

# **On dental erosion among Yemeni children, adolescents, dentists and dental students**

Prevalence, scoring system, risk indicators and awareness

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## **List of abbreviations**

AA	Amin Al-Ashtal
AKJ	Ann-Katrin Johansson
BEWE	Basic Erosive Wear Examination
DMFS/T	Decayed Missed and Filled permanent Surface or Tooth
dmfs/t	decayed missed and filled primary surface or tooth
EPRS	Erosion Partial Recording System
EPRS-M	Erosion Partial Recording System-Modified
GBI	Gingival Bleeding Index
GER(D)	Gastroesophageal Reflux (Disease)
IBM	International Business Machines
K	Cohen's Kappa
L	Liter
NY	New York
SEPRS	Simplified Erosion Partial Recording System
SPSS	Statistical Package for the Social Sciences
TFI	Thylstrup-Fejerskov Index
UST-DC	University of Science and Technology – Dental College
USA	United States of America
VPI	Visible Plaque Index

## **Scientific environment**

The work in this thesis was carried out during the period August 2013 to August 2016 at the Department of Clinical Dentistry - Cariology, Faculty of Medicine and Dentistry, University of Bergen, Bergen, Norway. Data collection was carried out at the University of Science and Technology Dental College in Sanaa, Yemen (**Papers I & II**) and at dental clinics in Sanaa (**Paper III**). The work supervised by Professor Ann-Katrin Johansson as a main supervisor from the University of Bergen, Bergen, Norway and Professor Ridwaan Omar as a co-supervisor from Kuwait University, Kuwait. The project was supported by the Department of Clinical Dentistry, Faculty of Medicine and Dentistry, University of Bergen, Bergen, Norway.

## Summary

**Background:** Dental erosion is a multifactorial oral health problem with an increasing prevalence among children and adolescents in many countries. Awareness of the condition among lay people is generally lacking, and methods for its clinical grading also need further improvements.

**Aim:** The aims of this thesis was to investigate various aspects of dental erosion including prevalence and risk indicators, to evaluate the recording system used, and to assess the awareness of dental erosion in children, adolescents, and dental professionals in Sanaa, Yemen.

**Methods:** From a total of 6163 individuals, a random selection of 668 individuals aged 5-6, 13-14 and 18-19 years agreed to participate in the study. Participants underwent questionnaire and clinical examination. Dental erosion was graded using an erosion partial recording system (EPRS) which was subsequently modified (EPRS-M). General dental practitioners (n=323) in Sanaa and all final year dental students (n=97) at the University of Science and Technology Dental College, completed a different questionnaire.

**Results:** Advanced dental erosion into dentin was found in 6.8%, 3.0% and 14.6% within the three age groups. Prevalence rates by EPRS and EPRS-M were not significantly different. Advanced dental erosion was associated with higher frequencies of lime sucking and teeth sensitivity in the first age group, and with greater consumption of carbonated soft drinks in the second age group. In the third age group, it was associated with greater total consumption of acidic beverages, higher intake of cola-type soft drinks/pure fruit juices, absence of fluorosis and not having been breastfed. Advanced dental erosion was significantly more common in the oldest age group (OR=5.6). Only 17.4% of all participants stated they had heard about dental erosion, 4.8% had received information about it from their dentists and 7.5% knew how to prevent it. Acidic drinks were reported as a causative factor for dental erosion by 52% of students and 41% of dentists. The use of an index for grading dental erosion was reported by 27% of the students and dentists, while 51% considered reduction of acidic drink intake to be a preventive measure.

**Conclusions:** Advanced dental erosion was common in the 5-6 and 18-19 year age groups but not in the 13-14 year group. EPRS-M showed to be a reasonable tool and is recommended for future research. Information campaigns targeting negative life style habits and risk factors for dental erosion are advocated. Awareness of dental erosion among children, parents and adolescents as well as within the Yemeni dental profession was poor and needs to be improved. Knowledge about the causative factors of dental erosion, diagnosis and prevention were insufficient among dental students and dentists indicating a need for educational improvement.

## List of articles

This thesis is based on the following original publications and manuscripts, which will be referred in the text as Papers I-III.

- I-     **Al-Ashtal A, Johansson A, Omar R and Johansson AK.** Dental erosion in groups of Yemeni children and adolescents and the modification of an erosion partial recording system. *Int J Paediatr Dent.* 2016; doi: 10.1111/ipd.12263. [Epub ahead of print]
  
- II-    **Al-Ashtal A, Johansson A, Omar R and Johansson AK.** Risk indicators and awareness of dental erosion in Yemeni children and adolescents. *Submitted manuscript.*
  
- III-   **Al-Ashtal A, Johansson A, Omar R and Johansson AK.** Awareness and knowledge of dental erosion among Yemeni dental professionals and students. *BMC Oral Health* 2015; 15: 119.



## **1. Introduction**

In many countries, patterns of oral diseases have changed over recent decades. For example, several countries have seen a substantial decline in the prevalence of dental caries among both children and adolescents [1-3]. A reduction in the prevalence and severity of periodontal diseases has also been reported [4, 5]. These changes have been accompanied by a marked increase in the prevalence and severity of dental erosion, which has attracted the attention of researchers to more concertedly investigate this oral health problem since about the mid-1990s [6]. An important outcome of these efforts has been that the etiology of dental erosion has been found to be multifactorial and its occurrence among children and adolescents to be attributed largely to changes in life style especially dietary habits [7, 8].

### **1.1 Definition and terms**

Dental erosion was early on defined by Pindborg [9] as “loss of dental hard tissue by a chemical process that does not involve bacteria”. Later, Imfeld proposed another definition, stating that “The clinical term dental erosion is used to describe the physical result of a pathologic, chronic, localized, painless 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; they stem from dietary, occupational or intrinsic sources” [10].

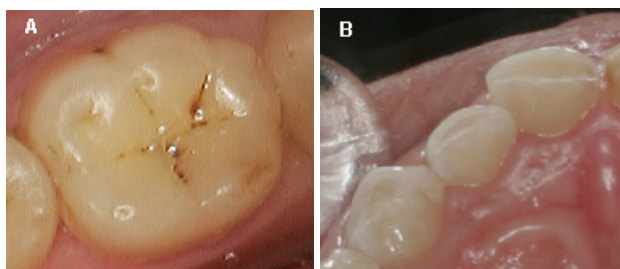
Dental erosion is considered to be the main contributing factor in the development of severe “tooth wear”, which occurs usually as a result of the combined effects of several mechanisms including erosion, abrasion, attrition, and abfraction [11]. The term “dental erosion” is commonly used to describe the loss of dental hard tissue by a chemical process that does not involve bacteria as stated by the definition [9]. Alternatively, the term “dental erosive wear” has been proposed to be used to describe the loss of hard tissue as the clinical manifestation of dental erosion [12]. In this thesis, the two terms “dental erosion” and “dental erosive wear” will be used synonymously.

## 1.2 Clinical appearance of dental erosion

In its early stage, dental erosion results in smoothening of the enamel surface that becomes shiny or glazed and without major changes in its original morphology. The luster of enamel surface may change, appearing irregular, matt, rounded, melted or flat [13]. During clinical examination, these minor changes could be easily overlooked as the color of the enamel and surface texture are not affected. Major morphological changes become apparent with progress of the lesion that might result in large concavities on the tooth surface, exposure of the dentine, or cupping (Figures 1 and 2). Cupping is a distinctive feature of dental erosion that results in the formation of a concavity on the cusp tip or incisal edge resembling a cup [14]. Such major morphological changes may eventually lead to esthetic problems, but could also cause tooth sensitivity, and even endodontic and functional problems.



**Figure 1.** Dental erosion on palatal surfaces of primary maxillary central and lateral incisors.



**Figure 2.** Cuppings on occlusal surfaces of a mandibular right first permanent molar (A) and on incisal edges of maxillary right primary incisors (B).

### **1.3 Indices for measuring dental erosion**

Indices to detect and grade the severity of dental erosion and tooth wear were early on proposed by Eccles (1979), and later by Smith & Knight (1984) [15, 16]. These two indices were subsequently modified to form other dental erosion indices including those by Linkosalo and Markkanen (1985) [17]; Lussi (1996) [18]; Johansson et al. (1996) [13]; Larsen et al. (2000) [19]; O’Sullivan (2000) [20]; Bartlett et al. (2008) (BEWE) [21]; Mulic et al. (2010) (VEDE) [22]; Hasselkvist et al. (2010) (SEPRS) [23] and Isaksson et al. (2014) [24].

These indices as well as others have been variously used in epidemiological studies to investigate the prevalence of dental erosion among several populations and age groups. Some of these studies have carried out full mouth recordings, by grading of all teeth, during their investigations [25, 26]. Other studies preferred partial recordings by depending on certain marker teeth [27-30]. Maxillary incisors and first molars were the most frequently used marker teeth as they were found to be more affected by dental erosion in several previous investigations [31-37]. The partial recording of teeth offers the advantages of time saving and cost reduction especially when population-based investigations are conducted.

A recent erosion partial recording system (EPRS) for grading dental erosion on anterior and posterior teeth was proposed by Hasselkvist et al. [23, 38]. The system combines two scales, one five-point ordinal scale (from 0 to 4) for grading erosion on maxillary anterior teeth that was developed by Johansson et al. [13], and another five-point ordinal scale for grading erosion/cupping on posterior teeth that was constructed by Hasselkvist et al. [23]. Thus the EPRS grades the severity of dental erosion on marker teeth including the buccal and palatal surfaces of maxillary anterior primary and permanent teeth and occlusal surfaces of first permanent molars and all primary molars (totally 16 permanent surfaces or 20 primary surfaces).

Hasselkvist et al. [23] have also proposed the simplified erosion partial recording system (SEPRS) which uses the same combined two ordinal scales but only on the palatal surfaces of maxillary central primary or permanent incisors and occlusal surfaces of mandibular first permanent molars or all first primary molars (totally 4 permanent surfaces or 6 primary

surfaces). The sensitivity and specificity of SEPRS in relation to the EPRS was validated on a Swedish population [23] and found to be sufficiently high to enable the SEPRS to be used as a new time-efficient dental erosion scale for future research. Nevertheless, SEPRS still needs to be evaluated in relation to the EPRS on different populations as dental erosion may affect teeth surfaces differently depending on the roles of population-specific lifestyle factors such as dietary habits.

Today, there is no dental erosion index that has been universally adopted by researchers. Indices are therefore used by dental erosion researchers according to individual study aims and also their preferences. Thus, further efforts are needed to evaluate these indices clinically and to try to reach agreement on a universal dental erosion index to be more universally used.

#### **1.4 Epidemiology of dental erosion**

Studies from different countries around the world have confirmed the presence of dental erosive lesions among different age groups [39-46]. Although primary and permanent teeth are both affected by dental erosion to varying degrees, it has been suggested that the enamel of primary teeth is more prone to erosive wear due to significantly lower micro-hardness [47]. Previous studies that examined the primary dentition in children aged 3-6 years have found the prevalence of advanced dental erosion (extending into dentine) to be between 1-34% [23, 29, 48-51]. Hasselkvist et al. [23] found that 13% of the examined Swedish children in the age group 5-6 years had at least one tooth surface with erosive lesion extending into dentine. In the age group 12-16 years, the prevalence of advanced erosive lesions ranged from 13-53% [23, 51-54]. Bardolia et al. examined 629 children aged 13-14 years in the Isle of Man and found that 20% of them had erosive lesions extending into dentine [53].

