue loss less than 50% of the surface area
3	Exposure of dentine, < ⅓ of the surface involved	3*	Hard tissue loss more than 50% of the surface area
4	⅓ - ⅔ of the dentine exposed		
5	> ⅔ of dentine exposed, or pulp exposed		

* dentine is often involved

The two scoring systems were tested on intraoral photographs at tooth surface level. Cases were randomly selected from the University dental school's patient photo-archive, and also from the examination of 18-year-olds referred to the dental school from the Public Dental Services (PDHS) due to clear or suspected signs of dental erosive wear. Five examiners with dental professional experience from 3 to 35 years examined the pictures, while three of the same five clinicians examined the adolescents.

Papers II & III Dental erosive wear and associated risk indicators among adolescents

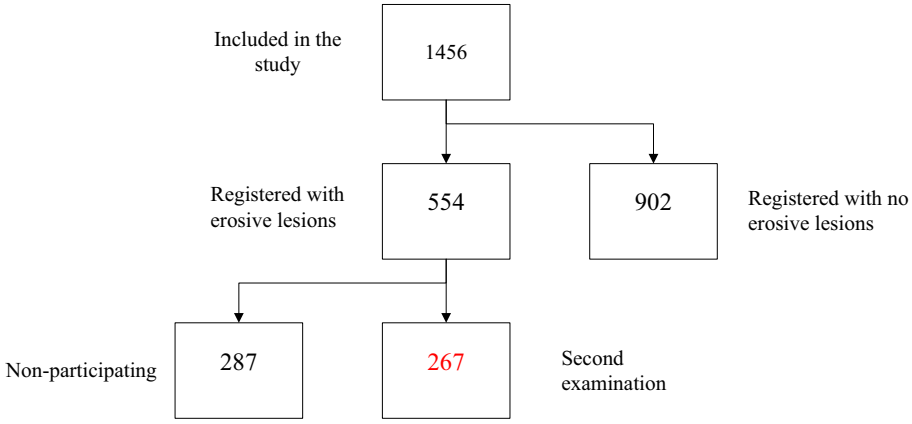
The focus of these Papers was to study the prevalence of and potential risk factors for dental erosive wear among adolescents. The studies included clinical examinations and a questionnaire. A prevalence of 25% was used to calculate the sample size based on reported prevalence values of 5% to 31% from other available Scandinavian countries [Arnadottir et al., 2003; Jarvinen et al., 1991; Larsen et al., 2005], a non-response rate of 30% and a drop-out of 26% [Wang and Schiøth, 2000]. The minimum sample to fulfil the requirement was estimated to be 265 adolescents (95% CI).

All 18-year-olds scheduled for clinical examination in 2008 in the city of Oslo were invited to participate. This provided a total of 3206 individuals, 50% of the 18-year-olds in Oslo. Of these, 55% (n=1750) declined to participate, leaving 1456 individuals to take part in the study (Figure 2).

Figure 2. Participants included in the study.

The study had a cross-sectional design, and was undertaken at all 20 Public Dental Health Service (PDHS) clinics. Data collection was performed by dentists or dental hygienists in the period January-December 2008. The participants with erosive lesions registered at the PDHS clinics were thereafter offered a more detailed examination (second examination) (Figure 3) by a previously calibrated clinician (AM) (Papers I, IV).

Figure 3. Distribution of the adolescents enrolled in the study.



Paper IV Erosive wear in physically active people

This Paper describes the presence of dental erosive wear and the rate of salivary flow in physically active young adults. Sample size calculation showed that 120 participants were needed in each group (exercise group and comparison group) to detect a difference between the two groups at a two-sided alpha level of 5% (type I error) and 80% power (type II error of 20%), when expecting 40% prevalence of erosive wear in the exercise group and 30% among the comparison participants.

The study population included 220 individuals, divided in an exercise group and a comparison group (Table 4). The exercise group consisted of 104 participants who worked out at a fitness centre in Oslo twice or more per week. The comparison group included 116 individuals attending PDHS in Oslo and participating in the study among Norwegian 18-year-olds (Paper II). The inclusion criterion for these adolescents was no regular exercise during the last five years outside school. All participants were non-smokers.

Table 4. Participants included in the study.

	Exercising group (n=104)		Comparison group (n=116)
Age group	18-28 (mean 22 yr)	26-32 (mean 29 yr)	18
n	63	41	116
♀	46	22	75
♂	17	19	41

This study included a clinical examination, saliva collection and a questionnaire. The data collection was performed in the period July - October 2009, and was carried out at the fitness centre and at the PDHS clinics in the city of Oslo by a previously calibrated clinician (AM) (Papers I, IV).

Paper V Dental erosive wear and wine

The study aimed to assess the prevalence and severity of dental erosive wear among wine tasters and involved 48 adults, one group of wine tasters and one group of comparison participants (Table 5).

Table 5. Participants included in the study.

	Wine tasters (n=18)	Comparison group (n=30)
Age group	30-56 (mean 39 yr)	24-55 (mean 39 yr)
♀	3	9
♂	15	21

The study was initiated at the request of AS Vinmonopol, the state owned alcoholic beverage retailer, and included all full-time wine tasters. These professional wine tasters test all wines for quality, taste and flavour before approval for sale in the state liquor outlets. They have on average tasting sessions on 60 days a year, and a typical wine session last 6 hours with two 30 minute breaks. In addition to the tasting sessions, the wine tasters typically attend 10 full day courses a year with several wine tasting sessions daily. The comparison group was randomly selected from a group of gender- and age- matched patients at the Institute of

Clinical Dentistry, University of Oslo. The inclusion criterion was consumption of wine or spirits less than once a week.

The study included clinical examination and a questionnaire. The data collection was undertaken in the period January - May 2008, and was performed at the University clinic by previously calibrated clinicians (Paper I).

Reliability description

Prior to the start of the main survey (Papers II, III, IV and V), five clinicians were calibrated and trained on clinical intraoral pictures with different tooth groups, surfaces and severity grades of erosive tooth wear. Based on 30 close-up photographs, the examiners were trained by discussing the criteria of the two systems, VEDE and BEWE and by giving specific feedback for each diagnosis when agreement was reached. The training was concluded with an inter- and intra-examiner reliability test, in which the clinicians examined photographs of other 74 surfaces. All examinations were carried out in the same room and under identical lighting conditions and the assessments were repeated after 14 days (intra-examiner agreement). Two separate examination sessions were arranged, VEDE was used in the first session and BEWE in the second, one month later (Paper I).

Three of the five clinicians were also trained on 562 tooth surfaces in 30 randomly selected 18-year-old adolescents. The final score of erosive wear was based on consensus which was reached upon agreement between the examiners. To calculate the intra-examiner agreement, 15 adolescents were re-examined by the main investigator 10 to 21 days after the first examination. As part of a further calibration between the examiners, four of the five clinicians examined 18 wine tasters (Paper V). The subsequent examinations of participants (Papers II and IV) were carried out by only one examiner (AM).

The inter- and intra-examiner reliability was expressed as weighted Cohen's kappa score (k_w) [Landis and Koch, 1977]. For the five graded VEDE system, 80%, 60%, 40% and 20% credit was given for scores deviating one, two, three and four erosion scores, respectively. For the four graded BEWE system, 67% and 33% credit was given for scores deviating by one or two scores, respectively. The weighted kappa statistics did not contain any scores regarding missing teeth and surfaces.

The study in Paper II was performed at the PDHS clinics (n=20) in Oslo by dentists and dental hygienists (1-2 in each clinic). The clinicians were trained by attending information meetings accompanied by several lectures on dental erosive wear presented by the calibrated investigator (AM). Furthermore, instruction in the use of the VEDE system was provided and the pictorial manual was distributed to the clinicians [Mulic et al., 2010]. The information meetings were repeated twice during the data collection period.

Clinical examination (Papers II-V)

The standard conditions for clinical facilities included lighting, mouth mirrors and probes. Surfaces were dried by compressed air/cotton rolls and, if necessary, cotton rolls were used in addition to remove debris prior to the examinations. The examination performed by the PDHS clinicians in Papers II/III included all teeth and surfaces (yes/no erosion), followed by grading with the VEDE system by the main investigator (Paper II) on 20 surfaces per participant: the occlusal surfaces of the first and second molars in both jaws and the labial and palatal surfaces of the upper incisors and canines. The cuppings were classified as score 1: initial loss of enamel, no dentine exposed; score 2: pronounced loss of enamel, no dentine exposed; score 3: exposure of dentine. The differentiation between enamel and dentine cuppings was based on colour, depth of the cuppings and whether there was sensitivity on probing or not in the cupping. In Papers IV and V, the registration was performed on 16 and

12 surfaces, respectively. Participants with erosive lesions in at least one tooth were considered to have dental erosive wear. Each examination lasted approximately 1-2 hours and comprised information on the project, oral examination, questionnaire, as well as a feedback to each participant on the oral health. In the Paper IV, saliva samples before and after exercise were also collected.

As part of the clinical examination described in Paper II, patients' caries experience was measured as DMFT index as described by WHO Oral Health Surveys [World Health Organization, 1997] recorded from participant's dental record by the PDHS clinicians. The participants were defined as having no caries experience when $D_{0\text{-}2}MFT=0$, and having caries experience when $D_{3\text{-}5}MFT>0$ where the D component included only caries into dentine.

Dental erosive wear was classified by the VEDE system. Only lesions considered to be obvious dental erosive defects were recorded and scored, including cuppings/grooves on the molar cusps. Attritions on occlusal and wedge-shaped defects on incisal surfaces were not graded. When index surfaces were either filled, bonded with a retainer, considered to have attrition and wedge-shaped defects or the tooth had been extracted, the surfaces and teeth were recorded as missing and excluded.

Saliva sampling (Paper IV)

In addition to the dental examination, saliva samples were provided from 70 physically active individuals. Prior to the saliva sampling the participants relaxed in an upright sitting position for a few minutes. A standardized 10 minutes collection of whole unstimulated saliva was collected by letting the saliva drip into a plastic tube. After unstimulated saliva sampling, the participants were given paraffin gum to chew at a constant rate for five minutes to collect stimulated whole saliva. Swallowing was not permitted. The same process was repeated immediately after exercise. Saliva flow rate (ml/min) was determined for each saliva sample.

Questionnaire (Papers II-V)

The questionnaire was self-administrated, structured and standardized, and was completed by all the individuals participating in the studies described in Papers II-V at the time of the oral examination. The questionnaire was pre-tested on a pilot group (n=10) to ensure understanding and ease of reading. The clinical examiners were blinded to all information obtained from the questionnaire. For more detailed information about the questionnaire, see Appendix 3.

Papers II/III

The participants' socio-economic status and national background were collected from the questionnaire. In Paper II socio-economic status was categorized into east- and west end of the city of Oslo, according to the area of residence. The distinction between these areas is defined by Statistics in Norway based on the household net income (east-end: low income, west-end: high income) [Statistics Norway. Income. 2011]. In Paper III, the adolescents' occupational level was determinant for socio-economic status: both being at work, unemployed or choosing vocational studies were considered as indicators of lower socio-economic status for 18-year-olds in Norway. National background was recorded according to mother's and the participant's country of birth. Their national origin in Paper II was combined into one variable and thereafter dichotomized as western origin (both mother and participant born in a western country) or non-western origin (either mother or participant born in a non-western country). In Paper III, national origin was combined into one variable and thereafter trichotomized as western origin (mother or both mother and participant born in a western country other than Norway), non-western origin (either mother or participant born in a non-western country) or Norwegian origin (mother or both mother and participant born in Norway). Non-western origin included the individuals with birth place in countries from

Eastern Europe, Asia, Africa, South and Central America [Statistics Norway. Immigration and immigrants. 2010].

Papers III, IV and V

In addition to the clinical intraoral examination, the self-administered questionnaire was designed to assess potential risk indicators assumed to be related to dental erosive wear. Apart from the selected background variables (gender, occupation, national background), the questionnaire covered details of selected behavioural, dietary and medical variables. Dental hygiene habits, the frequency and duration of tooth brushing, supplemental fluoride use and time for last dental visit were recorded. The medical history included information about possible gastro-oesophageal reflux, vomiting and type and frequency of any medication used regularly. The dietary questionnaire covered details of the consumption frequency of common drinks and foods associated with dental erosive wear such as orange, apple and grapefruit juices, carbonated beverages, sports drinks and some fruits like oranges, grapefruits and apples.

In Paper IV, information about frequency and amount of exercise, as well as drinking habits during working out, was collected. Additional information was collected from the wine tasters about the frequency of wine tasting, the number of years in the occupation, the number of wine tasting sessions per week and oral hygiene habits after wine tasting (Paper V).