Studies conducted on adolescents aged 18-21 years found the prevalence of advanced erosive lesions to be between 1-22% [13, 23, 41, 55]. Søvik et al. [41] found that 15% of the examined 16-18 years old Norwegian adolescents had one or more tooth surfaces affected by advanced erosive lesions. Fewer studies have examined older adults aged 24-56 years [56, 57]. Overall, the results of the foregoing reports found the prevalence of dental erosive lesions to be from 7% to 39%. Unfortunately, it is difficult to compare the results of

these prevalence studies due to methodological variations such as differences in the scoring systems used, the selected teeth, age, gender and number of recruited participants (Table 1).

A few studies have attempted to detect the incidence and progression of dental erosion over time [52, 58, 59]. El Aidi et al. [60] examined 622 children in the Netherlands with a mean age of 12 years. They reported an increase in the prevalence of dental erosion from 32% at baseline to 43% over a period of 1.5 years. Another longitudinal study in England [52] examined 1753 children aged 12 years and re-examined 1308 of them at age 14 years. There was an increase in the prevalence of dental erosion from 56% at baseline to 64% at age 14 years. A recent longitudinal follow-up study among 13-14 year old adolescents in Sweden found that dental erosion severity had progressed by one grade in 32.3% and by two grades in 2.6% of all examined surfaces over a period of four years [38]. Although such longitudinal dental erosion studies are scarce, the available reports indicate that dental erosive lesions increase in number and progress in severity over time.

The prevalence of dental erosion was found to be significantly higher in boys according to some studies [60, 61] , while other studies reported more erosive lesions in girls [62, 63]. However, a population-based study from Brazil examined 675 adolescents aged 15-19 years and found no statistical difference between boys and girls regarding the occurrence of dental erosion [42].

**Table 1.** Prevalence studies on dental erosion among different age groups and populations. Listed prevalence rates refer to advanced dental erosion that extends into dentine or deeper.

Country	Age (years)	Sample size (n)	Prevalence	Author(s) and publication year
<b>Children</b>				
Saudi Arabia	5-6	354	34.0%	Al-Majed et al. 2002 [51]
China	3-5	1949	1.0%	Luo et al. 2005 [29]
Sweden	5-6	135	13.3%	Hasselkvist et al. 2010 [23]
Germany	3-6	775	56.8%	Tschammler et al. 2016 [58]
<b>Adolescents</b>				
Saudi Arabia	12-14	862	26.0%	Al-Majed et al. 2002 [51]
Iceland	12	757	0.9%	Arnadottir et al. 2010 [32]
Sweden	13-14	227	12.0%	Hasselkvist et al. 2010 [23]
France	14	339	39.0%	Muller-Bolla et al. 2015 [59]
Sweden	18-19	247	22.0%	Hasselkvist et al. 2010 [23]
Norway	16-18	795	15.0%	Søvik et al. 2014 [41]
Sweden	20	494	18.0%	Isaksson et al. 2014 [24]
China	18-21	600	1.0%	Chu CH et al. 2015 [55]
Poland	18	1886	28.9%	Struzycka et al. 2016 [61]

Although it is known that any tooth surface in the oral cavity could be affected by dental erosion, studies show that some tooth surfaces are more susceptible than others. For example, it has been found that the palatal surfaces of maxillary anterior teeth and the occlusal surfaces of molars are the most commonly affected [32, 34, 64, 65]. In another study, the buccal surfaces of maxillary incisors were more affected by dental erosive lesions [66]. Occlusal surfaces of first permanent molars were also reported to be more affected by dental erosion in some studies [60, 67]. Cupping is a characteristic sign of erosion and is considered as a marker for the onset of dental erosion [14, 68]. In addition, some studies have found a correlation between cuppings on molars and severity of dental erosion on

anterior teeth [23, 69]. Therefore, the presence and severity of cuppings should not be overlooked during any clinical examination for dental erosion.

## **1.5 Etiology of dental erosion**

Dental erosion is a multifactorial oral health problem that occurs when acids from different sources come in contact with the teeth [70]. The source of the acids could be “extrinsic” or “intrinsic” [71]. Extrinsic acids often come from the consumption of acidic foods and/or beverages. Airborne acids in the form of vapors or gases, emitted in some industrial processes, or accompanying some occupations, are also classified under external sources of acids [72, 73]. Intrinsic acids arise mainly from the stomach where stomach acids with low pH pass back through the esophagus to the oral cavity, and may occur during vomiting, or due to certain diseases including gastroesophageal reflux disease or self-induced vomiting connected with eating disorders such as bulimia nervosa [74, 75].

Oral factors and lifestyle factors may also affect the presence or severity of dental erosion. These include, for example, saliva, plaque, oral hygiene habits, mouth breathing, method of drinking, and physical activity [76-80]. Systemic diseases such as diabetes, asthma and Sjögren's syndrome might have indirect effects on dental erosion as a result of changed quality or quantity of saliva or due to the medications taken by the patient [81-83].

### **1.5.1 Extrinsic factors**

#### ***1.5.1.1 Diet***

Acidic drinks and foods are considered the most important extrinsic factors involved in the development of dental erosion [23, 84-86]. Several types of acidic beverages and foods have erosive potential such as carbonated soft drinks, fruit juices, sport and energy drinks, wine, fresh fruits, tomato ketchup, and sour candies [44, 56, 87-89]. The consumption of such acidic beverages and foods has increased markedly over the past decades in developed and in developing countries too [13, 90]. This increase in consumption of acidic drinks has been found to be significantly related to the occurrence and severity of dental erosion [63, 86, 91].

The acidity or low pH level of drinks and foods is an important factor in their erosive potential, but not the only one. Other factors including the acid type and mineral contents

can affect the erosive potential of such drinks and foods. The use of malic acid instead of citric acid, for example, could reduce the erosive potential of beverages [92]. Modifying the formula of beverages by the addition of ions such as calcium, phosphate and fluoride was found also to be capable of reducing their erosive potential [93-95].

Studies have also found that the manner in which soft drinks are consumed and the duration of drinking could increase the severity of dental erosion [79, 96]. Edwards et al. [97] have found that drinking directly from a cup has more erosive potential than drinking from a straw positioned towards the back of the mouth. Furthermore, Johansson et al. [69] have found that individuals who preferred to keep the soft drink in the mouth for a longer period of time before swallowing were more prone to have higher levels of dental erosion than controls.

#### ***1.5.1.2 Medications and occupation***

Medications with low pH such as iron tonic products, vitamin C, liquid hydrochloric acid, aspirin and some oral hygiene products have a dental erosive potential and have been shown to be correlated with the existence of dental erosion [98]. Intake of supplemental vitamins was also positively associated with dental erosion progression in a recent study [99]. Some occupations may predispose workers to other forms of external acidic challenges. Previous studies found a higher prevalence of dental erosion among people who work in battery and phosphate factories and subjected to acid fumes, or those people involved in sulfuric acid handling [72, 100, 101]. Other occupations and sports activities that were related to a higher prevalence of dental erosion include professional wine tasters and competitive swimmers, the latter group subjected to gas-chlorinated water in swimming pools [56, 102].

### **1.5.2 Intrinsic factors**

#### ***1.5.2.1 Acid reflux***

Gastroesophageal reflux refers to the backward flow of acidic stomach contents into the esophagus that often occurs after meals [103]. Gastroesophageal reflux is considered a physiologic phenomenon when limited to certain episodes per day [104]. However, gastroesophageal reflux disease GER(D) is a term used to describe the pathologic form of



gastroesophageal reflux, which is usually associated with clinical symptoms such as heartburn and acid regurgitation [104]. As a consequence of GER(D), the acidic contents of the stomach may reach the surfaces of the teeth and result in dental erosion and is regarded as an oral manifestation of GER(D) [103, 105].

Studies have investigated the association between GER(D) and dental erosion. Holbrook et al. [106] conducted a study in 249 Icelandic children and adults with age range from 6-65 years and found that individuals with confirmed GER(D) (n=91) were more likely to have dental erosion. However, another study found no association between dental erosion and GER(D) [107]. A recent systematic review that included 16 studies found a significant association between GER(D) and dental erosion in only seven of the studies [108].

#### ***1.5.2.2 Eating disorders***

Eating disorders refers to abnormal eating behaviors characterized by either restrictive eating or binge eating as manifested, respectively, in anorexia nervosa and bulimia nervosa. These conditions are often associated with self-induced vomiting that impose an acidic challenge to the teeth and is thus related to dental erosion [109, 110]. Johansson et al. [75] examined the oral health status of 54 patients with eating disorders (mean age 21.5 years; range 10-50 years), and compared them with controls of the same age and gender. The results showed that patients with eating disorders had a significantly higher risk for dental erosion.

A recent systematic review and meta-analysis that included fourteen papers found that patients with eating disorders had a higher risk of dental erosion. The authors suggested a causal relationship between eating disorders and dental erosion [111].

### **1.5.3 Oral health factors**

#### ***1.5.3.1 Saliva***

Saliva is an important biological protective factor against dental erosion, and is achieved through several mechanisms [112]. First, saliva has the potential to dilute dietary acids due to its buffering capacity. O'Sullivan et al. [113] investigated the salivary factors affecting dental erosion in 103 children and found that the highest proportion of participants in the erosion group had low salivary buffering capacity. Second, the salivary flow clears the oral

cavity from acids during the process of chewing [114]. Järvinen et al. [115] found that low salivary flow ( $\leq 0.1\text{ml/min}$ ) was associated with five times higher risk of dental erosion. Third, saliva contributes to the formation of the acquired pellicle which acts as a protective barrier on the enamel surface against acidic challenges [116]. Hara et al. [117] found that enamel surfaces covered with acquired pellicle in situ had lower demineralization after 10 minutes of exposure to orange juice. Fourth, saliva has mineral contents such as calcium, phosphate and fluoride which counteracts enamel demineralization and enhances remineralization [118].

Individuals with hyposalivation are therefore at a higher risk of developing dental erosion. Several factors may lead to hyposalivation including certain diseases such as Sjögren's syndrome, side effects of some drugs such as antihistamines, treatment of head and neck cancer with radiation, and excessive exercise [80, 119].

#### ***1.5.3.2 Plaque or pellicle***

The acquired salivary pellicle is a bacteria-free layer of proteins and glycoproteins that is derived from saliva and adsorbs onto the oral and enamel surfaces directly after teeth cleaning. This layer becomes heavily colonized by several types of oral bacteria within hours and eventually forms plaque on the teeth surfaces [120]. Plaque or pellicle were found to have a protective role against dental erosion by acting as a barrier that prevents direct contact between different acids and the teeth surfaces [117, 121]. Johansson et al. found that subjects with higher erosion level had less plaque accumulation on the palatal surfaces of maxillary teeth [69]. In addition, Amaechi et al. found an inverse relationship between severity of dental erosion and acquired pellicle thickness and concluded that pellicle provided protection against dental erosion [122].