Statistical analyses

The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Inc. Chicago, IL, USA version 16). The inter- and intra-examiner agreement was measured by linear weighted Cohen's Kappa (κ_w) and intraclass correlation coefficient (ICC). The absolute frequencies and proportions were obtained for descriptive and bivariate analyses

(Chi-squared test and Fisher's Exact test) to test for possible associations between the variables. In Paper III, multicollinearity diagnostics for independent variables was performed using Variance Inflation Factor (VIF). VIF was < 5 for all associations, indicating the absence of multicollinearity. Logistic regression analysis was used to assess the association between the presence of dental erosive wear and selected independent variables, taking into account hierarchical relationships between the independent variables, controlled for the other variables included in the analyses.

Results were reported using odds ratio (OR) and confidence intervals (CI). The level of significance was set at 5%. Table 6 gives detailed information about the different methods used for each paper.

Table 6. Summarized statistical methods and tests used in the thesis.

Statistical methods/tests	**Paper I**	**Paper II**	**Paper III**	**Paper IV**	**Paper V**
Linear weighted Cohen's Kappa (κ_w)	+	+	+	+	+
Percentage agreement (%)	+				
Intraclass correlation coefficient (ICC)					+
Chi-Squared test		+	+	+	+
Fisher's Exact test				+	+
Logistic regression (OR)			+		
Variance Inflation Factor (VIF)			+		

Ethical clearance

The studies were approved by the Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Service, as well as biobank registration. Written informed consent was obtained from all the participants.

SUMMARY OF RESULTS

Reliability of the examinations

The mean κ_w inter-examiner value was 0.77 (range 0.70-0.85) (examination of pictures) and 0.73 (range 0.71-0.76) (examination of adolescents). The mean intra-examiner κ_w agreement was 0.87 (range 0.79-0.94) (examination of pictures). The intra-examiner agreement of the main investigator (AM) was 0.85 (on pictures) and 0.95 (clinical examination). In Paper V, the inter-examiner agreement for the four examiners expressed by mean κ_w was 0.68 (range 0.61-0.78), and ICC was 0.77 (CI 0.73-0.81).

The obtained agreement expressed by linear weighted Cohen's Kappa (κ_w) was defined as "substantial to almost perfect" according to the scale suggested by Landis and Koch [1977].

Paper I Clinical scoring systems for dental erosive wear

The purpose of this study was to evaluate and compare two clinical scoring systems before initiating an epidemiological study on dental erosive wear.

Examination of dental surfaces on photographs

The total number of surfaces examined was 74, almost equally distributed between the scores (0-5 for the VEDE and 0-3 for the BEWE). The inter-examiner agreement showed slightly higher mean κ_w value for the VEDE ($\kappa_w = 0.77$) compared with the BEWE ($\kappa_w = 0.69$), and varied more when using BEWE (range 0.58-0.91) than VEDE (range 0.70-0.85). Higher intra-examiner agreement was also shown for the VEDE system ($\kappa_w = 0.87$, range 0.79-0.94) compared with the BEWE ($\kappa_w = 0.78$, range 0.66-0.95).

Clinical examination

The total number of examined surfaces was 562. All scores, except score 5 (VEDE), were used. The majority of the surfaces were registered with score 0, 2 and 1, respectively. An

equal inter-examiner agreement (mean $\kappa_w = 0.73$) was found for the two systems indicating acceptable agreement. Slightly higher κ_w intra-examiner measurement was registered, 0.95 and 0.92 for the VEDE and BEWE, respectively.

For the VEDE system, the highest examiner agreement was found for score 0 (86%) and score 3 (67%), while enamel scores 1 (30%) and 2 (57%) had the smallest agreement.

Paper II Dental erosive wear among adolescents

The aim of this Paper was to assess the prevalence of dental erosive wear among a group of 18-year-olds, to describe the distribution and severity of the erosive lesions, and to study possible associations between dental erosive wear with certain background variables.

The examination revealed 554 (38%) participants with at least one tooth with erosive lesions. Of the 267 participants re-examined, 13.5% were without lesions, 54.3% had erosive wear in enamel only, whereas 32.2% had at least one lesion extending into dentine. Approximately half (n=119) had lesions in both molars and anterior teeth, only molars were recorded in 36% (n=83), while 12% (n=29) had erosive lesions solely on anterior teeth. The highest frequency of erosive lesions was registered on the upper central incisors (46%), followed by first molars (44%). Cuppings were registered in 62% (n=144) of the individuals, usually on the first molars (n=225, 85%) and on the mesio-buccal surface (n=90, 34%). The cuppings were confined to enamel in 79% and to dentine in 21% of the individuals. More males (52%) than females had dental erosive wear (p=0.01), and males (62%) had more dentine lesions (p=0.03). Participants with caries experience 39%, (n=419) had significantly more erosive lesions than the adolescents with no caries 32%, (n=110) ($p<0.01$). There was no association between prevalence of erosive wear and socio-economic status or national background.

Non-attendance

Of 3206 individuals invited to participate, 1750 declined and 1456 were examined (45% of all 18-year-olds scheduled for dental examination in 2008), 53% females and 47% males. No statistically significant differences were shown regarding DMFT and gender between the non-responders (n=1750) and examined participants (n=1456): mean DMFT values were 3.9 and 4.0, respectively; males comprised 48% and 47% of the groups, respectively.

Of 554 participants registered with dental erosive wear, 287 did not participate in the second examination. A telephone interview was used in order to contact and collect information from all these 287 individuals. Forty (14%), 24 men and 16 women, responded. The main reasons reported for not participating were lapse of memory (28%) or lack of time (25%). The rest stated dental fear or already knowing about the presence of dental erosive wear as the main reasons for non-attendance.

Paper III Risk indicators associated with dental erosive wear

The purpose of the study was to investigate certain risk indicators associated with dental erosive wear among 18-year-olds.

The results from the bivariate analyses showed associations between the presence of dental erosive wear and being male, at work or unemployed, brushing teeth less than once per day and for less than half a minute daily. Reported occurrence of vomiting and gastro-oesophageal reflux, as well as consumption of fruit juices, squash, sugary soft drinks and chips with sour dip showed a trend of association with dental erosive wear.

Multivariable logistic regression analysis was conducted to explore associations between the presence of erosive wear and background (gender, occupation) variables (Model I), and behavioural (tooth brushing frequency and time), medical (gastro-oesophageal reflux and

vomiting) and dietary variables (fruit juice-, squash, soft drinks- and chips with sour dip consumption) controlled for gender and occupation (Model II).

In Model I, being male (OR 1.6) and occupation of participants [choosing vocational studies (OR 1.3) or being at work or unemployed (OR 2.2)] were both significantly associated with the presence of erosive wear. In the Model II analysis, the effect of occupation became non-significant, while the presence of erosive lesions was associated with being male (OR 1.4), brushing teeth once or less per day (OR 1.3), reporting vomiting (OR 1.9) or having gastro-oesophageal reflux daily or weekly (OR 2.0), as well as consuming fruit juice several times per day (OR 1.6) and sugary soft drinks several times per day (OR 1.9) or daily to once per week (OR 1.3).

For males, following vocational studies (OR 1.5), consumption of sugary soft drinks several times per day (OR 2.0) and daily to once per week (OR 1.5) were significantly related to the presence of erosive lesions. For females, reported presence of vomiting (OR 2.4) and daily or weekly gastro-oesophageal reflux (OR 2.5) were significantly associated with the presence of erosive lesions. Furthermore, females who consumed fruit juice frequently had a 2.2 times significantly higher probability of having erosive lesions than those who consumed fruit juice less than once per week.

Paper IV Erosive wear in physically active people

The main aim of the present Paper was to describe dental erosive wear, salivary flow and diet among a group of physically active young adults. The prevalence of erosive wear in the exercise group was 64% (n=67), 57% (n=36) among 18-25 year olds and 76% (n=31) in the age group 26-32 years ($p<0.01$). Upper central incisors (33%) and first molars (27%) were most commonly affected teeth. The majority of the lesions were confined to enamel. No

significant association was found regarding the gender; but more males (78%) than females (57%) were affected, and dentine lesions were mostly registered in men (n=18) (p=0.047). In the non-exercise group, only 20% (n=23) of 18-year-olds had dental erosive wear (p<0.001).

Saliva flow and erosive lesions

Reduced *stimulated salivary flow* was registered after exercise in 64% (n=45) of the 70 individuals, and 36% (n=25) had dental erosive wear. A significant increase in salivary flow was observed in 36% (n=25), of whom only 9% (n=6) had erosive lesions (p=0.001). Regarding *unstimulated saliva* there was nearly the same number of participants with reduced salivary flow (n=32, 46%) after exercise as with increased flow (n=31, 44%). In seven individuals (10%), the unstimulated flow rate remained unchanged.

Dentine lesions were observed more frequently (27%) when a reduction in stimulated salivary flow was registered compared with an increase (4%). Participants (n=24, 34%) with a stimulated salivary flow rate <0.1ml/min before the training had significantly more erosive lesions than those with higher flow rate (n=46, 66%) (>0.1ml/min; p=0.002).

Questionnaire

Although about one quarter (23%) of the individuals at the fitness centre reported symptoms of reflux, no significant correlation with erosive lesions was found. The same result was found concerning consumption of acidic drinks and foods even though high consumption (once per day or more) of acidic drinks [43% (n=45)] and acidic fruits [23.5% (n=24)] was reported. Sports drinks consumption was high in only three persons. Of those with erosive wear, 82% (n=85) had not been informed by their dentist or dental hygienist about the presence of these lesions.

Half (n=58) of the comparison participants reported a high consumption of acidic drinks; of these, 29% were registered with erosive lesions (p=0.083). Only 13% (n=15) consumed fruits daily and all participants reported that they consumed sports drinks rarely or never.

Paper V Dental erosive wear and wine

The purpose of the present study was to assess the prevalence and severity of dental erosive wear among wine tasters.

Nine (50%) of the wine tasters and six (20%) of the comparison participants were recorded as having dental erosive wear (p=0.03); wine tasters were more severely affected (into dentine). No significant association was found regarding the gender, but more males than females were affected. In the wine tasters, the occlusal surfaces of the lower first molars (36/46) were usually affected with erosive lesions, while in the comparison group the palatal surfaces of upper central incisors (11/21) were mostly registered with lesions. No statistically significant difference between severity, numbers of dental erosive lesions and years in the occupation as wine taster could be found.

Questionnaire

Low consumption of acidic drinks and citrus fruits in both groups was revealed. Although there was no statistically significant difference, some trends in consumption were noted. Twenty eight percent (n=5) of the wine tasters consumed soft drinks and/or juices several times a day, compared with three persons (10%) in the comparison group. Two of these wine tasters did not have any erosive lesions, while the other three had lesions in enamel and/or dentine. Once a day consumption of these drinks was more frequent in the comparison group (n=26, 73%) compared with the wine tasters (n=9, 50%), of whom three had erosive wear in enamel. Fifty-five percent (n=10) of the wine tasters and 67 % (n=24) of the comparison group reported consumption of citrus fruits mostly once per week.

Two (11%) of the wine tasters and thirteen (43%) of the comparison group used daily fluoride rinses. At the end of the test sessions, all wine tasters rinsed their mouths with non-

fluoridated tap water, six (33%) of them also used fluoride solutions or fluoride tablets. Of the wine tasters with erosive wear, four (44%) brushed their teeth directly after the tasting session, and all of these had dental erosive wear into dentine.

The participants in both groups made regular dental visits: 72% of the wine tasters and 60% of the comparison participants had had their most recent last dental examination six months prior to the examination. Seven of the nine wine tasters registered with dental erosive wear had not been informed by their dentist or dental hygienist about the presence of these lesions.

DISCUSSION

Methodological considerations

Study population

The study population, on which the present thesis is based, includes three different samples. In **Papers II** and **III**, all 18-year-olds (n=3206) scheduled for recall examination during 2008 in Oslo were invited to participate. The purpose of inviting all 18-year-olds was to increase the information and knowledge on dental erosive wear in this group of adolescents, and to collect information on gender, DMFT, socio-economical and national background factors on those who declined to participate in the study, as well as of those who agreed.

The 18-year-old study group was chosen for several reasons. At this age the selected index teeth, first and second molars and anterior teeth have been present and exposed to erosive challenges for several years. In young people there is a higher probability of finding surfaces exposed to erosive challenge only, as attrition and abrasion are less present compared with older individuals [Ganss, 2008; Van't Spijker et al., 2009]. Furthermore, in Norway young people aged 18 years are offered a final free of charge examination at the PDHS clinics, which assures a high attendance: of 3620 individuals scheduled for recall examination in 2008, 3206 attended the examination at the PDHS clinics.

There was a relatively low response rate (45 %) in this study (**Papers II** and **III**), increasing the likelihood of non-response bias [Alderman and Salem, 2010; Lesaffre et al., 2009]. Comparison of the participants with non-attenders regarding known background characteristics revealed no differences in relation to gender, DMFT values, socio-economic and national background factors. Despite this similarity between the groups, it remains uncertain whether the sample was representative of the 18-year-olds. The fact that all 18-year-olds scheduled for free check up during 2008 were invited to participate, resulted in a

reasonably large study sample. Lapse of memory or lack of time was pointed out as the main reasons for non-attending. In addition, restrictions in approaching the non-attenders set up by the Regional Ethical Committee illustrate that there are considerable practical difficulties in obtaining the representativeness in epidemiological studies among adolescents.

In **Paper IV** the comparison group differed from the exercise group in several ways which may have influenced the results. They were on average four years younger that the exercise participants (mean 22 years) with whom they were compared and the examination conditions differed between the groups. The participants in the comparison group were receiving dental examinations at the PDHS with regular dental equipment, while the exercise group was studied under less ideal conditions (e.g. garden chair). Since hitherto there have been no prevalence studies on dental erosive wear from Norway, and due to the difficulty of comparing studies from other countries because of different populations/age groups and examination standards, we decided to include the comparison group even though it was not perfectly matched. El Aidi et al. [2008] have shown that the incidence of new erosions on erosion free surfaces decreased significantly with age (examined 11 years and 15 years old children). Although, progression of already existing lesions has been documented [Dugmore and Rock, 2004; El Aidi et al., 2008], a review [Kreulen et al., 2010] concluded that the increase in wear on permanent teeth with age was not substantiated.

Our sample size calculation indicated a need for 120 participants in each group. Unfortunately, for practical reasons, our final sample consisted of 116 (comparison group) and 104 participants (exercise group). The comparison group, containing participants from Papers II and III, included 116 subjects who did not exercise and thus were available as comparison participants. Only 104 young adults were present at the fitness studio at the time of examination. The smaller sample size did not substantially affect our results as a

statistically significant difference in prevalence of dental erosive wear was found between the comparison group and the exercise group, despite the smaller sample size. On the other hand additional risk indicators might have been identified in a larger study group.

Paper V consisted of all wine tasters employed at the AS Vinmonopolet and a randomly selected gender- and age- matched comparison group. The decision to include a comparison group was based on the sparse of other studies on prevalence among adults from the early 1990s [Johansson et al., 1996; Lussi et al., 1991], and because no investigations from Norway have been done. The representativeness of the comparison participants to the general population is open to discussion as the participants were under treatment at the university clinics. It may be speculated that subjects in need of more advanced therapy or with lower income might seek treatment at the university clinics where fees are lower.

With only 18 wine tasters employed at AS Vinmonopolet, the sample size limited the statistical analyses that could be drawn. A significant difference was found in the prevalence of dental erosive wear between the groups, but given that the choice of p-value at $p<0.05$ is arbitrary, non-significant results could also have been considered informative, especially when being close to 0.05.

Clinical examination

The reliability of a scoring system intended for use in epidemiological investigations should be known and evaluated before initiating a study, to reduce diagnostic uncertainties. A scoring system as accurate as possible in identifying and grading severity of dental erosive wear was an important issue for our study, and testing the scoring systems was thus essential. In the present investigation, the VEDE system was used for severity grading of the lesions, and compared with BEWE, a relatively new system at the time the studies were conducted. The type of a planned investigation will reasonably influence the choice of a system. In

Papers II and III, a large sample of individuals was examined by several clinicians, and a simple registration method (yes/no erosion) was chosen as most appropriate for recording the number of lesions. The VEDE system was used only as a supporting tool as a pictorial manual was included. To be able to diagnose the severity of dental erosive wear, which is important, especially for preventive care and treatment planning, a more detailed scoring system should be applied. For instance, early lesions restricted to the enamel are commonly found among children and adolescents and, to study progression and plan preventive strategies, early diagnosis is important. This implies that the VEDE system was suitable with a detailed, visual severity scale description.

Detailed training and calibration sessions for the main investigator (AM) with other experienced investigators were performed prior to the onset of the study. The clinical data collection (except the screening session) was mainly performed by one examiner (AM) with inter- and intra- examiner weighted Kappa values defined as "substantial" to "almost perfect" according to Landis and Koch [1977].

The clinical examination by dentists or dental hygienists at the PDHS clinics in **Papers II/III** was performed as a screening session. They participated in information and calibration meetings with the main investigator (AM). Since great variation between examiners when recording erosive lesions have been reported [Larsen et al., 2005], the clinicians were told to register without severity grading the presence or absence of dental erosive wear in the screening session. Despite this simple registration method, 13.5% had no erosive lesions and considered as false-positives when 267 individuals were re-examined. This indicates an over-registration which was expected as the clinicians were encouraged to record lesions also when in doubt. This must be taken into account when interpreting the prevalence data in the study.

The clinical examination was performed on index teeth and surfaces. The selection of the surface was based on earlier "full mouth recording" studies among adolescents [Al-Dlaigan et al., 2001b; Ganss et al., 2001; Larsen et al., 2005; Milosevic et al., 1994; van Rijkom et al., 2002], demonstrating highest prevalence of dental erosion on occlusal surfaces of molars and labial and palatal surfaces of maxillary anterior teeth. The dentists or dental hygienists at the PDHS clinics were instructed to screen all teeth and surfaces for dental erosive wear and it was confirmed that most lesions were seen on the occlusal surface of molars and the labial and palatal surfaces of maxillary anterior teeth. A full mouth scoring is time consuming and it may decrease the accuracy of the scoring system and diagnosis of dental erosive wear [Young et al., 2008]. In the study with the wine tasters (**Paper V**) other index teeth were selected. The participants in this study were older than the participants involved in **Papers II/III** and **IV**, and they were assumed to have different habits concerning consumption. When testing wine, it was retained in the mouth and thereafter rolled around the mouth before being expectorated. Studies among adults have demonstrated that in addition to the already selected index teeth, premolars are frequently affected [Chikte et al., 2005; Lussi et al., 1991]. Furthermore, it was considered important to distinguish between erosive wear and wear assumed to be pure attrition/abrasion. Surfaces and teeth, such as mandibular front-teeth supposed to be influenced by attrition/abrasion were thus excluded.

Saliva sampling

It is known that, prior to collecting unstimulated whole saliva, the patient should refrain from eating, drinking and smoking for at least 60 minutes to avoid influencing the flow rate [Dawes and Chebib, 1972]. As **Paper IV** was a field study, it was not possible to standardize the protocol regarding diet and liquid consumption prior to the exercise. Clearly this may raise some concern regarding a possible influence on our results. Olfactory stimuli (food intake) and tobacco smoking, compared with gustatory stimuli, have relatively small effects

on salivary flow [Edgar et al., 2004]. Another issue which may have biased our results is the consumption of liquid by participants during exercise sessions: many would normally do this. The intention was to create a "real life" situation. Liquid consumption during exercise may help maintain normal salivary function [Horswill et al., 2006] and thus could have influenced the outcome of the study. With the limited resources we had, only the first 70 participants arriving at the fitness centre were asked to provide saliva samples. There is no reason to believe that the variations in flow rate between these participants should be different from the others and comparing the prevalence of erosive lesions among the "saliva providers" (n=70) with the "non-saliva providers" (n=44) revealed no significant difference. Nevertheless, due to these uncertainties, the results should be interpreted with caution.

Questionnaires

Essential to this investigation were the results and conclusions drawn from the questionnaires in **Papers II-V**. Concurrently with the clinical examination, each participant completed a self-administered questionnaire designed to assess potential risk indicators related to dental erosive wear. Completing the questionnaire in connection with the clinical examination insured a good response rate and reduced the risk of non-response bias [Alderman and Salem, 2010; Lesaffre et al., 2009]. Information was gathered from the questionnaire before the clinical outcome was known, presence of dental erosive wear. In this way a possible information bias was eliminated.

Even though the questionnaires were pilot tested and modified according to comments before to the study commenced to ensure understanding and ease of reading, some questions were still vague when analysed. The questions considered to be unclear were therefore excluded from the analyses.

The most common method of determining dietary behaviour in large studies is through validated questionnaires. Unfortunately, there is no standardized questionnaire in

epidemiological surveys of erosive wear and this might explain some of the contradictory results between different studies, making the results difficult to compare. Furthermore, assessing the effects of acidic diet and other related factors based on questionnaires may not provide accurate data as the answers are limited by the respondents' ability to recall.

Although a large number of different dietary items were included, there is always a possibility that other important items have been overlooked. Frequency of meals, quantities consumed and the way of drinking have also been shown to influence the erosion outcome [Jarvinen et al., 1991; Johansson et al., 2002; Johansson et al., 2004; Moazzez et al., 2000], and could therefore have been included and investigated.

Discussion of main results

Scoring systems for dental erosive wear

Evaluation and comparison of the two clinical scoring systems, VEDE and BEWE, proved acceptable for registration of dental erosive wear. The results showed substantial κ_w values between the examiners, in contrast to the study by Larsen et al. [2005]. In that study, nine clinicians examined the same subjects and low inter-examiner agreement was observed. The average number of eroded surfaces by the examiners ranged from 4.1 to 21.3. One explanation for the difference in level of agreement between the two studies may be found in the calibration of the examiners and the definition of categories of the scoring systems. On the other hand, the smaller number of examiners contributing in the present study could have reduced variability compared with the study by Larsen et al. [2005]. The review from 2010 [Kreulen et al.] showed insufficient reporting of examiner-agreement: of 29 studies, only nine described intra- and inter-examiner agreement in their papers. In addition, as far as we know, there are very few studies which have tested the scoring system prior to the onset of an

investigation [Larsen et al., 2005; Margaritis et al., 2011]. When reliability of the scorings systems is not known the results from different studies are difficult to compare.

The BEWE score 2, defined as a distinct defect, with hard tissue loss of less than 50% of the surface area and score 3, which is a hard tissue loss of more than 50% of the surface area, are broadly defined as they cover tissue loss from minimal, surface loss to the loss of almost all enamel and even dentine. As there are no clear distinctions between the severity grades, the lesion's progression is difficult to estimate. For the VEDE, the limitation may be its detailed scale, especially the characteristics between no dental erosive wear (score 0), initial loss of enamel (score 1) and pronounced loss of enamel (score 2). This could influence the reproducibility of the scores as shown by the inter-examiner agreement levels in the clinical examination, which was just 30% for score 1. Nevertheless, to register early lesions restricted to the enamel is important from an epidemiological, preventive and treatment planning point of view. Therefore, a detailed scoring system should be applied. This study does not show whether the low examiner agreement is due to the system's detailed scoring scale or the examiners' weakness in recording initial lesions in general. In the study by Larsen et al. [2005], the examiners also had difficulty differentiating between intact enamel and early enamel lesion.

Another concern is whether the use of photographs is a suitable tool for detecting these minor lesions. The present results show a reasonable spread of data between scores 0 and 1, assuming that the use of pictures-based classification (as VEDE) may be preferable for measuring dental erosive wear and may be on a par with clinical examination. An unpublished study by Hove et al. [2012] investigating the reliability of clinical photographs and study models compared with a clinical examination, concluded that both methods gave

reliable estimates and could be considered suitable for diagnosing and following lesion progression over time.

The BEWE system does not distinguish between enamel loss and exposed dentine, which could be regarded as a way of avoiding diagnostic uncertainties [Bartlett et al., 2008]. This view is shared by Ganss et al. [2006], as well as supported in a later study by Holbrook and Ganss [2008], who concluded that the visual diagnosis of exposed dentine is difficult. The VEDE has two scores for enamel loss and a detailed distinction between dentine scores (scores 3, 4 and 5), which did not seem to influence the variability between observers compared with the BEWE. A higher proportion of agreement was found between the examiners for VEDE dentine score 3 (67%), compared with the enamel scores 1 (30%) and 2 (57%). This does not support doubts regarding dentine diagnosis, as pointed out previously [Bartlett et al., 2008; Ganss et al., 2006; Holbrook and Ganss, 2008]. One should bear in mind that the differentiation between the enamel and dentine may be an important factor for recording progression of dental erosive wear [Fares et al., 2009; Ganss et al., 2006] and for treatment planning. Another advantage in defining dentine exposure is its wide use by most scoring systems, making the results from other studies easier to compare.