#### ***1.5.3.3 Dental caries***

The relationship between dental erosion and caries is controversial. Previous studies have found a statistically significant association between the existence of dental erosion and caries [70, 123, 124], while such association was not found in other studies [125, 126]. Dental erosion is more common on plaque-free tooth surfaces [127], while plaque is the most important factor in the initiation and progression of dental caries [128]. Further

investigations are therefore needed to explain the concomitant existence of dental erosion with dental caries in some individuals.

#### **1.5.4 Lifestyle factors**

##### ***1.5.4.1 Physical activity***

Regular and strenuous exercise when associated with the consumption of sport drinks of known erosive potential may contribute to the development and severity of dental erosion [129]. This might be explained by the fact that salivary flow rate reduces during exercise due to the dehydration that results from sweating and rapid breathing [130, 131]. The reduction in salivary flow rate may result in decreased protection against dental erosion, so that consumption of acidic sport drinks during exercise may result in higher susceptibility for dental erosion. Järvinen et al. [115] found that the risk of erosive lesions increased four times among athletes who consumed sport drinks weekly. In addition, Coombes et al. [132] have concluded that consumption of sport drinks provided no more benefits in comparison with water for most athletes. Nevertheless, several researchers have found no association between consumption of sport drinks and dental erosive lesions among athletes [133-135].

##### ***1.5.4.2 Oral hygiene***

Tooth brushing is an important preventive oral hygiene habit against dental caries and periodontal diseases; however, it may enhance or counteract erosive tooth wear in different ways. The previously described protective effects of plaque against dental erosion might be reduced by tooth brushing with abrasive toothpaste, which was shown to remove or reduce the thickness of the acquired pellicle layer in previous reports [136, 137]. This could be supported by a result from another study that found less plaque accumulation among patients with higher levels of dental erosion [69]. On the contrary, modern toothpastes contain fluoride which helps in enamel remineralization and has a preventive effect against dental erosion [138].

Tooth brushing may have an abrasive effect especially on a previously eroded tooth surface, as was demonstrated in previous reports by the reduced abrasion resistance on demineralized teeth surfaces [139-141]. In another experimental study, excessive brushing had significantly increased abrasion of acid-eroded enamel while sound enamel surfaces

were not significantly affected [142]. At the same time, an increase in the loss of eroded hard dental tissues was found with increased abrasivity of toothpaste [143]. Therefore, abrasive particles in the toothpaste seem to be more responsible for this abrasion rather than the toothbrush itself [141]. However, Addy et al. concluded that normal tooth brushing of non-eroded teeth with toothpaste would not result in enamel wear in a lifetime while it may lead to only clinically insignificant loss of dentine (less than 1 mm) after 100 years [144].

A delay of one hour before tooth brushing was suggested to allow for enamel remineralization by saliva after an acidic challenge in a previous report [140]. On the other hand, it was suggested that this recommendation be reconsidered following a recent study which found that erosive tooth wear was not reduced in acid eroded enamel even after a four-hour exposure to saliva [145].

#### **1.5.5 General health factors**

The relationship between the existence of dental erosion and certain systemic diseases is still not clear. Previous reports found a higher prevalence of dental erosion among asthmatic individuals and attributed this increased prevalence to the acidic drugs that are prescribed and used by asthmatic patients [82, 146, 147]. On the contrary, Dugmore and Rock found no association between the presence of dental erosion and asthma [148]. In addition, they concluded that asthmatic drugs lack erosive potential. Intake of acidic medications has also been correlated with the presence of dental erosion, as already mentioned. Other systemic diseases that have been linked to the presence of dental erosive wear include diabetes and Sjögren's syndrome [81, 83]. These diseases cause dry mouth that may lead to increased consumption of acidic drinks, while at the same time lacking sufficient buffering capacity due to the decreased quantity/quality of saliva.

Another cause of dry mouth is mouth breathing which could be habitual or due to nasal obstruction. Mouth breathing was also found to be more common among people suffering from higher level of erosive lesions [69].

#### **1.6 Awareness about dental erosion**

As described previously, it is currently well-known that dental erosion has a multifactorial etiology. In addition, it was found that dental erosive lesions progress in severity if

etiological factors were not identified and prevented [62]. Therefore, dental professionals should be able to diagnose the presence of dental erosion clinically and recognize its etiological factors as early as possible.

Unfortunately, detection of dental erosion at an early stage is not an easy task for dental professionals [33, 149]. In addition, previous studies from the United Kingdom and Brazil have found inadequate awareness about dental erosion among dental professionals [150, 151]. Furthermore, there is lack of awareness about the condition in the community [152], and the majority of patients arrive at the dentist's office when erosive lesions are at an advanced stage, and restorative therapy is possibly unavoidable already [153].

The possibility of detecting an erosive lesion at an early stage depends mainly on the ability of the dental professional to both detect and recognize the early changes that occur on the enamel surfaces. However, a previous study conducted in a Brazilian dental school found that knowledge about dental erosion was not widely evident among faculty members, students and patients [151]. Out of 298 participants in the study, more than 60% of dental students and about a quarter of faculty members did not feel prepared to diagnose dental erosion.

On the other hand, awareness about dental erosion was found to be high (93.5%) among a population of 18 years old Norwegians [154]. However, patients only occasionally or rarely received advice from their dentists about the presence of dental erosion in other studies from Norway and England [56, 150, 155]. Therefore, it seems important to explore and to raise the awareness and knowledge about dental erosion among dental professionals and people in each community.

### **1.7 Rationale of the study**

Yemen is a developing country in the Arabian Peninsula with an area of 528,000 km<sup>2</sup> and a population of approximately 25 million. Sanaa is the capital of Yemen which is where most of Yemeni people and dentists prefer to settle and work. Modern life styles with increased consumption of carbonated drinks and fruit juices among children and adolescents have become popular in Yemen as they have in many other developing countries. These countries generally lack population-based adequate dental health services due to economic factors and a lack of sufficient qualified medical staff.

In order to provide the best preventive advice and management, investigations are needed to identify the prevalence of dental erosion and all possible factors that could be associated with its occurrence in each population. In addition, there should be adequate awareness and knowledge about dental erosion among the dental professionals and the community to enhance prevention and reduce the occurrence of this oral health problem. Exploring the prevalence and risk indicators of dental erosion will help health authorities to identify high risk groups and the associated factors, and so to plan and implement effective preventive programs towards reducing the risk for dental erosion in the community. Exploring the existing knowledge of general dental practitioners about dental erosion will help the dental educational sector to improve the level of awareness about dental erosion among dental students.

Most of the epidemiological studies on dental erosion have been conducted in developed countries and only a few reports are available from developing countries [44, 156]. Therefore, investigations are needed to explore the current status of dental erosion in developing countries, including Yemen, to provide preventive advice as early as possible and where needed. In addition, such investigations will provide a baseline for future prevalence and incidence studies in these countries and will enable broad comparisons with other populations in the world. So far, no epidemiological study of dental erosion has been performed in Yemen.

## **2. Objectives**

The general aim of this study was to investigate various aspects of dental erosion including prevalence, evaluation of recording system, risk indicators and awareness in three groups of Yemeni children and adolescents, and to explore the level of knowledge and perceived awareness among a group of Yemeni dental practitioners and dental students in Sanaa.

### **Specific objectives**

- 1- To assess the prevalence and severity of dental erosion among three groups of Yemeni children and adolescents in Sanaa (Paper I).
- 2- To clinically compare an erosion partial recording system (EPRS) with its simplified version (SEPRS) in three groups of Yemeni children and adolescents, and modify it if necessary (Paper I).
- 3- To investigate risk indicators of advanced dental erosion among three groups of Yemeni children and adolescents in Sanaa, Yemen, and to explore the awareness about dental erosion in these groups (Paper II).
- 4- To explore awareness and knowledge about dental erosion among a group of Yemeni dentists and dental students (Paper III).
- 5- To study associations between dental erosion awareness and some variables among a group of Yemeni dentists and dental students (Paper III).

The hypothesis was that dental erosion would be a common finding among these groups of Yemeni children and adolescents and more so among boys, and that a reduced number of erosion marker teeth would correctly reflect the individual's erosion severity. Another hypothesis was that advanced dental erosion would be associated with consumption of acidic drinks and foods, and that awareness about dental erosion would be low among children, adolescents and dental professionals.

### **3. Materials and methods**

#### **3.1 Study area and population**

The present study (**Papers I and II**) was conducted at UST-DC in Sanaa which is the capital of Yemen. The source population from which the samples were drawn comprised all children and adolescents aged 5-6, 13-14 and 18-19 years (N=6163) who visited UST-DC in the period between September 2012 and June 2013.

The study in **Paper III** was conducted in the period from July to November 2013 in Sanaa. The study population comprised general dental practitioners in Sanaa and final (fifth) year dental students at UST-DC.

#### **3.2 Sample size calculation**

Simple random sampling was used in **Papers I and II** [157] to draw samples' sizes sufficient to detect prevalence among a population of one million or more. Sample size calculation was performed for each age group separately assuming a prevalence of dental erosion extending into dentin of 15% for the age groups 5-6 and 13-14 years, and 20% for the age group 18-19 years. This assumption was based upon a calculation of the mean of previously reported prevalence values of dental erosion extending into dentine from different countries [13, 23, 26, 29, 32, 51, 156, 158], that ranged from 1-34%.

The sample size was calculated using confidence level of 95%, precision of 0.05, design effect of 1 and population size of one million. This resulted in three samples with sizes of 196, 196 and 246 for the age groups 5-6, 13-14 and 18-19 years respectively. Assuming a response rate of 70%, the sample sizes were adjusted upwards by 30% and therefore increased by to be 280, 280 and 351, respectively.

#### **3.3 Enrollment procedure**

Contact information for all visitors to UST-DC during the previous academic year from September 2012 to June 2013 was obtained from UST-DC registry files. Visitors who were aged 4-5 (N=2163), 12-13 (N=1785) and 17-18 (N=2215) years in 2012-2013 and were expected to be aged 5-6, 13-14 and 18-19 years in 2013-2014 were identified (Table 2).



**Table 2.** Distribution of source population by gender in the three examined age groups who visited UST-DC during 2012-2013.

Age group (years)	Males (N)	Females (N)	Total (N)
4-5	1102	1061	2163
12-13	934	851	1785
17-18	1197	1018	2215
Total	3233	2930	6163

A complete numbered list for each age group was made from 1 to its specific N. Three random samples of 280, 280 and 351 (Total n=911) were then drawn from the three lists by simple random sampling utilizing a computer and online random sample generator software (Openepi version 3.01) to enroll children and adolescents in the study as shown in Table 3.

**Table 3.** Distribution of the randomly selected and invited children and adolescents from the source population by sex in the three age groups in 2013-2014.