Prevalence and distribution

The prevalence of dental erosive wear among the 18-year-olds was relatively high, 38% were registered with at least one tooth with erosive lesion. Although, the comparing different studies is difficult due to wide methodological variations, the dental erosive wear prevalence among the Norwegian 18-year-olds is somewhat higher than that found in other Scandinavian countries [Arnadottir et al., 2010; Esmark, 2009; Hasselkvist et al., 2010]. Great variations between examiners when recording erosive lesions have been reported [Larsen et al., 2005], and it should be emphasized that despite information and calibration meetings, the presence

of erosive wear was recorded in the screening session with a binary (yes/no erosion) response. Despite this simple registration method, 13.5% had no erosive lesions when 267 individuals were re-examined; these were considered false-positives. This over-registration was expected, as the clinicians were encouraged to register definite suspected lesions, and this must be taken into account when interpreting the prevalence.

Another consideration which may be taken into account when reporting on prevalence is whether the data are recorded at individual or tooth level. Furthermore, the severity grade (enamel/dentine) and the cuppings included may also influence the prevalence outcome. Among the Norwegian 18-year-olds, the adolescents with at least one tooth with an erosive lesion contributed to the prevalence, as did individuals with only cuppings, which could have increased the prevalence in our study. As expected, most of the lesions were confined to enamel, although dentine lesions were registered in 32% of the 267 individuals. It is important to take into account that those individuals with only one dentine lesions were included in the "dentine group". It may be discussed whether the presence of one dentine cupping is as serious as having one tooth with severe enamel lesion, or whether one surface with dentine exposure is more serious than severe enamel exposures on two teeth or more. It is important to relate the finding to each individual as progression and treatment need will require different follow-up from one individual to another. Having dentine lesions at age 18 is a worrying finding which may have major implications for the adolescents as well as for the dental health professionals. Therefore, categorizing the severity of erosive lesions on individual level is important for future treatment planning. The results may imply that in the future, a large quantity of restorative care may be required for these individuals. The findings also suggest that for the dental health personnel, the focus on detecting early enamel lesions should be emphasized so preventive strategies may be implemented.

For the wine tasters, a higher prevalence and more severe of dental erosive wear was shown compared with a group of non-wine consumers. The majority of the lesions in wine tasters involved dentine, while in the comparison group most erosive wear was confined to enamel. The prevalence of dental erosive wear among the physically active individuals was also high: 64% were registered with erosive lesions, which were more commonly found in the older participants (26-32 years). Even though there are only a few longitudinal studies on dental erosive wear [El Aidi et al., 2010; Lussi and Schaffner, 2000], the available studies suggest that with increased age, lesions progress. Our findings support this trend as the older participants had a higher prevalence and more severe lesions. This could be due to a longer acidic diets exposure to teeth in the older individuals. For eight of the nine wine tasters who had been extensively exposed to acid for several years (1-10 years), no wear could be registered, suggesting that there was no clear association between duration of wine tasting and the occurrence of lesions. On the other hand, five of the wine tasters who had worked at the AS Vinmonopolet for a short period (1-4 years) had several surfaces affected with severe lesions. The findings suggest that for some individuals it could be assumed that wine was the only risk factor in the development of erosive wear. It is unlikely than one isolated factor, such as wine, can be responsible for a multifactorial condition like dental erosive wear. One can speculate that in addition to behavioural factors, biological measures such as saliva and tooth structure and composition may contribute to development of dental erosive wear in some individuals. Another observation supporting this assumption is the data among the individuals who suffer from self-induced vomiting several times per day (Mulic et al., unpublished observations). Since these persons have extreme acidic exposure one could expect to find more erosive lesions than observed; in fact of 45 individuals, 22 were free of lesions. Recent studies have shown that certain enamel formation genes (ameloblastin, amelogenin, enamelin, tuftelin 1 and tuftelin interacting protein 11) are associated with high

caries experience and are able to modify caries susceptibility in humans [Deeley et al., 2008; Patir et al., 2008]. Perhaps these selected candidate genes that influence enamel formation may also explain individual protection against erosive components.

Dental erosive wear was predominantly found on the palatal surfaces of maxillary anterior teeth, as well as on the occlusal surfaces of lower first molars. This is also reported in other studies [Al-Dlaigan et al., 2001b; Arnadottir et al., 2010; Esmark, 2009; Ganss et al., 2001; Johansson et al., 1996; Larsen et al., 2005; van Rijkom et al., 2002]. It has been suggested that the abrasive effect of the tongue in combination with erosive components may contribute to a greater loss of tooth structure on the palatal surfaces [Amaechi et al., 1999; Gregg et al., 2004]. Furthermore, Amaechi et al. [1999] have shown that the thinnest pellicle is formed on the palatal surface of upper teeth, and on this site, the pellicle is less resistant to acidic exposure than the pellicle on the lower lingual surfaces. A high prevalence of lesions on lower first molars has also previously been reported [Arnadottir et al., 2010; Bardolia et al., 2010; Ganss et al., 2001; Truin et al., 2005], and may be explained by the significantly thinner enamel in lower molars than in upper molars, and that the enamel thickness is less in first molars compared with second and third molars [Smith et al., 2006]. The majority (52%) of the 18-year-olds had erosive lesions on both molars and anterior teeth, while 36% had lesions on molars only. This supports the finding of a cross-sectional and longitudinal investigation on study models [Ganss et al., 2001] where the authors conclude that the molars, especially the lower first molars, may be the site of the initial onset of dental erosion. Dentine erosive lesions were mostly found in lower first molars, while lesions confined to enamel dominated in upper anterior teeth. This distribution was also reported in the Dutch study [El Aidi et al., 2010] and could be explained by the fact that these molars are the first permanent teeth to erupt and thus are exposed during a longer period of time. In addition

Mandel [2005] have suggested in a case report that occlusal surfaces in molars are most likely to have contact with acid due to the gravity.

An expected finding in **Paper II** was the presence of cuppings on molars; this has been described in previous studies [Arnadottir et al., 2010; Hasselkvist et al., 2010; Johansson et al., 2002; Khan et al., 2001]. More than 60% of the participants were registered with cuppings on molars in addition to erosive lesions on other surfaces. In line with previous reports [Arnadottir et al., 2010; Hasselkvist et al., 2010; Johansson et al., 2002], the cuppings were registered on the lower first molars in 85% of the adolescents, especially on the mesio-buccal cusp tips, where the most severe lesions also were observed. Kono et al. [2002] showed that the enamel layer at and near the tip of the cusp in both upper and lower first molars is thin, and it has been suggested that cupping can occur when deeper enamel regions with lower microhardness are exposed [Meredith et al., 1996]. Although both Johansson et al. [2002] and Khan et al. [2001] concluded in their studies that cuppings may indicate early onset of active erosive lesions, it could be claimed that cupping is the most uncertain criterion of dental erosive wear, since it can be an effect of abrasion as well as of erosion. However, in industrialized countries, abrasion is not expected to be a significant factor in young people [Ganss, 2008; Van't Spijker et al., 2009], and therefore cupping occurring at younger ages is likely to be a result of erosive challenge.

Risk indicators

One of the purposes of the present investigation was to identify individuals at risk of dental erosive wear, and in order to be able to assess potential risk indicators for erosive lesions, background, behavioural, dietary and medical variables were evaluated.

Risk is defined as the probability that an event will occur within a given period of time [Rothman, 2002], and is used to express the probability of a particular outcome (i.e. disease)

to occur following an exposure [Burt, 2005]. A *risk factor* may be defined as "an environmental, behavioural, or biological factor confirmed by temporal sequence, usually in longitudinal studies, which, if present, directly increases the probability of a disease occurring, and if absent or removed reduces the probability" [Beck, 1998]. A *risk indicator* may be defined as "probable risk factor established in cross-sectional studies, in which correlations between various conditions and disease are investigated" [Rothman, 2002], and if validated in longitudinal studies may be a risk factor [Beck, 1998]. As this was a cross-sectional study, the strength of association identified was therefore limited to indicators for disease.

Background factors

In general, a higher prevalence of erosive wear was found in male participants than in female participants. This is in agreement with previous reports [Al-Dlaigan et al., 2001b; Arnadottir et al., 2010; Bardolia et al., 2010; Hasselkvist et al., 2010; Larsen et al., 2005]. Significantly more males had also extensive wear involving dentine. A study by Smith et al. [2006] showed that females have significantly thicker enamel than males. Furthermore, Bardsley et al. [2008] suggested that the reason why males have more lesions than females may be due to differences in the strength of musculature, biting forces and consumption of carbonated drinks, the last being in agreement with other studies [Al-Dlaigan et al., 2001a; Asmyhr et al., 2012; Bere et al., 2008b; Hasselkvist et al., 2010]. When introducing behavioural, dietary and medical variables in **Paper III**, the effect of gender became weaker, indicating that some of the effect of gender on dental erosive wear might be mediated by other significant variables. Therefore, whether observed gender differences in dental erosive prevalence are due to the biological or behavioural risk indicators remains unclear.

A secondary aim in **Paper III** was to assess risk indicators separately for males and females, and a difference between the genderes was revealed. For males, only vocational studies and frequent consumption of sugary soft drinks were significantly associated with erosive wear. For females, reported vomiting or reflux as well as consumption of fruit juice, were found to be significantly related to the presence of lesions. Previous studies have shown that the consumption of soft drinks is higher and more frequent in males than in females [Al-Dlaigan et al., 2001a; Asmyhr et al., 2012; Bere et al., 2008b; Hasselkvist et al., 2010]. On the other hand, it has been shown that girls tend to consume more fruit and juice [Al-Dlaigan et al., 2001a; Asmyhr et al., 2012; Bere et al., 2008a; Wang et al., 2010], and eating disorders are more common among females [Kjelsas et al., 2004]. These findings suggest that gender specific interventions in prevention of dental erosive wear might be an appropriate preventive approach, and when counselling adolescents at risk, gender specific risk indicators should be taken into account.

Erosive lesions were significantly more frequent in adolescents with caries experience, expressed by DMFT, than among those with no caries experience (**Paper II**). This trend has also been found by others [Bardolia et al., 2010; Dugmore and Rock, 2004], and may reflect, as suggested by Dugmore and Rock [2004], more frequent cariogenic and erosive diets among people with higher levels of caries experience. It has also been shown that children with high levels of caries experience consume soft drinks more frequently than those with low caries experience [Kleemola-Kujala and Rasanen, 1979].

The associations between the presence of dental erosive wear and socio-economic factors have shown inconclusive results as different social gradients were applied (**Papers II** and **III**). No association with dental erosive wear could be found when the socio-economic status was categorized according to the area of residence (**Paper II**), which is in accordance with

the results by Dugmore and Rock [2004]. By contrast, in **Paper III**, where the adolescent's occupational level was determined by socio-economic status, it was indicated that adolescents who were at work or unemployed and chose vocational studies were more vulnerable to dental erosive wear than those 18-year-olds who pursued general studies. The effect of education became insignificant when behavioural, dietary and medical variables were entered. The effect of education on dental erosive wear was mediated through soft drink consumption. This is supported by the findings of another Norwegian study on pupils with a mean age of 15.5 years (9^{th} and 10^{th} graders) where the absence of plans for a university education seemed to be a determinant of increased soft drink consumption [Bere et al., 2008b]. It should be borne in mind that comparing socio-economic status in different countries is difficult, due to different social structures, and because different social gradients are defined.

Behavioural factors

While good oral hygiene is of proven value in the prevention of periodontal disease and dental caries, frequent and prolonged tooth brushing may accelerate dental erosive wear [Bardolia et al., 2010; Zero and Lussi, 2005]. It has been suggested that health-conscious individuals tend to have better than average oral hygiene [Jaeggi and Lussi, 2006], so the finding that brushing teeth for more than two minutes at a time was associated with erosive lesions among the exercising participants was expected (**Paper IV**). Surprisingly, among the 18-year-olds, brushing once per day or less significantly increased the risk of erosive wear compared with twice per day or more (**Paper III**). Perhaps oral hygiene habits and dental erosive wear can partly be explained by personal behaviours related to dental health attitudes and awareness. One may speculate that individuals with a high consumption of sugary soft drinks brush their teeth less frequently, and therefore have increased presence of caries and erosive wear. Only a few studies have described dental health awareness in relation to dental

erosion [Asmyhr et al., 2012; Dugmore and Rock, 2003b; Hermont et al., 2011]. Both physically active participants and wine tasters registered with erosive lesions reported having received little information from the dental personel, indicating that better communication and understanding is needed. This should be investigated further.