Age group (years)	Males (n)	Females (n)	Total (n)
5-6	149	131	280
13-14	151	129	280
18-19	188	163	351
Total	488	423	911

All randomly enrolled children's parents and adolescents were contacted by phone to invite them to come for a check-up appointment and participate in the study. A total of 668 (73.3 %) children and adolescents agreed to participate (Table 4) and were given appointments for the questionnaire interviews and clinical examinations at UST-DC in the period from October 2013 to June 2014.

**Table 4.** Distribution of children and adolescents who agreed to participate in the study by sex in the three age groups in 2013-2014.

Age group (years)	Males (n)	Females (n)	Total (n)
5-6	102	104	206
13-14	108	94	202
18-19	135	125	260
Total	345	323	668

In **Paper II**, two sub-groups with high and low dental erosion severity were extracted from participants in **Paper I**. The high erosion group (n=58) comprised participants who were diagnosed as having severe/very severe dental erosion (grades 3 and 4, extending to dentine), while low erosion group (n=610) comprised those who were diagnosed as having mild/moderate dental erosion (grades 1 and 2, within enamel), according to the erosion grading scale used.

In **Paper III**, a list of Yemeni Dental Association members in Sanaa was obtained from the Association, and included general dental practitioners working in the government (n=86) and private clinics (n=237). Another list of enrolled dental students (n=97) in their final year (fifth year) at UST-DC was obtained from the student affairs department in the Dental College. All of these (n=420) were invited to participate in the study during July to November 2013.

### **3.4 Calibration**

The principal investigator (AA), who is a qualified dentist, was trained and calibrated with an experienced researcher (AKJ) on the dental erosion grading scale prior to the start of the study (**Papers I and II**). For this purpose, 95 dental casts were used. The severity of erosion was graded and recorded first by AKJ, and after that by the principal investigator. The readings of both researchers were then compared. This process was repeated three times to assure the highest possible accuracy in grading severity of dental erosion. In addition, clinical examinations for children and adolescents (n=37) were carried out at the

Department of Clinical Dentistry, University of Bergen in Norway and at UST-DC in Sanaa, Yemen.

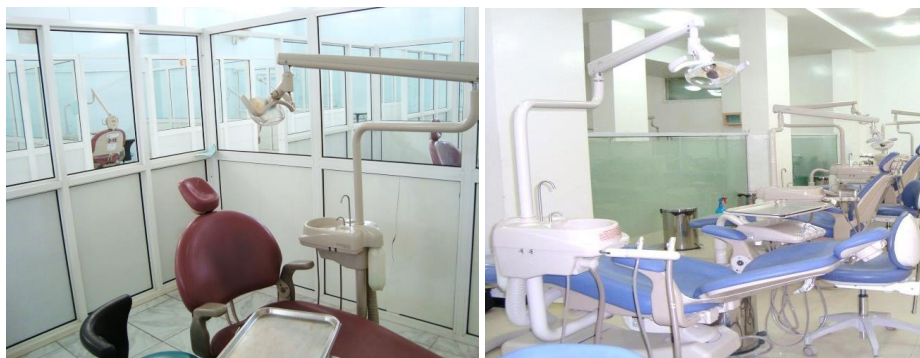
### **3.5 Reliability of grading**

In **Papers I and II**, out of the examined 95 dental casts, 23 casts were randomly selected and examined by the principal investigator two times with a time interval of three weeks between the two examinations. The reliability of grading was tested by percentage agreement (concordance) and Cohen's kappa (K). The records of the last two examinations that included a total of 368 tooth surfaces in each examination, were used to test intra-examiner concordance and Cohen's kappa scores for (AA) at tooth surface level, while inter-examiner concordance and Cohen's kappa scores between (AA) and (AKJ) were tested by using records of the two researchers.

### **3.6 Clinical examination**

All clinical examinations in **Papers I and II** were performed by the principal investigator (AA) using a modern standard dental clinical setting and sterilized instruments (Figures 3 and 4). A special registration form was designed to be used during the clinical examination (Appendix 1). The presence of plaque and gingival bleeding were examined on maxillary anterior teeth and registered according to the visible plaque index (VPI) and the gingival bleeding index (GBI) by Ainamo and Bay [159]. If needed for subsequent clinical registrations, professional calculus and plaque removal followed by polishing were carried out after the registration of VPI and GBI.

After air-drying of the teeth, the presence of dental caries was examined in the whole dentition according to the World Health Organization criteria for epidemiological studies at tooth level (DMFT or dmft) and also at surface level (DMFS or dmfs) [160]. Dental fluorosis presence and severity was registered on maxillary anterior teeth using Thylstrup-Fejerskov index (TFI) [161, 162]. Following that, dental erosion was graded by one ordinal scale on the anterior teeth and another on the posterior teeth. The two scales were then combined into one scale that was used on different marker teeth according to the two partial recording systems.



**Figure 3.** The standard clinical setting and dental units used for dental examination at the UST-DC.

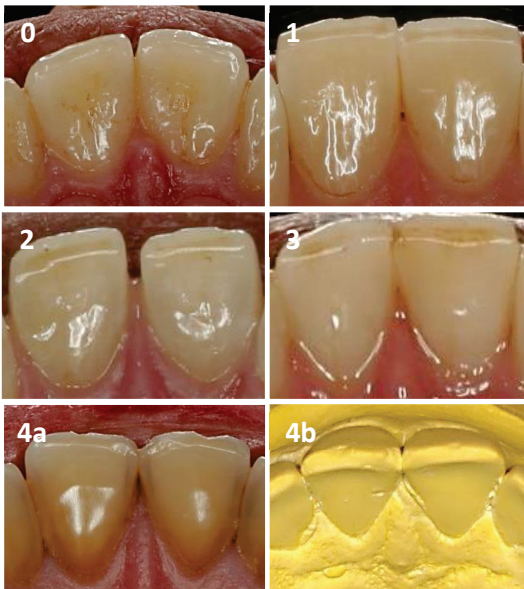


**Figure 4.** Dental instruments used in the clinical examination.

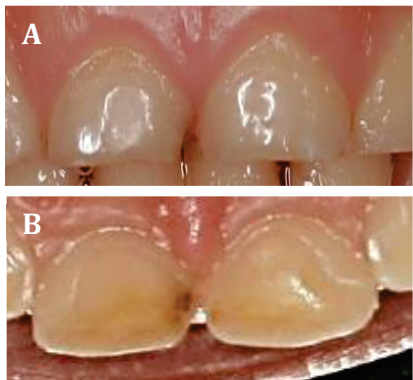
### ***Dental erosion on anterior and posterior teeth***

The presence and severity of dental erosion (Figures 5 and 6) was firstly graded on the buccal and palatal surfaces of primary or permanent maxillary anterior teeth (totally 12 tooth surfaces; teeth numbers 53, 52, 51, 61, 62, 63 or 13, 12, 11, 21, 22, 23) according to an ordinal dental erosion scale which was previously developed and used by Johansson et al. [13] (Table 5).

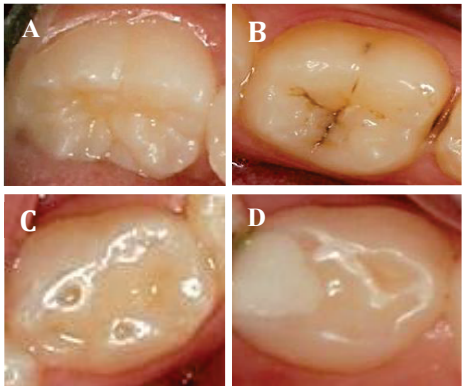
Cupplings (Figure 7) on the occlusal surfaces of all primary molars and all first permanent molars (totally 8 primary and 4 permanent tooth surfaces; teeth numbers 54, 55, 64, 65, 74, 75, 84, 85 or 16, 26, 36, 46) were then graded using a similar scale developed by Hasselkvist et al. [23] (Table 6).



**Figure 5.** Clinical photos illustrating severity of dental erosion from grades 0 to 4 (Table 7) on the palatal surfaces of maxillary permanent central incisors. 4b is a photo of dental cast of the case in 4a.



**Figure 6.** Clinical photos illustrating severity of dental erosion on the buccal surfaces (A= grade 3; Table 7) and on the palatal surfaces (B= grade 4) of first maxillary primary central incisors.



**Figure 7.** Clinical photos illustrating degrees of cupplings. (A) = grade 0 on mandibular first permanent molar. (B) = grade 1 on mandibular first permanent molar. (C) = grade 2 on mandibular first primary molar. (D) = grade 3 on mandibular first primary molar.

**Table 5.** Ordinal scale for grading severity of dental erosion on the buccal and palatal surfaces of maxillary anterior teeth [13].

Grade	Criteria
0	No visible changes, developmental structures remain, macro-morphology intact.
1	Smoothed enamel. Developing structures have vanished completely or partially. Enamel surface is shiny, matt, irregular, “melted”, rounded or flat. Macro-morphology generally intact.
2	Enamel surface as described in grade 1. Macro-morphology clearly changed. Facetting or concavity formation within the enamel. No dentinal exposure.
3	Enamel surface as described in grade 1 and 2. Macro-morphology greatly changed (close to dentinal exposure of large surfaces) or dentin surface exposed by $\leq 1/3$ .
4	Enamel surface as described in grade 1, 2 and 3. Dentin surface exposed by $> 1/3$ or pulp visible through the dentine.

Note: Approximal erosion and presence of “shoulder” should be recorded.

**Table 6.** Ordinal scale for grading cuppings on the occlusal surfaces of the first permanent molars and all primary molars [23].

Grade	Criteria
0	No cupping/intact cusp tip.
1	Rounded cusp tip*.
2	Cupping $\leq 1$ mm.
3	Cupping $> 1$ mm.
4	Fused cuppings: at least two cuppings are fused together on the same tooth.

\*Changed morphology compared to the assumed original anatomy at the time of eruption.

### ***Dental erosion by the erosion partial recording system (EPRS)***

The combination of the two above mentioned scales (Table 7) forms the “erosion partial recording system” (EPRS) according to Hasselkvist et al. [23, 38]. In the EPRS scale, the highest recorded grade for erosion on maxillary anterior teeth (teeth numbers 13-23 or 53-63) and cuppings on molars (teeth numbers 54, 55, 64, 65, 74, 75, 84, 85 or 16, 26, 36, 46) (totally 16 permanent or 20 primary marker teeth) was used to classify the cases into:

- No erosion (grade 0).
- Mild erosion (grade 1).
- Moderate erosion (grade 2).
- Severe erosion (grade 3).
- Very severe erosion (grade 4).

Thus, a participant would be classified as having moderate erosion (grade 2) if the maximum graded erosion on maxillary anterior teeth and cuppings on molars was 2 and the remaining surfaces were registered with grade 2 or less.

### ***Dental erosion by the modified erosion partial recording system (EPRS-M)***

EPRS-M was proposed as a further simplification of EPRS that applies the same erosion scale (Table 7) but utilizes fewer marker teeth surfaces, and was calculated by the use of the same previous clinical registrations. Thus, EPRS-M includes only the buccal and palatal surfaces of maxillary centrals (teeth numbers 11, 21) and occlusal surfaces of mandibular first molars (teeth number 36, 46) in the permanent dentition, while it includes the buccal and palatal surfaces of maxillary centrals (teeth numbers 51, 61) and occlusal surfaces of maxillary and mandibular first molars (teeth numbers 54, 64, 74, 84) in the primary dentition.