Dietary factors

An acidic diet is considered to be an important contributor to the presence and progression of dental erosive wear [Lussi et al., 2004], confirmed by the findings of the present thesis. Frequent intake of acidic fruit juices and sugary soft drinks was significantly associated with the presence of erosive wear (**Paper III**), a finding supported by several other studies [Al-Dlaigan et al., 2001a; Jarvinen et al., 1991; Jensdottir et al., 2004; Wang et al., 2010]. Moreover, several times daily consumption of these items increased the risk of dental erosive wear for both drinks, indicating a dose-response relationship (greater consumption places the dentition to a greater risk), as previously suggested [Al-Dlaigan et al., 2001a; Jarvinen et al., 1991; Jensdottir et al., 2004]. This is a worrying finding, especially considering that the consumption of such drinks (mineral water, juice and soft drinks) has increased over recent decades. The estimated annual mean consumption of the fruit juice and soft drinks in Norway is well over 100 litres per person [Bryggeri- og drikkevareforeningen, Norway. 2012], putting Norway in the top five European countries. Although other acidic drinks included in the questionnaire, such as squash, low calorie soft drinks, sport drinks, flavoured water and alcoholic drinks, have similar erosive potential as fruit juice and sugary soft drinks, our results did not reveal associations between them and erosive lesions. This may be explained partly by a generally lower consumption of these drinks compared with fruit juice and soft drinks (Table 3, **Paper III**). Only 8% of the 18-year-olds reported daily or several times daily consumption of low calorie soft drinks, while 14% and 35% consumed sugary soft drinks and fruit juice daily, respectively. The findings are supported by the study of Asmyhr et al. [2012]

who also showed that only 4.9% of Norwegian 19-20 year-olds drank low calorie soft drinks daily or several times per day, while 17.5% consumed sugary soft drinks and 34.1% juice as often.

Some studies have demonstrated that sports drinks consumed during exercise are not associated with erosive lesions [Coombes, 2005; Mathew et al., 2002; Milosevic et al., 1997; Sirimaharaj et al., 2002], whereas Järvinen et al. [1991] found a four-fold increase in the risk. In the present thesis, consumption of sports drinks was not related to erosive wear. This could be explained by the small number of responders consuming sports drinks. Less than once per week consumption was registered by 87% of the 18-year-olds, while only three of the physically active young adults had a high consumption of sports drinks. It may be that the physically active participants, although regularly exercising, but not necessarily competitively, did not use nutrient replacements, and were possibly aware of the fact that the sports drinks offer no more benefit than water [Coombes, 2005].

Biological and medical factors

It is well known that high salivary flow rate favours the prevention and reduces the effect of acid attack [Hara et al., 2006]. Several studies have demonstrated that reduced salivary flow increases the risk of dental erosive wear dentition [Jarvinen et al., 1991; Lussi et al., 2006; Zero and Lussi, 2005]. Järvinen et al. [1991] found low stimulated salivary flow in 16 erosion cases and six controls, while a reduction in unstimulated flow was seen in seven erosion cases and six controls. They also found that individuals with a salivary flow rate of $\leq$ 1 ml/min were at a five-times greater risk of developing dental erosions than those with higher flow rates. These findings are in accordance with the results in **Paper IV** which support the statement of Järvinen et al. [1991] that salivary flow rate is an important factor determining whether erosive lesions occur. Although most participants studied demonstrated normal

salivary flow rate, the stimulated salivary flow of more than one third was in the lower rage (≤ 1ml/min) and significantly more erosive lesions were registered than in subjects with higher flow rates. Earlier studies have demonstrated that saliva flow rate appears to be modified during exercise [MacKinnon and Jenkins, 1993; Walsh et al., 2004]. During physical activity, decreased stimulated salivary flow was observed among more than half (64%) of the participants, which might be explained by an increase in sympathetic activity during intense exercise. Sympathetic innervations cause a marked vasoconstriction, resulting in reduced salivary volume [Chicharro et al., 1998]. This may also be a consequence of sweat-induced dehydration and restricted fluid intake during exercise. In a study by Horswill [2006], a significantly lower stimulated salivary flow rate and volume were shown even when consuming water during the training session.

Prolonged exercise may reduce the unstimulated salivary flow [Gatti and De Palo, 2011]. Our results showed no consistency - the unstimulated salivary flow increased as often as it decreased among the participants. One could speculate that the duration of the training session was too short to give measurable changes in unstimulated saliva, since it has been suggested that modification of hydration status can at the earliest be detected three hours after exercise [Oliver et al., 2008]. Another explanation of variability in the salivary flow rate may be individual variations [Kaufman and Lamster, 2002], as well as consumption of fluids during the exercise [Horswill et al., 2006; Walsh et al., 2004]. The findings in the **Paper IV** suggest that decreased salivary flow rate may be one of many factors contributing to dental erosive wear, and that the relationships between the factors leading to erosive lesions are complex.

A higher prevalence of erosive wear in patients complaining of reflux symptoms has been reported [Holbrook et al., 2009; Jarvinen et al., 1991]. Holbrook et al. [2009] found, in the

Icelandic study, a significant association between gastro-oesophageal reflux disease (GERD) and dental erosive wear, where 33.7% of the patients with pathological reflux symptoms had severe erosion into dentine. The 18-year-olds (**Paper III**) with a daily or weekly reported reflux symptoms had a two-times increased risk for dental erosive wear compared with a monthly or less frequent presence. Females had a higher risk than males. Although no significant association could be found between presence of erosive lesions and reflux symptoms among the physically active participants (**Paper IV**), more than one quarter reported occasions of reflux symptoms, a higher frequency than in the comparison group. This indicates that physically active individuals may be at risk of development of erosive lesions which can be related to reflux. Previously, it has been noted that gastro-esophageal reflux may be associated with some forms of tough exercise [Clark et al., 1989; Moses, 1990]. The study by Clark et al. [1989] has shown that running and weightlifting induced reflux in healthy individuals, and that reflux persist through a 1-hour run.

Vomiting is commonly found in patients with eating disorders, and has been associated with erosive lesions [Johansson et al., 2012; Milosevic and Slade, 1989; Robb et al., 1995; Rytomaa et al., 1998]. Among the adolescents in **Paper III** a significantly higher probability of erosive wear was revealed when self-reported vomiting was reported. In this study, adolescents with eating disorders had a 1.9 times increased risk of having erosive lesions, and girls were at a higher risk.

One should bear in mind that the reported presence of vomiting and reflux may be under-estimated. Adolescents may fail to report vomiting, as eating disorders often are related to guilt, shame and self-denial [Johansson et al., 2012]. Studies have also shown that there are patients with reflux oesophagitis who do not show reflux discomfort, known as “silent reflux” [Johansson et al., 2012; Rai and Orlando, 2001]. Even though only 4% and 14% of examined

18-year-olds (**Paper III**) reported presence of vomiting and reflux, respectively, a significant association with erosive lesions was revealed in the study.

CONCLUSIONS

This thesis aimed at describing the prevalence and distribution of dental erosive wear in different population groups in Norway, and to identify possibly, related risk indicators.

The major conclusions of the present survey are:

- Both scoring systems used for diagnostic purposes showed acceptable reliability in assessment of erosive lesions
    - A scoring system should clearly define categories of dental erosive wear
    - Visualisation (use of pictures) of a scoring system seems to improve the identification and assessment
    - A system that differentiates between erosive tooth wear in enamel and dentine is valuable for assessing progression and for treatment planning, and does not seem to reduce the variability between observers
- More than one third of the 18-year-olds and more than 60% of the individuals exercising regularly had dental erosive wear
    - Prevalence of dental erosive wear was higher in males than in females and in individuals with caries experience
    - The majority of erosive lesions were confined to enamel
    - The most affected teeth were maxillary anterior incisors and mandibular first molars, and a common finding was cuppings as one of the signs of erosive wear

- Half of the wine tasters had erosive lesions
    - No clear connection between duration of being a wine taster and occurrence of lesions was found
- Males, occupational status, frequent consumption of fruit juice and sugary soft drinks, and reported reflux and vomiting were all associated with presence of erosive wear among 18-year-olds in Oslo
    - Different risk indicators for dental erosive wear among males and females were revealed: for males, only engagement in vocational studies and frequent consumption of sugary soft drinks were significantly associated with erosive wear, for females, reported vomiting or reflux and consumption of fruit juice, were found to be significantly associated with the presence of lesions
- Decreased stimulated salivary flow rate during exercise may be associated with erosive wear

Before initiating an epidemiologic study of dental erosive wear, the scoring system should be tested for its reliability, as reliability testing may be an attempt to avoid diagnostic uncertainties. Dental erosive wear is a common, multifactorial finding in individuals who may be at risk, and information related to life style should be offered by dental personnel. The risk indicators identified may increase the possibility of targeting individuals with the highest risk of dental erosive wear so that preventive strategies may be put in place.

FURTHER RESEARCH

There is a need to conduct further studies in this field of research. Studies should explore methods for validation of erosive wear scoring systems, with a goal of reaching a consensus so that loss of tooth substance can be recorded correctly and studies worldwide can be compared.

Future research should be based on longitudinal studies, as there are no investigations on progression of erosive lesions among young adults.

As a follow-up to this thesis, an epidemiological study among 18-year-olds in the county of Rogaland has been initiated. The number and characteristics of erosive lesions will be described, and a questionnaire will be administrated. A further research area should be to explore knowledge, attitudes and beliefs related to dental erosive wear among 18-year-olds as it may seem that presence of dental erosive wear can partly be explained by personal behaviours.

In this thesis it has been shown that dental erosive wear is a multifactorial condition with certain background, behavioural and biological factors involved. It remains unclear whether dental erosive wear is affected by genetic variation and whether a hereditary factor is involved. Selected candidate genes that influence enamel formation may also explain individual protection against erosive wear, and identifying these genes could contribute to reveal individuals at risk.

THE CANDIDATE'S CONTRIBUTION

The candidate's contribution to the work in Papers I to V is indicated by asterisk as follows:

PAPER I:

- → study design and experimental protocol
- → data collection and calibration*
- → data analyses*
- → manuscript writing*
- → corresponding author*

PAPER II:

- → study design and experimental protocol
- → data collection and calibration*
- → data analyses*
- → manuscript writing*
- → corresponding author*

PAPER III:

- → study design and experimental protocol
- → data collection and calibration*
- → data analyses*
- → manuscript writing*
- → corresponding author*

PAPER IV:

- → study design and experimental protocol*
- → data collection and calibration*
- → data analyses*
- → manuscript writing*
- → corresponding author*

PAPER V:

- → study design and experimental protocol*
- → data collection and calibration*
- → data analyses*
- → manuscript writing*
- → corresponding author*

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UNIVERSITETET I OSLO
DET ODONTOLOGISKE FAKULTET

APPENDIX 1

1a. Invitation letter

Dette er en forespørsel om å delta i en vitenskapelig undersøkelse om

Syreskader på tenner – hvor ofte forekommer det?

- et spørsmål vi gjerne vil finne svar på ved å undersøke alle 18-åringer i Oslo.

Syreskader på tennene kan skyldes sure oppstøt i forbindelse med fordøyelsesbesvær eller syre fra brus og juice. I mange tilfeller er det ikke lett å finne noen spesiell årsak til disse syreskadene. Det kan faktisk være slik at noen får lettere slike skader på tennene enn andre selv ved normalt forbruk av sure drikker.

Formålet med studien er å kartlegge hvor mange som har slike syreskader og samtidig prøve å finne forhold som har betydning for utviklingen av disse. Vi ønsker å bruke og publisere resultatene i en doktorgrad, men enkeltpersoner vil ikke gjenkjennes i publikasjonene.

Undersøkelsen av tennene dine vil være på samme måte som du er kjent med fra tidligere. Det vil i tillegg bli stilt noen spørsmål knyttet til kosthold, vaner og livsstil. Svarene på spørreskjemaet og funnene fra tannundersøkelsen er de opplysninger som samles inn om deg. Alle opplysningene blir behandlet konfidensielt, og alle som arbeider med undersøkelsen har taushetsplikt.

Dersom det viser seg at du har syreskade på tennene, vil du få tilbud om en nærmere undersøkelse av spesialister ved Det odontologiske fakultet.

Det er helt frivillig å delta i undersøkelsen, og du kan trekke deg på hvilket som helst tidspunkt uten å oppgi noen grunn og vil få samme behandling som de som ikke deltar i undersøkelsen.

Hvis du ønsker å delta, ber vi deg å gi ditt skriftlige samtykke.