In addition, the presence and number of cervical defects that showed clear demarcation was recorded for the whole dentition according to Johansson et al. [13]. Absent teeth and surfaces with large restorations or caries were excluded during all erosion gradings. The results of the clinical examination were explained to the participant/parent(s) and any indicated preventive advice was given. If indicated, any restorative treatment was offered free of charge in a subsequent scheduled appointment. Intra-oral dental photos were taken together with dental casts for selected cases (Figures 5, 6 and 7).

**Table 7.** The “erosion partial recording system” (EPRS) which is a combination of the two scales in Tables 4 and 5 [23]. Buccal and palatal surfaces of maxillary anterior primary and permanent teeth and occlusal surfaces of all primary molars and all first permanent molars are graded.

Grade	Severity	Teeth	Criteria
0	No erosion	Anterior teeth	No visible changes, developmental structures remain, macro-morphology intact.
		Molars	No cupping/intact cusp tip.
1	Mild erosion	Anterior teeth	Smoothened enamel. Developing structures have vanished completely or partially. Enamel surface is shiny, matt, irregular, “melted”, rounded or flat. Macro-morphology generally intact.
		Molars	Rounded cusp tip*.
2	Moderate erosion	Anterior teeth	Enamel surface as described in grade 1. Macro-morphology clearly changed. Faceting or concavity formation within the enamel. No dentinal exposure.
		Molars	Cupping $\leq$ 1mm.
3	Severe erosion	Anterior teeth	Enamel surface as described in grade 1 and 2. Macro-morphology greatly changed (close to dentinal exposure of large surfaces) or dentin surface exposed by $\leq$ 1/3.
		Molars	Cupping $>$ 1mm.
4	Very severe erosion	Anterior teeth	Enamel surface as described in grade 1,2 and 3. Dentin surface exposed by $>$ 1/3 or pulp visible through the dentine.
		Molars	Fused cuppings: at least two cuppings are fused together on the same tooth.

\*Changed morphology compared to the assumed original anatomy at the time of eruption.



### 3.7 Questionnaires

A previously used questionnaire [13, 23, 163] was modified in **Paper II** to comply with Yemeni culture (Appendices 2&3). The modification included addition of new questions about lemon sucking, Qat chewing, smoking, miswak use, tooth paste use, having been breast fed and awareness of dental erosion, while questions considered specific to a European country of origin were dropped. The questionnaire was translated from English into Arabic in forward and backward directions to ensure conceptual equivalence between languages. A pilot study was performed with twenty Yemeni children and adolescents before the start of the main study to test the questionnaire and assure understanding and clarity and was adjusted accordingly.

The questionnaire inquired about information relating to lifestyle factors such as dietary intake, drinking habits (type, frequency and amount of drinks consumed), oral health, oral hygiene habits, medication intake, general health conditions and awareness about dental erosion. To help the participants in the estimation of the quantity of drinks consumed, cans and glasses of different sizes were made available. A specially trained dentist performed the questionnaire interviews with the children, adolescents and parents. The principal investigator (AA) was blind to the results of the questionnaire interview before the clinical examination of each patient. The time required for the clinical examination and questionnaire interview was approximately 45 minutes.

In **Paper III**, a questionnaire about dental erosion awareness was developed in English (Appendices 4&5). The questionnaire consisted of four parts and twenty close-ended questions. The first part contained questions regarding demographic information such as sex, age, nationality, type of dental practice, place and date of graduation. The second part inquired about participants' knowledge about dental erosion, such as the common features of dental erosion and its distribution among male and female patients. The third part included questions about methods of dental erosion diagnosis and grading, perceived etiological factors and the clinical manifestations of dental erosion. The fourth part contained questions about the preferred and applied dental erosion preventive methods.

Before the start of the main study (**Paper III**), a pilot study of the questionnaire was conducted on ten Yemeni dentists to ensure understanding and clarity and was adjusted as necessary. The principal investigator (AA) distributed the questionnaire personally to all participants. The objectives of the study were explained to all invited participants and they were informed that participation in the study was voluntary and that the return of the questionnaire was considered as their acceptance to participate. The questionnaire was collected at a later visit. Two phone reminders, after two and four weeks respectively, were made to participants who failed to return the questionnaire before they were considered as non-respondents.

### **3.8 Statistical methods**

Data analyses were performed using the Statistical Package for the Social Sciences (SPSS, IBM Corporation, Armonk, NY, USA) versions 20 and 22.

#### **Paper I**

Inter-examiner and intra-examiner agreements were calculated at tooth surface level using percentage agreement and Cohen's kappa coefficient. Descriptive statistics were performed to calculate response rate, gender distributions, means, standard deviations and percentage distribution of graded dental erosion, dental caries and dental fluorosis. Comparisons between groups were calculated using Chi-square test. Comparison between prevalence figures obtained by EPRS and EPRS-M was conducted with McNemar's test. Correlation between severity of dental erosion and other variables such as cuppings and cervical defects were tested using Spearman's correlation. Level of statistical significance was set at  $P < 0.05$ . The prevalence of severe/very severe erosion (advanced erosive lesions) was determined at the individual level and surface level among participants according to the "erosion partial recording system" (EPRS) (Table 6) which classifies the cases according to the highest recorded erosion grade on all marker teeth. The simplified erosion partial recording system (SEPRS)[23], which is a previous modification of EPRS, was also calculated together with its sensitivity and specificity in relation to EPRS. The modified erosion partial recording system (EPRS-M) was proposed and calculated. EPRS-M is a proposed modification of EPRS and by which the same grading criteria are used but only

on the buccal and palatal surfaces of maxillary central incisors (primary or permanent, teeth numbers 11, 21 or 51, 61) and occlusal surfaces of either mandibular first permanent molars or mandibular and maxillary primary first molars (teeth numbers 36, 46 or 54, 64, 74, 84) (totally six permanent or eight primary tooth surfaces). The sensitivity and specificity of EPRS-M in detecting advanced erosive lesions in relation to the erosion partial recording system (EPRS) were calculated by cross-tabulation. It is to be noted that SEPRS is identical to EPRS-M but does not include the buccal surfaces of maxillary central incisors in the graded marker teeth surfaces.

## **Paper II**

Logistic regression was used to detect associations between high and low erosion groups (dependent variable) and selected independent variables. The high erosion group (n=58) comprised participants who were diagnosed as having dental erosion grades 3 and 4, while the low erosion group (n=610) comprised those who were diagnosed as having dental erosion grades 1 and 2 according to the erosion grading scale used. Independent variables were included in the final model if they were theoretically related to or statistically associated with the dependent variable with P value of  $\leq 0.05$ . Thus, unadjusted logistic regression with crude odds ratio (OR) was first calculated between the dependent variable and each independent variable separately. This was followed by including independent variables that fulfilled the above criteria in the final adjusted logistic regression models and calculation of adjusted odds ratios with their 95% confidence intervals by forward stepwise conditional method [164-166]. Gender was included in all the adjusted models and separate logistic regression was conducted for each age group, while a pooled analysis was conducted for age groups 13-14 and 18-19 years to include age as an independent factor with the permanent dentition. Associations that had P level less than 0.05 were considered significant. Variance Inflation Factor was calculated for all associations, which being always less than 2, indicated absence of multicollinearity between independent variables.

## **Paper III**

Descriptive statistics were performed to calculate response rates, gender distribution, and choices and frequencies of answers for each question in the questionnaire. Logistic regression analysis was used to assess any possible associations between selected independent and dependent variables. The independent variables comprised sex, age, nationality, country of graduation, referral pattern of dental erosion cases and participant type (dentist or student). The dependent variables comprised choices made by participants on questions regarding causative factors and preventive methods for dental erosion. Unadjusted odds ratios were first calculated for each independent variable separately. Final logistic regression model was then constructed for each dependent variable by including all independent variables using Enter method to obtain adjusted odds ratios. Odds ratios with their 95% confidence intervals were calculated and significance level was set at  $P < 0.05$ . Variance Inflation Factor was calculated for all associations, which being always less than 2, indicated absence of multicollinearity between independent variables.

### **3.9 Ethical clearance**

#### **Papers I, II and III**

The project protocol was approved before the start of the study by the Regional Committee for Medical and Health Research Ethics (REK), Western Norway (Ref. 2013/981/REK Vest) and the Research Ethical Committee at the Faculty of Dentistry, University of Science and Technology in Yemen (Ref. 10/2013). Participation in the study was voluntary. The questionnaires were number coded and no identification information such as respondent's name or address was sought so as to ensure anonymity of the participants. All participating children, adolescents or their parents/guardians signed an informed consent (Appendices 6&7) prior to the start of the study. Dental professionals were informed that acceptance to participate in the study will be assumed by the filling and return of the questionnaire.

## 4. Results

### ***Reliability of grading (Papers I and II)***

The intra-examiner percentage agreement and Cohen's kappa scores for (AA) were 81.7% and 0.70, while the inter-examiner percentage agreement and Cohen's kappa scores between (AA) and (AKJ) were 76.4% and 0.66 respectively. All tooth surface disagreements were by not more than one scale unit, except in one case only where the disagreement was by two scale units; furthermore, disagreements occurred only with respect to grades 1 and 2 (enamel erosion).

### ***Non-participation (Papers I and II)***

A total of 243 (26.7%) enrolled children and adolescents did not participate in the study for different reasons. 63 did not attend their appointments while 180 were either ill (n=9), preferred not to sign the consent (n=45), had no time (n=102), or had traveled outside Sanaa (n=24). Non-response analysis revealed no significant differences between participants and non-participants regarding their age and gender.

### **4.1 Prevalence of dental erosion**

Using EPRS and according to the highest recorded dental erosion grade on anterior and posterior teeth per individual, severe/very severe dental erosion cases (grades 3 and 4) were present in 6.8% of the 5-6 year olds, 3.0% of the 13-14 year olds, and 14.6% of the 18-19 year olds with an overall prevalence of 8.7%. The highest prevalence (19.2%) was found among girls aged 18-19 years and this was significantly higher than boys (10.4%) in the same age group ( $P=0.044$ ; Figure 4, Paper I). No significant differences were found between boys and girls in the other age groups. Mild/moderate dental erosion (grades 1 and 2, within enamel) were present in 91.3% of all participants, while the percentage was 93.2% in the 5-6 year age group, 97.0% in the 13-14 year age group and 85.4% in the 18-19 year age group.

At tooth surface level, grade 0 erosion was found on 17.9% (n=2040) of all graded teeth surfaces (n=11372), while grade 1 erosion was found on 53.4% (n=6077) of surfaces, grade 2 erosion on 27.2% (n=3091) of surfaces, grade 3 erosion on 1.2% (n=136) of surfaces and grade 4 on 0.25% (n=28) of surfaces.

The percentage distribution of dental erosion grades on all buccal and palatal surfaces of maxillary anterior teeth and occlusal surfaces of examined molars in the three age groups are illustrated in Figures 1, 2, and 3 (Paper I). Very severe dental erosion (grade 4) was found only on the palatal surfaces of maxillary anterior teeth, while severe dental erosion (grade 3) was the highest recorded erosion grade on buccal surfaces of anterior teeth and on occlusal surfaces of posterior teeth. Severity of dental erosion on the maxillary anterior teeth was significantly correlated with the severity of cuppings on posterior teeth ( $r=0.14$ ,  $P=0.039$ ) in the 5-6 years age group, while such correlation was not found in the other age groups (13-14 years and 18-19 years).

Cervical defects were not found among the 13-14 year age group while 4.9% and 1.9% of the 5-6 and 18-19 year olds had 1-5 buccal cervical defects respectively. There was no significant correlation between the number of cervical defects and the severity of dental erosion in any of the groups.

#### **4.2 Scoring systems**

Using SEPRS, thus according to the highest recorded dental erosion grade on anterior and posterior teeth per individual, severe/very severe dental erosion cases (grades 3 and 4) were present in 5.8% of the 5-6 year olds, 2.5% of the 13-14 year olds, and 7.3% of the 18-19 year olds with an overall prevalence of 5.4%. Sensitivity and specificity for predicting severe/very severe dental erosion by SEPRS in relation to the “erosion partial recording system” (EPRS) were respectively, 85.7% and 100% for primary teeth and 54.5% and 100% for permanent teeth. Disagreements between EPRS and SEPRS in detection of severe/very severe erosion were due to the presence of advanced erosive lesions on 32 buccal maxillary anterior marker teeth surfaces, 13 palatal maxillary anterior marker teeth surfaces and 9 occlusal posterior marker teeth surfaces, all of which surfaces are included in EPRS only.

Using EPRS-M, severe/very severe dental erosion cases (grades 3 and 4) were present in 5.8% of the 5-6 year olds, 3.0% of the 13-14 year olds, and 11.9% of the 18-19 year olds with an overall prevalence of 7.3%. Sensitivity and specificity for predicting severe/very severe dental erosion by SEPRS in relation to the “erosion partial recording system”

(EPRS) were respectively, 85.7% and 100% for primary teeth and 84.1% and 100% for permanent teeth. There were no statistically significant differences between prevalence figures obtained by EPRS and those obtained EPRS-M among boys and girls in the three age groups (Table 4, Paper I).

### **4.3 Risk indicators for dental erosion**

#### ***Dental and medical history***

Dental pain was reported by 54.9%, 36.6% and 41.5% (overall 54.2%) of the children and adolescents in the three age groups. Tooth sensitivity with hot and cold drinks and foods once or more per month was reported by 33.0%, 49.0% and 46.5%, in the respective groups. Acid reflux/heartburn once or more per month was reported by 14.6%, 25.7% and 54.6% among the three age groups, while 1.0%, 1.0% and 5.4% reported having asthma. Current intake of medication was reported by 1.5%, 2.5% and 4.6% of the participants in the three age groups with antibiotics and antacids being the most reportedly used medications by 1.9% and 2.1% respectively of all participants.

#### ***Dietary habits***

The average total reported levels of consumption of carbonated soft drinks (including cola-type soft drinks, other carbonated soft drinks and energy drinks) were 21.2 L/year, 22.7 L/year and 53.3 L/year in the three age groups. The overall average was 36.2 L/year. The reported quantities of total average intake of acidic non-carbonated drinks such as fruit juices and fruit drinks were 50.8 L/year, 40.8 L/year and 50.1 L/year in the three ages. The total quantities of all acidic beverages (carbonated and non-carbonated drinks) were 72.0 L/year, 63.5 L/year and 103.4 L/year in the three age groups. Daily intake of fresh fruits was reported by 25.7%, 21.3% and 26.2% of the participants, respectively. Lime sucking/chewing was reported to be two or more times per week by 8.8%, 9.9% and 13.1% of the participants in the three age groups. Daily intake of milk was reported by 23.8%, 11.9% and 11.5% in the three age groups, while the corresponding figures for yoghurt were 22.3%, 23.8% and 22.3%, respectively. All participants reported daily water consumption. The majority of participants in the three age groups (94.2%, 91.1% and 85.4) reported having been breastfed. Of those, 87.4%, 71.3% and 73.5% were breastfed for six months or more.

### ***Other lifestyle factors***

Tooth brushing once or more daily was reported by 18.5%, 39.6% and 45.7% of the children and adolescents in the three age groups, respectively. Of those who reported tooth brushing, 64.1%, 58.9% and 64.2% respectively reported using toothpaste. In the three groups 30.1%, 18.3% and 19.6% reported that they did not brush their teeth at all. The time spent each day in front of the TV/computer was reported to be 0-1 hours by 55.8%, 59.9% and 55.8% of the three groups, and 2-3 hours by 44.2%, 40.1% and 43.8% of the groups. Sports activity once or more per week was reported by 53.4%, 60.9% and 56.5%. Qat chewing and smoking habits were only investigated among the 18-19 year olds. In this group, qat chewing was reported by 16.5% and smoking by 5.1%.

### ***Awareness about dental erosion among children and adolescents***

The interviews showed that 32.0%, 2.0% and 17.7% of the participants in the three age groups had heard about dental erosion (overall 17.4%). In addition, 7.8%, 2.0% and 4.6% (overall 4.8%) reported that they had received information about dental erosion from their dentists. 10.7%, 2.0% and 9.2% (overall 7.5%) reported that they know how to prevent dental erosion, and their only reported method of dental erosion prevention was reduction of soft drink consumption.

### ***Factors associated with erosion severity in high and low erosion groups***

#### ***5-6 year group***

The unadjusted bivariate associations between severity of erosion and various independent factors were assessed in the 5-6 year old age group (Table 2; Paper II). Children who had higher frequency of teeth sensitivity (OR=4.1), higher frequency of lime sucking (OR=5.1) or spent more time in front of the TV/computer (OR=3.4) were significantly more likely to have advanced erosive lesions. There were no other significant bivariate associations between erosion severity and tested variables (Table 2). All significant variables were included in a final adjusted model. Higher frequency of teeth sensitivity [OR=4.4; 95% CI 1.4-14.0;  $P=0.013$ ] and higher frequency of lime sucking/chewing [OR=5.5; 95% CI 1.4-21.1;  $P=0.015$ ] were found to be the best predictors of advanced erosive lesions in the final adjusted model among 5-6 year olds.



### ***13-14 year group***

An unadjusted significant bivariate association was found only between severity of dental erosion and higher frequency of carbonated soft drink consumption (Table 3; Paper II). In the final model, carbonated soft drink consumption could predict advanced erosive lesions in 13-14 year olds [OR=7.8; 95% CI 1.4-44.0;  $P=0.020$ ].

### ***18-19 year group***

Among 18-19 year old adolescents, unadjusted significant bivariate associations were found between severity of erosion and female gender (OR=2.1), absence of fluorosis (OR=3.0), higher consumption frequency of cola-type soft drinks (OR=6.4), fruit juices (OR=2.8), fruit drinks (OR=3.2), higher total quantity of acidic beverages (OR=13.7), not having been breastfed (OR=4.8) and being breastfed for a longer period (OR=0.9). Other tested variables did not show association with the presence of advanced erosive lesions (Table 4; Paper II). The final model showed that the best predictors of advanced erosive lesions among 18-19 year olds were absence of fluorosis [OR=3.9; 95% CI 1.6-9.5;  $P=0.003$ ], higher frequency of cola-type soft drink [OR=7.4; 95% CI 1.6-34.7;  $P=0.011$ ] and fruit juices consumption [OR=3.2; 95% CI 1.4-7.3;  $P=0.005$ ], higher total quantity of acidic beverage intake [OR=11.4; 95% CI 1.5-87.8;  $P=0.020$ ] and not having been breastfed [OR=8.2; 95% CI 3.2-21.0;  $P<0.001$ ]. The risk of having advanced erosive lesions was higher among adolescents aged 18-19 years than participants aged 13-14 years [OR= 5.6; 95%CI 2.3-13.5;  $P<0.001$ ].

## **4.4 Awareness about dental erosion among dental professionals**

### ***Response and non-participation***

Out of all invited dentists and dental students ( $n=420$ ), 332 agreed to participate and returned the questionnaires, giving an overall response rate of 79.0% (332/420). The response rate among dentists was 77.7% (251/323), while it was 83.6% (81/97) among dental students. The age range of all participants was 21 to 58 years. Those who did not return the questionnaires (72 dentists and 16 dental students) were considered as non-respondents.

### ***Knowledge and awareness about dental erosion among dental professionals***

Knowledge about dental erosion was reported as having been gained from dental school by 60.5% (201/332) of respondents, through their own studies by 26.5% (88/332) and from the media and continuing education courses by the rest of respondents (Table 2; Paper III). Acidic drinks were reported as causative factors for dental erosion by 41% (103/251) of dentists and 51.9% (42/81) of dental students. Excessive tooth brushing using a hard toothbrush and bruxism were thought to be causative factors for dental erosion by 11.6% (29/251) of dentists and 16.0% (13/81) of dental students. Acidic drinks were more likely regarded as causative factors of dental erosion by younger ( $\leq 35$  years) respondents (OR=3.18; P=0.009) (Table 3; Paper III).

Systemic diseases such as gastric reflux and eating disorders were identified as possible causative factors for dental erosion by 41% (103/251) of dentists and 45.7% (37/81) of dental students. In addition, these systemic diseases were more likely to be identified by younger ( $\leq 35$  years) participants (OR=2.7; P=0.024) (Table 4; Paper III). High sugar consumption was thought to be a possible causative factor for dental erosion by 4.8% (12/251) of dentists and 4.9% (4/81) of dental students. In addition, biting on hard objects such as fingernails and pens was thought to be a possible causative factor for dental erosion by 12.0% (30/251) of dentists and 19.8% (16/81) of dental students.

### ***Diagnosis, prevention and treatment of dental erosion***

Enamel surface smoothening was reported as an early clinical sign of dental erosive lesions by 57.0% (143/251) of dentists and 49.4% (40/81) of dental students. An erosion index was reportedly more likely (OR=2.98; P<0.001) (Table 5; Paper III) to be used for grading dental erosion severity by dental students (44.4%; 36/81) than by dentist (21.1%; 53/251). However, the majority of dentists (75.7%; 190/251) and just over half of dental students (53.1%; 43/81) preferred not to use an index and instead to rely on the general clinical signs of dental erosion. During history taking, 90.8% (228/251) of dentists and 85.2% (69/81) of dental students reported that asking about the patient's dietary habits would help in the diagnosis and treatment planning of dental erosive lesions.

To prevent dental erosive lesions, 47.0% (118/251) of dentists and 61.7% (50/81) of dental students advised their patients to reduce consumption of acidic drinks. This preventive advice was significantly more likely to be given by younger ( $\leq 35$  years) respondents (OR=2.9; P=0.012) (Table 6; Paper III). A small number thought that taking muscle relaxants can prevent progression of dental erosive lesions (5.6% (14/251) of dentists and 2.5% (2/81) of dental students). The use of fluoridated toothpastes to prevent dental erosion was advised by 37.5% (94/251) of dentists and 37.0% (30/81) of dental students, while prevention by wearing a night guard was advised by 10.8% (27/251) of dentists and 4.9% (4/81) of dental students, and 0.8% (2/251) of dentist and 8.6% (7/81) of dental students thought that stopping biting on hard objects could help to prevent dental erosion.