Prosjektet er godkjent av Regional etisk komité og Norsk samfunnsvitenskapelige datatjeneste.
Opplysninger om eventuell syreskade på dine tenner vil bli overført til et register hvor navn og adresse vil bli erstattet av et nummer. Samme nummer benyttes på spørreskjemaet. Disse opplysningene oppbevares atskilt og konfidensielt ved Det odontologiske fakultet der dataene vil bli bearbeidet. Du har når som helst innsynsrett i de opplysninger som blir registrert på deg. Prosjektet avsluttes i 2012, men data vil bli oppbevart ved Norsk samfunnsvitensskapelige datatjeneste i 10 år. Dersom det er ønskelig med en videre oppfølging/langtidsstudier, vil du bli kontaktet. Hvis du ikke hører noe, vil dataene anonymiseres senest innen 2022.

Alle som deltar, vil være med i trekningen av 10 gavekort à kr 1000,-.

Dersom du har spørsmål om undersøkelsen kan du kontakte en av de undertegnede.

Vennlig hilsen

Tannlege/stipendiat Aida Mulic tlf. 996 28 363

Førsteamanuensis Anne Skaare tlf. 22 85 21 86

Studien gjennomføres av: Universitet i Oslo, Det odontologiske fakultet, Institutt for klinisk odontologi, Pb 1109 Blindern, 0317 Oslo og Tannhelsetjenesten Oslo KF, Hagegaten 23**,** 0653 Oslo

1b. Informed consent

Pasient-/Journalnr. ☐☐☐☐☐☐☐

Samtykke-erklæring

Tittel på prosjektet: Dentale erosjoner blant norske ungdommer – forekomst og årsakssammenhenger

Navn på forskere: Førsteamanuensis Anne Skaare

Professor Anne Bjørg Tveit

Førsteamanuensis Nina J. Wang

Stipendiat/tannlege Aida Mulic

Vennligst kryss av i rubrikken

1. Jeg har lest informasjonen og forstår at deltagelsen er frivillig og at jeg kan trekke meg når som helst uten å oppgi noen grunn ☐
2. Jeg vil være med i undersøkelsen ☐
3. Jeg tillater at tannhelsedata kan hentes fra journal ☐
4. Dersom jeg har syreskader på tennene, ønsker jeg en nærmere undersøkelse ☐
5. Jeg tillater at data kan lagres i 10 år ☐

…….. …… ……..

Navn Dato Underskrift

(Bruk blokkbokstaver)

APPENDIX 2

2a. Registration form used in the clinical examination at the PDHS clinics

Registreringsskjema – erosjoner

Fylles ut av tannlege/tannpleier

Pasientens navn:

(bruk blokkbokstaver)

Adresse:

1 Pasient-/Journalnr. 2 Klinikknavn ……

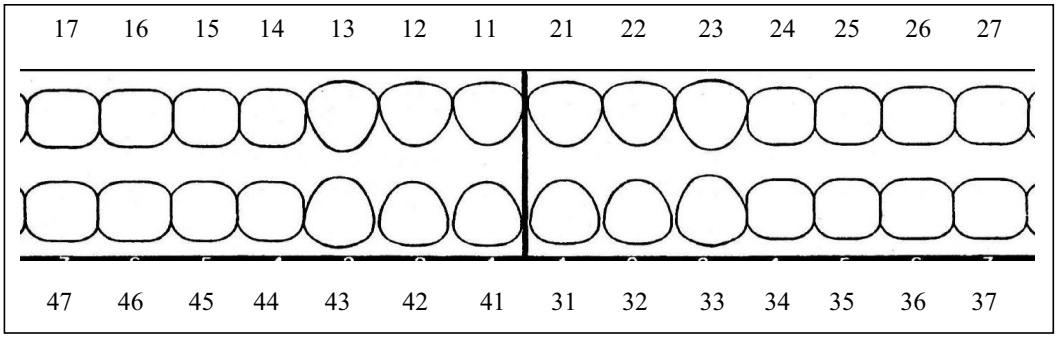
☐☐☐☐☐☐☐

3 **Undersøkelsesdato**: _____

4. **DMFT** ☐☐

5. **Erosjon:** Nei ☐ Ja ☐

Hvis ja, angi med **E** på den eller de tenner som har erosjonsskade



Kommentarer: ……..

Spørreskjema, registreringsskjema og samtykke sendes til:

Førsteamanuensis Anne Skaare

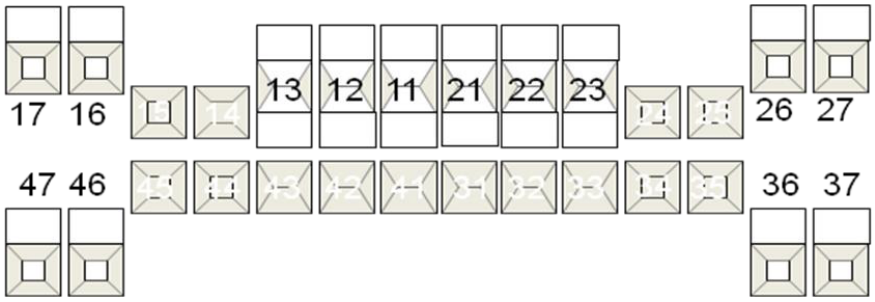
Inst. for klinisk odontologi

Postboks 1109 Blindern 0317 Oslo

2b. Registration form used in the second examination

Pas nr:

Undersøkelsesdato:



APPENDIX 3

Questionnaire

SPØRRESKJEMA

Fylles ut av tannklinikken

Pasient-/Journalnr. ☐☐☐☐☐☐

Klinikknavn ……..

Vennligst svar på alle spørsmål

Kjønn: Mann ☐ Kvinne ☐

Er du født i Norge? Ja ☐ Nei ☐ Hvis nei, i hvilket land: ……..…

Hvilket land kommer dine foreldre fra? ………...

Utdanning/arbeid: Allmennfaglig studieretning ☐ Yrkesfaglig studieretning ☐

Yrkesaktiv ☐ Arbeidsledig ☐

Tannhelse- og tannhelsevaner

Svar på alle spørsmål og sett kun **ett** kryss for hvert spørsmål

1. Hvor lenge er det siden sist du var hos tannlege/tannpleier?

0-6 mnd	1
7-12 mnd	2
13-24 mnd	3
Mer enn 24 mnd	4

2. Hvor ofte pusser du tennene?

Mer enn 2 ganger daglig	1
2 ganger daglig	2
1 gang per dag	3
Sjeldnere	4

3. Hvor lang tid omtrent bruker du på tannpuss daglig?

Mer enn 5 min	1
Mellom 2 og 5 min	2
Mellom ½ og 2 min	3
Mindre enn ½ min	4

4. Bruker du fluortabletter, fluorskyllevann eller fluortyggegummi?

Daglig	1
2-3 ganger pr uke	2
1 gang i uken	3
Sjelden eller aldri	4

5. Har du hørt om syreskader på tenner?

Nei	1
Ja	2

5a. Hvis ja, tror du selv du har syreskade?

Nei	1
Ja	2

6. Har tannlegen nevnt noe om syreskader på dine tenner?

Nei	1
Ja	2

7. Tror du god munnhygiene kan forebygge/stanse slik syreskade?

Nei	1
Ja	2
Vet ikke	3

Vennligst sett **et kryss på hver linje**

8. Hvor ofte drikker du eller spiser du følgende

		Flere ganger daglig	1 gang daglig	3-5 ganger i uken	1-2 ganger i uken	Sjeldnere enn 1 gang i uken
Drikker:	a. Juice					
	b. Saft					
	c. Brus (Cola, Pepsi, Solo, Mosell, Iste etc)					
	d. Lettbrus (Cola light, Zero, PepsiMax, Solo light, Iste light etc)					
	d. Sportsdrikker (XL1, Maxim etc)					
	e. Urtete, fruktte (eks. eplete, sitronte etc)					
	f. Flaskevann (med eller uten kullsyre)					
	g. Flaskevann med tilsatt smak (eks. dråpe sitron, bær, eple etc)					
	h. Rusbrus/vin					
Spiser:	a. Appelsiner/ grapefrukt/kiwi					
	b. Epler					
	c. Salat m/eddikdressing					
	d. Potetgull/chips med dip/dressing (eks. Kim's, Maarud)					
	e. Sure/syrlige godterier (eks. sure sild, sitrondrops etc)					
	f. Sugetabletter/drops med C-vitaminer					
	g. Youghurt					
		1	2	3	4	5

9. Hvor mye drikker du totalt av drikkene over pr. dag (unntatt flaskevann uten smak)?

Mer enn 2 liter	1
1-2 liter	2
½ - 1 liter	3
0 – ½ liter	4

10. Hvordan drikker du?

Svelger rett ned	1
Holder drikken i munnen en stund før den svelges	2
"Skyller" drikken rundt i munnen før den svelges	3

11. Hvordan drikker du <u>vanligvis</u> leskedrikker?

Av glass	1
Av flaske	2
Av sportsflaske, flaske med "drikketut"	3
Av sugerør	4
Like mye av glass og flaske	5

12. Driver du eller har du drevet med fysisk trening utenom gymtimene de siste 5 år?

a.

Nei ☐ 1
Ja ☐ 2

Hvis ja,
hva slags: ……

b. og hvor ofte?

Daglig ☐ 1
4-6 ganger i uken ☐ 2
2-3 ganger i uken ☐ 3
Ukentlig ☐ 4
Sjelden eller aldri ☐ 5

c. Trener du nå?

Nei ☐ 1
Ja ☐ 2

d. Hvor lang periode trente du eventuelt?
fra …… års alder til …… års alder

13. Drikker/drakk du under eller etter trening?

Nei ☐ 1
Ja, vann ☐ 2
Ja, annet ☐ 3

Hvis ja,
navn på drikken(e): ……

14. Bruker du medisiner?

Nei ☐ 1
Ja ☐ 2

a. Hvis ja, hvilken medisin (mot hva)?

……

b. Hvis ja, i hvilken form?

Tabletter ☐ 1
Mikstur ☐ 2
Spray ☐ 3
Inhalasjonsaerosol ☐ 4

15. Har du vært, eller er du, plaget med sur smak i munnen eller sure oppstøt?

Nei ☐ 1
Ja ☐ 2

Hvis ja, a) Hvor ofte?

Daglig ☐ 1
Noen ganger i uken ☐ 2
Månedlig ☐ 3
Sjelden eller aldri ☐ 4

b) Hvor lenge har det vart?

Uker ☐ 1
Måneder ☐ 2
Flere år ☐ 3

16. Har du vært, eller er du, plaget med oppkast?

Nei ☐ 1
Ja ☐ 2

Hvis ja, a) Hvor ofte?

Daglig ☐ 1
Noen ganger i uken ☐ 2
Månedlig ☐ 3
Sjelden eller aldri ☐ 4

b) Hvor lenge har det vart?

Uker ☐ 1
Måneder ☐ 2
Flere år ☐ 3

TUSEN TAKK FOR HJELPEN!

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BMC Oral Health

RESEARCH ARTICLE Open Access

Dental erosive wear and salivary flow rate in physically active young adults

Aida Mulic*, Anne Bjørg Tveit, Dag Songe, Hanne Sivertsen and Anne B Skaare

Abstract

Background: Little attention has been directed towards identifying the relationship between physical exercise, dental erosive wear and salivary secretion. The study aimed i) to describe the prevalence and severity of dental erosive wear among a group of physically active young adults, ii) to describe the patterns of dietary consumption and lifestyle among these individuals and iii) to study possible effect of exercise on salivary flow rate.

Methods: Young members (age range 18-32 years) of a fitness-centre were invited to participate in the study. Inclusion criteria were healthy young adults training hard at least twice a week. A non-exercising comparison group was selected from an ongoing study among 18-year-olds. Two hundred and twenty participants accepted an intraoral examination and completed a questionnaire. Seventy of the exercising participants provided saliva samples. The examination was performed at the fitness-centre or at a dental clinic (comparison group), using tested erosive wear system (VEDE). Saliva sampling (unstimulated and stimulated) was performed before and after exercise. Occlusal surfaces of the first molars in both jaws and the labial and palatal surfaces of the upper incisors and canines were selected as index teeth.

Results: Dental erosive wear was registered in 64% of the exercising participants, more often in the older age group, and in 20% of the comparison group. Enamel lesions were most observed in the upper central incisors (33%); dentine lesions in lower first molar (27%). One fourth of the participants had erosive wear into dentine, significantly more in males than in females ($p = 0.047$). More participants with erosive wear had decreased salivary flow during exercise compared with the non-erosion group ($p < 0.01$). The stimulated salivary flow rate was in the lower rage (≤ 1 ml/min) among more than one third of the participants, and more erosive lesions were registered than in subjects with higher flow rates ($p < 0.01$).