A small proportion of dentists (27.1%, 68/251) and dental students (19.8%, 16/81) stated that they preferred to treat all dental erosion cases themselves. However, severe dental erosion cases were preferably referred to a specialist by 58.2% (146/251) of dentists and 54.3% (44/81) of dental students. Referral of all dental erosion cases to a specialist was significantly more likely (OR=2.78; P=0.002) (Table 5; Paper III) to be done by dental students (25.9%; 21/81) than dentists (11.2%; 28/251). Acidic drink consumption was less likely to be identified as a causative factor for dental erosion by respondents who preferred referral of all dental erosion cases to a specialist (OR=0.41; P=0.012) (Table 3; Paper III).

## 5. Discussion

These are the first cross-sectional analytical studies from Sanaa, Yemen that investigated the prevalence, severity, risk indicators and awareness of dental erosion among groups of Yemeni children and adolescents in selected three ages. Furthermore, awareness and any associated factors about dental erosion were investigated for the first time among dental professionals in Sanaa. In addition, a previously developed erosion partial recording system (EPRS) [23, 38] was clinically compared with its simplified version (SEPRS) and a new modification (EPRS-M) was proposed to address the efficacy of utilizing specific erosion marker teeth surfaces. Therefore, all possible efforts were made in the project design to collect as much information as possible from the participants to provide baseline data for future oral health research, as well as for guiding oral health care improvement measures, in Sanaa, Yemen.

### 5.1 Methodological considerations

#### *Study location*

Yemen is a developing country in the southern part of the Arabian Peninsula that still lacks the benefits of much important scientific research that could provide the databases for future development and planning. For this reason, this study was conducted in Yemen and will hopefully provide part of this necessary baseline information. The capital, Sanaa, was chosen for **Papers I, II and III** because it is the most densely populated city in Yemen, where about 2.5 million people live. In addition, Yemeni people and dental professionals prefer to migrate and settle in Sanaa where the best living opportunities are available. Therefore, Sanaa can reasonably be expected to provide a population with wide diversity and drawing on people from all Yemeni cities and regions.

The choice was made to conduct the studies reported in **Papers I and II** at UST-DC for number of reasons. UST-DC is the largest dental care provider in Yemen with a dental facility comprising 120 up-to-date standard operating dental units. Regular dental check-ups and treatments are offered free of charge at UST-DC and is the preferred choice by the majority of people in Sanaa. Several schools from the public and private sectors schedule routine dental check-ups for their students at UST-DC to introduce them to dental care, and

this enabled inclusion of children and adolescents from different socioeconomic levels in the university hospital samples that made up the present study groups.

### ***Study design and participants***

In **Papers I and II**, participants were randomly selected from a sampling frame that comprised all children and adolescents in the selected age groups (N=6163) who visited the UST-DC in the previous academic year (2012-2013). The randomly selected participants were invited for a check-up visit and questionnaire interview during 2013-2014. Given that simple random sampling is the gold standard sampling method, the samples are representative for all individuals in the selected age groups who visited UST-DC during the whole previous academic year (2012-2013).

Sample sizes were calculated to be sufficient to detect the prevalence among a population of one million or more in each age group separately, even though the source population in each age group was approximately 2200 individuals. This was done to maximize the sample sizes as this was the first study from Yemen about dental erosion and the assumed prevalence in the sample size formula was taken as an average from previous dental erosion studies in other countries. In addition, after sample size calculation, the sample sizes were increased by a factor of 30% to accommodate any possible dropouts from the study. This assumption turned out to be correct, as the final response rate was 73.3% with 26.7% dropout. Therefore, the dropout did not affect the final obtained percentages. Moreover, the final obtained prevalence rates in the three age groups (6.8%, 3.0% and 14.6%) were all much less than the assumed prevalence rates during sample size calculations at the beginning of the study (15.0%, 15.0% and 20.0%) which means that the number of examined participants in each age group easily exceeded the minimum needed.

Drawing the same sample sizes directly from schoolchildren, as opposed to dental school attenders, would have been more representative for children and adolescents in Sanaa in the selected age groups, and this was a limitation of the study. Unfortunately it was not possible to draw on schoolchildren per se for several reasons. Accurate examination for dental erosion required, in many instances, pre-scaling and polishing. Also a proper dental setting, lighting and positioning as the type of light and angle of viewing could alter the

interpretation of erosion grading, and thus it was preferred not to do clinical examinations at schools. In addition, the clinical examination and questionnaire interview took approximately 45 minutes. This could have resulted in wasting students' class time and also would not have been accepted by school administrations. Furthermore, parents of 5-6 year old children needed to be present during interviews with their children, and unfortunately, Yemeni parents would not accept to come to school to be interviewed simply for research purposes. On the other hand, if participants or parents were invited from schools to the dental hospital, they would not accept the invitation unless it is made as a follow-up check-up and in connection with their previous visit to the hospital. For cultural reasons, examination of girls in the age groups 13-14 and 18-19 years would not be allowed for a male researcher in Yemeni schools. Yet it would be justified and easily accepted if done in a hospital facility as a follow-up check-up in connection with a previous visit to the hospital. For all these reasons, the study was hospital-based and the samples were drawn from visitors of UST-DC in the previous year (2012-2013).

Selection of the three age groups was based on different social and developmental considerations and is in agreement with previous studies [23, 59, 61, 167]. In the 5-6 year old children, mainly primary teeth are present and there is parental control over the children's dietary habits. In the second age group (13-14 years), mainly permanent teeth are present and more independence has been acquired by participants regarding their dietary habits, and especially so under the influence of the school environment and peers. Adolescents aged 18-19 years are in the final stage of secondary school, have more independent personalities and their dietary habits are mostly by their own choice. In addition, participants in the third age group have had their permanent teeth for a longer period of time which helps to explore the severity of dental erosion.

The results and conclusions in **Paper III** are representative for all general dental practitioners registered with the Yemeni Dental Association in Sanaa and all fifth-year dental students registered at UST-DC dental college administration. All these were included in the study without an attempt to draw a smaller representative subgroup of them as their total number (N=420) was not so large, thus providing full representativeness of the studied groups. The final year dental students were only included as a comparison group to

compare their more likely up-to-date knowledge about dental erosion with dentists who had previously graduated but who in turn have longer clinical experience. This enabled the evaluation of the possible importance of continuing education courses for general dental practitioners.

Dental specialists such as oral surgeons and orthodontist were excluded as they are not likely to deal with dental erosion cases. Cariologists and pedodontists are very few in Sanaa (N=5) and were excluded as better information could be obtained from general dental practitioners due to their expected regular involvement in the diagnosis and treatment of dental erosive wear cases [23, 32, 168], and to avoid a statistically very small and unnecessary comparison group.

### ***Clinical examination***

Grading of dental erosion in **Papers I and II** was made using the “erosion partial recording system” (EPRS) which consists of two combined ordinal scales [13, 23, 38]. These ordinal scales are sensitive in detecting early dental erosion especially within enamel and were used repeatedly in previous dental erosion studies [13, 23, 24, 38, 47, 69, 88]. This provides an opportunity to detect erosive lesions at an early stage so as to provide preventive advice at the proper time before progression of the lesion take place and restorative treatment becomes necessary. The comparability of other dental erosion scoring systems such as the VEDE [22] and BEWE [21] was investigated in a recent paper with a conclusion that the two systems were comparable for grading dental erosive wear [22]. The ordinal scale [13] used in the EPRS in this thesis is expected to have the same comparability as it is similar to the VEDE and with only one extra (fifth) score that is rarely used. Nevertheless, EPRS has the advantage of possible case monitoring and progression assessment as specific tooth surfaces are graded and can be followed up which is not possible with BEWE as it uses the highest grade in a sextant, thus, excluding the possibility for a tooth surface be recognized in a follow up examination by using BEWE. In addition, it has been claimed that BEWE lacks clarity as it was proposed first for individual case monitoring, but subsequently stated that progression measurement is not within the scope of BEWE [169]. Generally speaking, as of today there is no one dental erosion index that is considered as a gold standard and that can be used universally in dental erosion research [170-172].

The EPRS used utilizes the buccal and palatal surfaces of maxillary anterior teeth and occlusal surfaces of all primary molars or permanent first molars as “erosion marker teeth” surfaces for grading dental erosion. This was preferred over full mouth recording as many previous studies have found that these are the most repeatedly affected teeth surfaces and thus considered good markers for dental erosive wear [13, 32, 34, 57, 64-66, 172]. Moreover, full mouth recording is time-consuming and thus costly and might be unnecessary in view of the extended examination time required with questionable benefits for the patient.

Previous reports have found that the key factor in the development of the worn dentition is dental erosion while attrition and abrasion have a lesser effect [163, 173, 174]. In another report, it was concluded that abrasion during normal daily tooth brushing requires 100 years to remove less than 1 mm of dentine while it has no effect on enamel [144]. Nevertheless, the EPRS excludes the incisal surfaces of maxillary anterior teeth while only cupping is graded on the occlusal surfaces of molars. In addition, cupping has a distinctive appearance that forms a concavity like a hole on the cusp tip of molars which is easily differentiated from the flat surface appearance that results from tooth-to-tooth contact (attrition) [175]. Therefore, the EPRS is expected to grade mainly dental erosion and provides differentiation between dental erosion and attrition/abrasion.

All efforts were made to increase the reliability of clinical examinations through a number of steps. The clinical examinations were performed in a modern standard clinical dental setting with proper lighting. All clinical examinations were carried out by only one examiner to exclude inter-examiner variability in the clinical scoring that could have arisen if several investigators were involved. The principle examiner (AA) is a qualified dentist and was trained by and calibrated with an experienced researcher (AKJ) before conducting the study. Good agreement was achieved after the calibration according to Cohen’s kappa [176]. Therefore, the clinical dental erosion grading might be claimed to be reliable.

The terms “extending into dentine or advanced dental erosion” were used throughout the thesis to refer to severe/very severe dental erosion (grades 3 and 4 according to the EPRS). These terms were subjective, based on clinical examination and were used to describe deep



lesions that are clinically approaching dentine or within dentine, although histologically could be still in enamel [149, 170].

Dental erosion is the principal outcome in this thesis while oral health status expressed by several clinical parameters including dental caries, dental fluorosis, plaque and gingival bleeding were obtained with the main objective to explore possible associations between the existence of these clinical parameters and dental erosion.