Conclusion: The study showed that a high proportion of physically active young adults have erosive lesions and indicate that hard exercise and decreased stimulated salivary flow rate may be associated with such wear.

Keywords: Dental erosion, diet, exercise, prevalence, saliva

Background

Dental erosive wear is an irreversible condition of growing concern to dental practitioners and researchers. Recent publications have shown a high prevalence of erosive lesions in young individuals [1-3]. The severity of the condition depends on several factors, such as lifestyle and diet, type and time of exposure to an erosive agent, mineralization of dental tissue, and saliva composition [4]. Saliva is essential for the maintenance of oral health and decreased salivary flow causes a clinically significant oral imbalance [5]. Furthermore, diminished saliva production reduces the capacity to clear and neutralize dietary acids in the mouth contributing to erosive lesions in some individuals [6-8]. Järvinen et al. [6] found that patients with a salivary flow rate of ≤ 1 ml/min were at a five-time greater risk of developing dental erosions than those with higher flow rates.

An increased interest in "healthy" lifestyle involving regular exercise and healthy diet, can lead to dental problems such as erosive wear [7]. It is well-known that salivary flow rate and saliva's composition may be influenced by exercise [9,10], caused by rapid breathing and sweat-induced dehydration. As far as we know, there are no studies on a

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possible relationship between exercise, dental erosive wear and salivary secretions.

The aims of the present study were three-fold: i) to describe the prevalence and severity of dental erosive wear among a group of physically active young adults, ii) to describe the patterns of dietary consumption and lifestyle among these individuals and iii) to study possible effect of exercise on salivary flow rate.

Methods

Study population

The study involved 220 adults, 77 men and 143 women with an age range from 18 to 32 years (mean 21 years, SD 4). The sample of the adults was divided into two groups:

1) Exercise group: 104 participants (36 men, 68 women; age range 18-32; mean 25 years, SD 4) who worked out at a fitness centre twice or more per week. These participants were divided into two age groups: 18-25 years (n = 63; 17 men, 46 women; mean 22 years) and 26-32 years (n = 41; 19 men, 22 women; mean 29 years). All were non-smokers and free of any medications.

2) Comparison group: 116 individuals (41 men and 75 women, age 18 years), who attended the Public Dental Health Service (PDHS) for regular dental treatment and who were already participating in a study among Norwegian 18-year-olds. The inclusion criterion for these adolescents was no regular exercise during the last five years outside school.

Sample size calculation was performed prior to initiating the study, and showed that 120 participants were needed in each group to detect a difference between the two groups at a two-sided alpha level of 5% (type I error) and 80% power (type II error of 20%), when expecting 40% prevalence of erosive wear in the exercise group and 30% among the comparison participants.

Exercise session

Each exercise session lasted between 60 and 90 minutes, and the equipment included stationary bike ergometers and treadmills.

Clinical examination

In the exercise group, the examination was carried out at the fitness centre in a garden chair, using light, mouth mirror, dental probes and cotton rolls to dry the teeth. The comparison participants (controls) were examined as part of their regular dental visit at a PDHS clinic. The teeth were dried and, if necessary, cotton rolls were used to remove food debris. Sixteen surfaces per participant were examined: the occlusal surfaces of the first molars in both jaws and the labial and palatal surfaces of the upper incisors and canines. Dental erosive wear was classified by the Visual Erosion Dental Examination (VEDE) system [11], according to the following criteria: score 0: no erosion; score 1: initial loss of enamel, no dentine exposed; score 2: pronounced loss of enamel, no dentine exposed; score 3: exposure of dentine, < 1/3 of the surface involved; score 4: 1/3 - 2/3 of the dentine exposed; score 5: > 2/3 of dentine exposed. In cases of doubt the lower score was recorded. Only lesions that were considered as obvious dental erosive wear defects were registered, including cuppings/grooves of the molar cusps.

When index surfaces were filled, bonded with a retainer, considered to have attritions and wedge-shaped defects or the tooth was extracted, the surfaces and teeth were recorded as missing and excluded.

Saliva collection

With the allocated resources and of convenience the first 70 participants arriving to the fitness centre were asked to provide the saliva samples in a quiet, isolated room. The participants were fully informed of the process of the saliva collection.

Prior to the exercise, the participants were told to relax in an upright sitting position for few minutes before collecting the unstimulated whole saliva. Immediately afterwards, they performed a standardized, 10 minutes collections of saliva by letting the saliva drip into a graduated plastic tube. After collecting the unstimulated saliva, the subjects were given an unflavoured paraffin gum to chew at a rate of their own chewing frequency for 5 minutes to collect the stimulated whole saliva. Swallowing was not permitted. After the collection, the amount of saliva (ignoring the foam) was measured to an accuracy of 0.1 ml and flow rate (ml/min) was determined for each saliva sample. The same process was repeated immediately after the exercise. The participants were instructed to consume liquid during exercise session as they normally would do.

Questionnaire

In connection with the clinical intraoral examination, each participant was asked to complete a questionnaire. The questionnaire covered details of medical and dietary history and oral hygiene habits. The medical history included information about possible gastro-oesophageal reflux and type and frequency of any medication used regularly. The dietary questionnaire covered details of the frequency and quantity consumed of common drinks and foods associated with dental erosive wear such as orange/apple/grapefruit juice, carbonated beverages, sports drinks and some types of fruit like oranges, grapefruits and apples. Dental hygiene habits, the frequency and duration of tooth brushing, fluoride consumption and the time of last dental visit were also recorded.

Reproducibility of scorings

To register the number and severity of dental erosive lesions, the exercise group was examined by the first author (AM), who had previously undergone training, calibration and examination using the VEDE system on both clinical intra-oral photographs and on a group of individuals [11,12]. The mean inter-examiner value was 0.77 (κ_w) (on photographs) and 0.73 (κ_w) (on patients) indicating substantial agreement [11,13]. Re-examination of the participants was not performed in the present study due to practical reasons. However, inthe earlier study [11], thirty 18 year-old adolescents (600 surfaces) were re-examined by the first author (AM) 10 to 21 days after their initial examination, indicating a very good level of agreement (κ_w = 0.95) [13].

Statistical analyses

The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Inc. Chicago, IL, USA version 16). The absolute frequencies and proportions were obtained for descriptive and bivariate analysis (Chi-squared test) to test for possible associations between the variables. The level of significance was set at 5%. The statistical analysis for the weighted kappa (κ_w) was calculated using a spreadsheet programme (Microsoft Excel).

Ethical considerations

The study was approved by the local Regional Committee for Medical Research Ethics and The Norwegian Social Science Data Services. Written, informed consent was obtained from all participants.

Results

Prevalence and distribution of dental erosive wear

Dental erosive wear was registered in 64% of the exercising participants. In the age group 26-32 years, 76% had erosive lesions, while the prevalence was 57% among 18-25 year-olds ($p < 0.01$, Figure 1), higher than in the comparison group where 20% of the 18-year-olds had dental erosive wear ($p < 0.01$).

More men (78%) had erosive lesions than women (57%), but this difference was not statistically significant ($p = 0.064$). However, a significantly higher frequency of dentine lesions was found in men ($p = 0.047$; Figure 2).

No statistically significant differences were found between the numbers of lesions on contralateral tooth pairs. The highest frequency of erosive lesions was registered on the upper central incisors (33%), followed by first molars (27%). The majority of the lesions were confined to enamel. The highest occurrence of lesions with dentine involvement was found on the first molars (12%).

Saliva collection

In 64% (n = 45) of the individuals reduced stimulated salivary flow was registered after exercise whereas an increase was observed in 36%. The mean value before exercise was 1.43 ml/min (SD 0.09), while the mean value of 1.31 ml/min (SD 0.08) was measured after the training session. For the unstimulated saliva, nearly the same number of participants had reduced salivary flow (n = 32) as those who had an increased flow (n = 31) after exercise. In seven individuals (10%), the unstimulated flow rate remained unchanged (Figure 3). The mean value before exercise was 0.30 ml/min (SD 0.02), and 0.32 ml/min (SD 0.03) after exercise. A reduction in both stimulated and unstimulated salivary flow was registered in 36% (n = 25) of the participants, whereas 23% (n = 16) had an increase in both parameters. The remaining 41% (n = 29) had either an increase or a decrease in either unstimulated or stimulated salivary flow.

Of those with reduced stimulated salivary flow rate after exercise (n = 45), 36% had erosive wear, while of participants with increased salivary flow (n = 25), only 9% had erosive lesions ($p < 0.01$; Figure 4). Dentine lesions were registered more frequently among participants with reduced stimulated or unstimulated salivary flow compared with individuals with increased salivary flow (Table 1). Comparing the prevalence of erosive lesions among the "saliva providers" (n = 70) with the "non-saliva providers" (n = 44), no significant difference was observed.

Table 2 shows distribution of stimulated and unstimulated salivary flow rates before and after exercise. Of the participants, 34% (before exercise) and 41% (after exercise) had stimulated salivary flow rate in the lower range (≤ 1 ml/min). The participants with stimulated and unstimulated salivary flow rate in the lower range had more erosive lesions than those with higher flow rates ($p < 0.01$).

Questionnaire

Exercise session

Of the participants, 45% exercised 2-3 times per week, 37% 4-6 times per week, while 17% worked out daily. No statistically significant association could be observed between the presence of erosive wear and the amount of training ($p = 0.90$). During the exercise, all the participants reported consuming water, while three consumed sports drinks in addition.

Medical history

All participants in the exercise group were healthy adults, with no medical history. In the comparison group, 21 individuals (18%) used medications; but no dental erosive wear was seen in those participants.

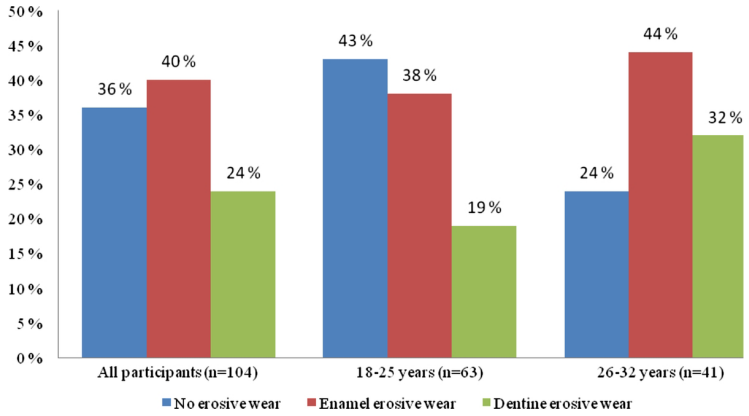

Figure 1 Frequency and severity of dental erosive wear according to participants' age among physically active young adults (n = 104).

Nearly one quarter (23%) of the individuals at the fitness centre reported the occurrence of gastro-oesophageal reflux and for 7% this was a weekly occurrence. No significant correlation between the occurrence of reflux and presence of erosive lesions could be observed. Only 4% reported reflux in the comparison group.

Dietary history

Consumption of acidic drinks and citrus fruits were dichotomized into high (once per day or more) and low (3-5 times per week or less) consumption. High consumption of acidic drinks was reported by 43%, while 23.5% had equivalent intake of acidic fruits (grapefruit, oranges, apples). Only 3% of the participants had a high consumption of sports drinks. No significant correlation between the intake of acidic drinks/fruits and the presence of dental erosive wear was found. The dietary questionnaire for the comparison group showed that 50% had a high consumption of acidic drinks; of these, 29% were registered with erosive lesions (p = 0.083). Furthermore, only 13% consumed fruits daily and all participants reported that they consumed sports drinks less than once per week.

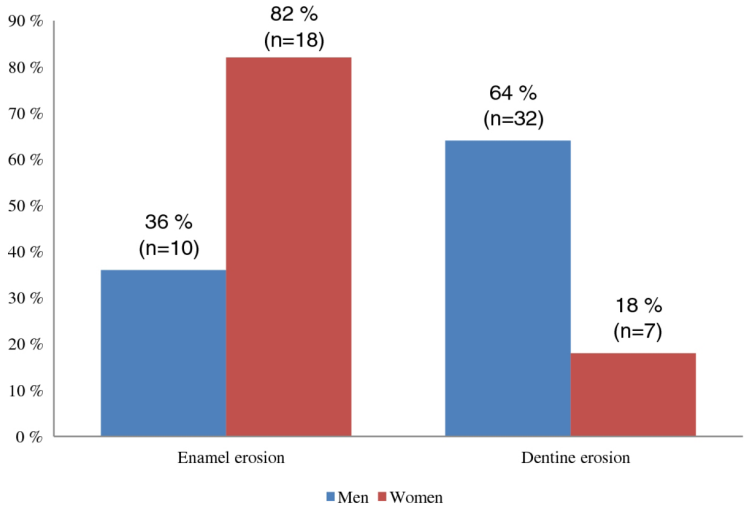

Figure 2 Distribution of erosive wear in the exercise group according to sex.

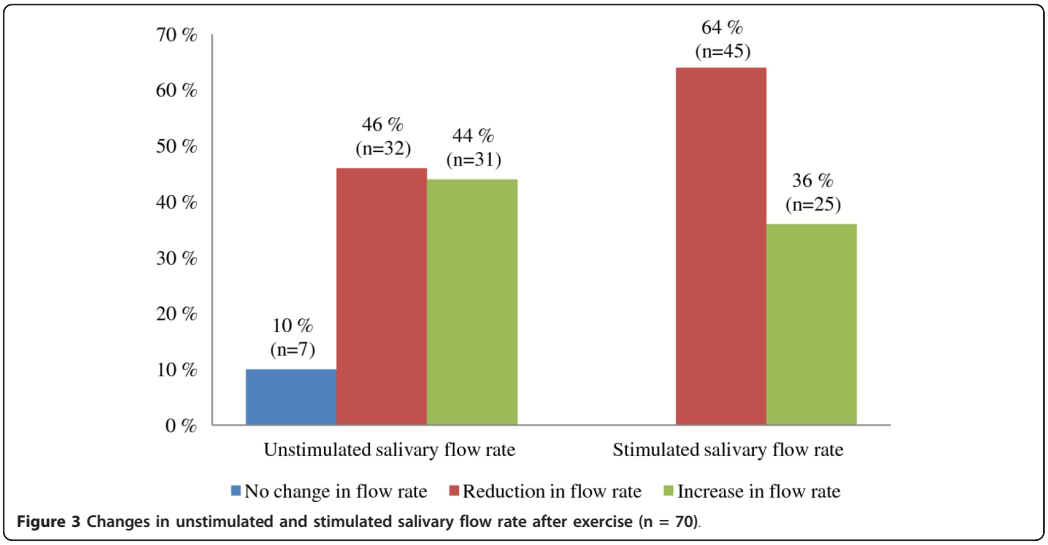

Figure 3 Changes in unstimulated and stimulated salivary flow rate after exercise (n = 70).

Oral hygiene habits

Both groups of participants brushed their teeth twice a day for approximately 2 minutes. Among those who brushed more that 2 minutes, significantly more erosive wear was registered (p = 0.01). Only 19% of the individuals in both groups used daily fluoride rinses.

The participants in both groups reported regular dental visits with a time interval from 6 months up to 2 years. In the comparison group 66% and in the exercise group 63% had made their last dental visit not more than12 months prior to the examination. No statistically significant difference was observed between men and women regarding their last dental visit (p = 0.151). In the exercise group, 82% registered with dental erosive wear had not been informed by their dentist/dental hygienist about the presence of these lesions.

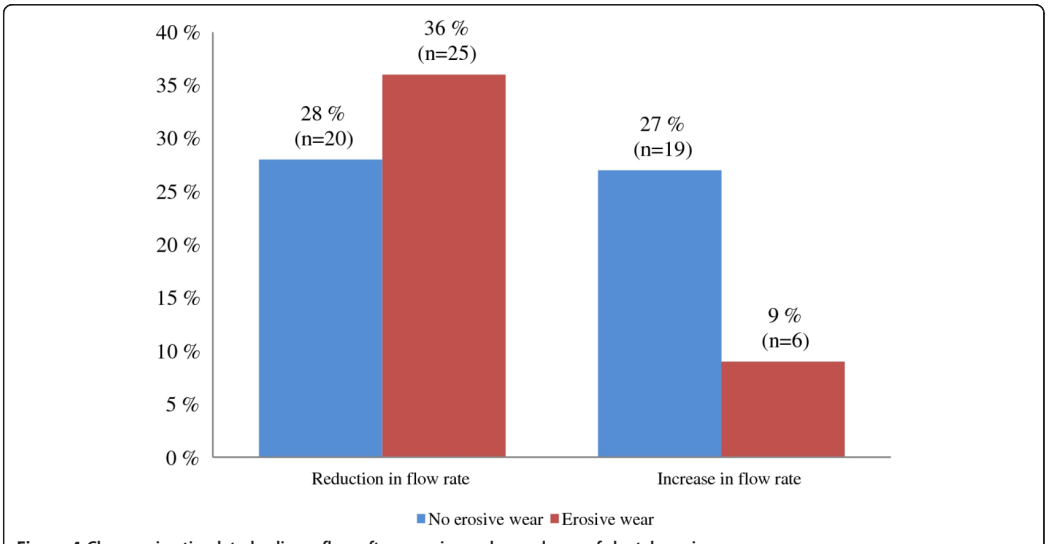

Figure 4 Changes in stimulated salivary flow after exercise and prevalence of dental erosive wear.

Table 1 Distribution and severity grade of dental erosive wear among physically active young adults (n = 70)

	Unstimulated salivary flow			Stimulated salivary flow		
	No change	Reduction	Increase	No change	Reduction	Increase
	N (%)	N (%)	N (%)	N (%)	N (%)	
No erosive wear	3 (43)	15 (47)	8 (26)	20 (44)	19 (76)	
Enamel erosive wear	3 (43)	6 (19)	15 (48)	13 (29)	5 (20)	
Dentine erosive wear	1 (14)	11 (34)	8 (26)	12 (27)	1 (4)	

Discussion

The present results revealed a higher prevalence of dental erosive wear among young physically active individuals compared with a group of young adults who did not exercise. A high consumption of acidic dietary components, such as beverages, citric fruits and sport drinks, as well as changes in salivary flow, have earlier been shown to increase the risk of erosive lesions [4,6,7,14-16]. In the present study, the questionnaire revealed a relatively high consumption of acidic beverages in both groups, particularly among the controls, but there was no significant association with erosive lesions. The consumption of citric fruits was relatively higher in the exercise group compared with the controls. Even though no association could be found with the erosive wear, the consumption may also be an explanation for the higher presence of lesions found among the individuals at the fitness centre. These findings suggest that isolating individual dietary components from other possible factors contributing to dental erosive wear may be too simplistic, and that the relationships between the factors leading to erosive lesions are complex. Furthermore, some studies have demonstrated that sports drinks used during exercise are not associated with erosive lesions in the athletes studied [14,17-19], whereas Järvinen [6] found a four-fold increase in risk of lesions when sports drinks were consumed. In the present study, consumption of sports drinks was not related to erosive wear. This could be explained by the small number of responders consuming sports drinks (only 3). As the participants were regularly undertaking exercise, but not necessarily competitively, they did not use nutrient replacements. In addition, the participants may have been aware of the fact that, for most individuals, the sports drinks offer no more benefits than water [19].

A higher prevalence of erosive wear in patients complaining of reflux symptoms have been reported [6,20,21]. In the study by Bartlett et al.[21], 64% of the patients with palatal erosion had pathological reflux symptoms. Although no significant association could be found in the present study, more than one fourth of the physically active participants reported occasions of reflux symptoms, a relatively higher frequency than reported in the comparison group. This indicates that physically active individuals may be at risk for development of erosive lesions which can be related to reflux symptoms. Previously, it has been noted that gastroesophageal reflux may be associated with some forms of tough exercise [22,23]. The study by Clark et al. [22] has shown that running and weightlifting induced reflux in healthy individuals, and that reflux persist through a 1-hour run.

While good oral hygiene is of proven value in the prevention of periodontal disease and dental caries, frequent tooth brushing may accelerate dental erosive wear [4]. It has been suggested that health-conscious individuals tend to have better than average oral hygiene [7]. The present study revealed that brushing teeth for more than two minutes at time was related to erosive lesions in both groups.

The questionnaire revealed that 82% of the physically active young adults with erosive wear who recently had been to their dentist/dental hygienist had not been informed about the presence of these lesions. This indicates a lack of awareness among dental practitioners regarding dental erosive wear and an increased risk for some physically active people who practice good oral hygiene.

The prevalence of dental erosion increases with age [24], because older individuals are more likely to have exposed their teeth to acidic diets for a longer time. The findings from the present study support this trend. The older age group (26-32 years) had a higher prevalence and more severe erosive lesions than participants in the age group 18-25 years.

Table 2 Distribution of unstimulated and stimulated salivary flow rates before and after exercise (n = 70)

Reference values	Unstimulated salivary flow		Reference values	Stimulated salivary flow	
	Before	After		Before	After
	N (%)	N (%)		N (%)	N (%)
≤ 0.1 ml/min	3 (4)	9 (13)	≤ 1 ml/min	24 (34)	29 (41)
> 0.1 ml/min	67 (96)	61 (87)	> 1 ml/min	46 (66)	41 (59)

However, the findings should be interpreted with caution since our study has some limitations. There were slightly more women than men among the cases, and the controls were on average four years younger. Furthermore, the conditions of the dental examination differ between the groups which could also have impacted our results. However, with no prevalence studies on dental erosive wear from Norway, and due to the difficulty of comparing studies from other countries because of different populations/age groups studied and examination standards, we decided to include a comparison group even though it was not perfectly matched. Furthermore, assessing the effects of acidic diet and other related factors based on questionnaires may not provide accurate data as the answers are limited by the respondents' ability to recall.

During physical activity, decreased stimulated salivary flow was observed among more than half (64%) of the participants. Earlier studies have demonstrated that saliva flow rate appears to be modified during exercise [9,10]. A decrease in salivary flow might be explained by an increase in sympathetic activity during intense exercise, since sympathetic innervations cause a marked vasoconstriction, resulting in reduced salivary volume [25]. This may also be a consequence of sweat-induced dehydration and restricted fluid intake during exercise. In a study by Horswill [16], a significantly lower stimulated salivary flow rate and volume was shown even when consuming water during the training session.

Prolonged exercise may reduce the unstimulated salivary flow [26]. Our results showed no consistency - the unstimulated salivary flow increased as often as it decreased among the participants. One could speculate that the duration of the training session was too short to give measurable changes in unstimulated saliva, since it has been suggested that modification of hydration status can at the earliest be detected three hours after exercise [27]. Another explanation of variability in the salivary flow rate may be individual variations [28], as well as consumption of fluids during the exercise [10,16]. Furthermore, by providing the saliva sample of only 70 out of 104 participants could have influenced the outcome. With the allocated resources and of convenience the first 70 participants arriving to the fitness centre were asked to provide the saliva samples. Comparing the prevalence of erosive lesions among the "saliva providers" with the "non-saliva providers", no significant difference was observed. Furthermore, there are no reasons to believe that the variations in flow rate between these participants should be different from the others. However, due to this uncertainty the results in the present study should be interpreted with caution. The participants consumed liquid during exercise session as they normally would with the intention to create a "real life situation" for the individuals. This could explain diversity in the unstimulated salivary flow rates and could have influenced the outcome of the present study, as liquid consumption during exercise may help maintain normal salivary function [16]. Another issue which could influence the salivary flow rates is diet and liquid intake before the exercise. It is known that previous stimulation of less than 1 hour prior saliva collection may influence the flow rate [29].

Several studies have demonstrated that reduced salivary flow may increase the risk to the dentition [4,6,7]. Järvinen et al. [6] found a low stimulated salivary flow in 16 erosion cases and 6 controls, while a reduction in unstimulated flow was seen in 7 erosion cases and 6 controls. These findings are in accordance with the present results. Although most participants studied demonstrated normal salivary flow rate, the stimulated salivary flow of more than one third was in the lower rage and significantly more erosive lesions were registered than in subjects with higher flow rates. Our findings support the statement of Järvinen et al. [6] that salivary flow rate is an important factor determining whether erosive lesions occur. One explanation could be the findings reported by Amaechi [30], higher salivary flow contributes to higher clearance and thus a lower erosive potential.

Conclusion

The high prevalence of dental erosive wear reported reflects a need for preventive programmes and counselling for physically active young adults as it has been shown that exercise and decreased salivary flow rate may be two of many factors contributing to dental erosive wear. However, in order to implement adequate preventive strategies, further research is still necessary to clarify the etiology of erosive wear, focusing on the biological, chemical and behavioural factors involved.

Acknowledgements

The authors would like to thank the participants for cooperation during the date collection.

Authors' contributions

AM carried out the data collection, assisted by DS and HS, data analysis and writing of the article. ABT initiated the idea and along with the ABS supervised the project and assisted in writing/editing of the article. All authors have read and approved the final manuscript.

Competing interests

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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