### ***Questionnaires***

The following measures might be expected to have increased the reliability of the questionnaire in **Paper II**. The questionnaire was tested and used in previous studies [13, 23, 163] and was modified to accommodate Yemeni dietary habits and culture. Efforts were made to cover the most likely related dietary items and habits present in Yemen. The questionnaire was then translated from English to Arabic by the principal investigator (AA) who is accustomed to the Yemeni traditions and whose mother tongue is Arabic. An independent backward translation from Arabic to English was then made to validate the translation. The questionnaire was then piloted on 20 randomly selected Yemeni children and adolescents, and any vague or unclear statements were modified as necessary. The answers to the questionnaire were obtained through an interview that was conducted by another well-trained Yemeni dentist (AS) and the participants to ensure that all questions were answered and to eliminate any misunderstanding and non-response bias. In addition, this assured that the answers to the questionnaire were blinded from the principal investigator to minimize any possible bias in the clinical examination. Furthermore, in order for the participants to gauge their own consumption of drinks they were shown different sizes of glasses and cans.

Despite all these measures, limitations and bias could not be fully excluded from the questionnaire. For example, the questionnaire is still subjected to possible recall bias as the answers to the questionnaire questions is dependent on the ability of the participant to recall information. Another limitation is in conducting interviews with 5-6 year old children, who can be expected to have difficulty with responding to complicated questions and therefore in most instances the answers were mainly obtained from the parents in this age group,

which may also increase the possibility of inaccuracy in the responses. Furthermore, in spite of the inclusion of a large variety of dietary components, some dietary items or habits might have been missed in the questionnaire.

The questionnaire in **Paper III** was self-administered and designed to increase the response rate as much as possible. This was done through several measures in accordance with a previous Cochrane systematic review about questionnaire investigations [177]. Therefore, all efforts were made to decrease the number of questions to make the questionnaire short and be easy to respond to in a reasonable time. In addition, the questionnaire was in the English language which is the dental education language in Yemen. Furthermore, the anonymity of the questionnaire was assured by the exclusion of any identifying information to encourage participation in the study and to comply with the ethical approval conditions that was granted for the study. The study aims were also briefly explained and the university sponsorship was mentioned so as to encourage participation by declaring the academic basis of the study. Moreover, participants who might have forgotten to answer the questionnaire were reminded by phone contact after two and four weeks to further increase response rate. All these measures fortunately resulted in a good response rate to the questionnaire.

Although these measures may be expected to have increased the response rate, some of them might have produced limitations in the questionnaire. For example, limiting the number of questions may have prevented the opportunity to include a larger variety of questions to explore other possible aspects about awareness and knowledge of dental erosion.

The easiest method to distribute the questionnaires was by sending them directly by e-mails or regular post. However, the principal investigator (AA) personally distributed all the questionnaires to the dental clinics as the postal system does not cover all places in Sanaa and many dentists do not have a postal or e-mail addresses. Therefore, this was the only and best method to ensure distribution to all general dental practitioners registered in the Yemeni Dental Association in Sanaa.

### *Statistical analysis*

In **Paper I**, while the prevalence of dental erosion was calculated for both enamel and dentine, the presentation of results and discussion was mainly concerned about the prevalence extending into dentine (grades 3 and 4). This is because clinical symptoms might be apparent at these levels of dental erosion where the dental tissue loss becomes clear and the condition could be considered pathological specially in children and adolescents [178]. In contrast, enamel erosion (grades 1 and 2) varies greatly and was found on at least one tooth surface in the majority of examined participants and could be considered physiological [178]. In addition, the process of calibrating the principal investigator showed that recording advanced erosive lesions (grades 3 and 4) was easier, clearer and more certain because of the well-defined loss of tooth tissue, while the few inter- and intra-examiner disagreements were found only in enamel erosion (grades 1 and 2). Furthermore, the emphasis on dental erosion extending into dentine provided a good chance to overcome the problem of comparing results with other studies that used different dental erosion indices since the prevalence of dental erosion into dentine is comparable regardless of the used index.

The highest recorded erosion grade at the individual level was used to classify the cases. This was done in line with the World Health Organization recommendations that suggested recording the severity of dental erosion according to the tooth with the highest score of erosion [179]. Therefore, for example an individual might have all surfaces graded with erosion grade 0 (no erosion) except maybe one or two surfaces with grade 1. At an individual level, such a case would be classified in the category of grade 1 erosion. This explains why there were no cases classified in the category of grade 0 erosion at the individual level, even though 18% of all examined surfaces in this study had grade 0 erosion at the surface level. Previous studies have similarly reported their results with grade 0 erosion being absent at the individual level even though at the surface level “no erosion” was not infrequently registered [180-183].

In **Paper II**, the dependent variable in the logistic regression analysis of possible associated factors with dental erosion was severity of dental erosion. Therefore, the high and low erosion groups comprised those who had dentine erosion versus those who had enamel

erosion utilizing enamel and dentine as a reasonable biological cut-off point for the dichotomization. This was done because the interest was in detecting factors associated with clinically significant erosion (i.e. advanced dental erosion) which could be considered the pathological stage of the condition specially in children and adolescents [178].

The logistic regression analysis models were constructed for each age group separately and also for the 13-14 and 18-19 years age groups pooled in one model to adjust for age as an independent factor. The pooled logistic regression model was mainly constructed to investigate the association between severity of dental erosion and age which has been shown to be significant in previous studies [27, 135, 184, 185]. However, age-stratified logistic regression models were necessary [186] due to the presence of different dentitions, dietary characteristics and habits in each age group. This was confirmed by the differences in the associated factors and their odds ratios across age groups.

Non-response analysis in **Papers I and II** was confined to the variables age and sex which represented the only data available about non-participants. However, it was not possible to conduct non-response analysis in **Paper III** as there was no information about non-participants and this could be considered a limitation in the study.

## **5.2 Discussion of the results**

### ***Prevalence of dental erosion***

Advanced erosive lesions (severe and very severe; grades 3 and 4) were quite common in **Paper I** among Yemeni children aged 5-6 years, 6.8% of whom had at least one primary tooth surface so affected [187]. In spite of the methodological variations in the conduct of similar studies, this prevalence rate was lower than those reported in previous studies from Saudi Arabia [51] and western countries [23, 48, 167] that ranged widely from 13.0-58.0%. Nevertheless, the prevalence rate was higher than those reported in other studies where the prevalence range was 1.0-3.7% [29, 65, 188].

In contrast, the prevalence rate of advanced erosive lesions was not common among Yemeni adolescents aged 13-14 years, with only 3.0% of them having at least one permanent tooth surface so affected. This is lower than the prevalence rates reported in studies from other countries [23, 53, 54, 59] that ranged from 12.0-53.0%. However, a

study from India in 2013 found that only 0.5% of adolescents aged 11-14 years were affected by advanced erosive lesions [43].

In the age group 18-19 years, the prevalence of advanced erosive lesions was common with 14.6% of Yemeni adolescents found to be affected on at least one permanent tooth surface [187]. Previous reports have found higher prevalence rates of advanced erosive lesions ranging from 15.0-32.0% among adolescents aged 18-21 years [23, 55, 124], while another study from Poland found that 13.4% of adolescents aged 18 years were affected by advanced erosive lesions [189].

In general, it might be concluded that the prevalence rates of advanced erosive lesions in the three examined age groups were lower than those reported in the majority of studies elsewhere, even though a few studies reported even lower prevalence rates. This might be explained by the fact that the modern lifestyle including soft drink consumption has relatively recently become part of Yemen. In addition, the difficulties through which the Yemeni economy is passing might have resulted in decreased consumption of soft drinks.

Dental erosion occurrence has been reported among both boys and girls with some studies reporting higher prevalence rates among boys [24, 41, 43, 55] while other studies found the prevalence rates to be higher among girls [190, 191]. On the contrary, a study from Brazil reported no significant difference in the prevalence of dental erosion between boys and girls aged 15-19 years [42]. There were no significant differences regarding the prevalence of dental erosion between the Yemeni boys and girls children and adolescents aged 5-6 years and 13-14 years. However, girls were found to have a higher prevalence of dental erosion than boys in the age group 18-19 years. This might reflect a trend towards higher consumption of acidic drinks and foods among the Yemeni girls studied in the third age group and thus should be considered during the planning phase of any future preventive programs.

Very severe erosive lesions (grade 4) were only found on the palatal surfaces of maxillary anterior teeth. Similarly, these surfaces were the ones predominantly affected by erosive lesions in previous studies [13, 23, 32, 172]. This might be explained by the oral factors involved in the process of dental erosion. The combination of the tongue and erosive

components might be expressed more on the palatal surfaces of maxillary anterior teeth due to the normal anatomical position of the tongue against these teeth surfaces during the swallowing process [122, 192]. In addition, thinner pellicle layer was found on the palatal surfaces of maxillary anterior teeth in previous reports, which may consequently result in lower resistance against any acidic challenges on these surfaces [69, 122]. Furthermore, palatal surfaces of maxillary anterior teeth may receive the greatest acidic challenge during gastroesophageal reflux or vomiting due to their anatomical position [103, 105].

On the other hand, severe erosion (grade 3) was the highest erosion grade found on the occlusal surface of first molars (cuppings), which, in the primary dentition, was correlated with the severity of dental erosion on maxillary anterior teeth. Previous reports have also reported the existence of erosive lesions on the first molars and positively correlated these lesions with those found on maxillary anterior teeth [23, 32, 53, 193]. Furthermore, previous reports have even concluded that mandibular first molars may serve as markers for the onset of dental erosion [14, 68]. Therefore, it seems important to give the maxillary anterior teeth and first molars great attention during the clinical examination as they may represent the best marker teeth for dental erosion.

### ***Comparison between EPRS, EPRS-M, SEPRS and the importance of marker teeth***

The sensitivity and specificity of an index are usually measured in relation to a gold standard. However, such a gold standard dental erosion index is not yet universally agreed upon [194]. In this study (**Paper I**), a trial was made to address the efficacy of utilizing specific erosion marker teeth and surfaces by comparing the prevalence of severe/very severe erosion obtained by one erosion scale but using fewer marker teeth surfaces according to three partial recording systems (EPRS, EPRS-M and SEPRS). Therefore, the sensitivity of SEPRS in detecting cases with severe/very severe erosion was first compared in relation to the erosion partial recording system (EPRS) and was found to be low in permanent dentition and reasonable in primary dentition while the specificity in detecting cases without severe/very severe erosion was very high in both primary and permanent teeth.

However, SEPRS had a very high sensitivity and specificity in relation to EPRS for both primary and permanent dentitions in a previous study [23]. This could be explained by the fact that severe/very severe lesions (grades 3 and 4) were mainly found on the palatal surfaces of maxillary anterior teeth and occlusal surfaces of mandibular first molars in this previous study [23]. Therefore, the surfaces that are included in SEPRS appear to have perfectly coincided with the prevailing location of erosive lesion in the studied population of the previous study [23]. On the contrary, very severe lesions (grade 4) were similarly found but only on the palatal surfaces of maxillary anterior teeth (including lateral incisors and canines) among participants in the present study, while severe lesions (grade 3) were also common on all buccal surfaces of maxillary anterior teeth and occlusal surfaces of maxillary posterior teeth as well, which are not included in SEPRS.

Due to the fact that SEPRS includes only palatal surfaces of maxillary central incisors and occlusal surfaces of all primary first molars or mandibular first permanent molars, using SEPRS would have underestimated the prevalence of advanced erosive lesions in the present study, although it worked well in the previous study [23] due to the differences in the prevailing location of advanced erosive lesions among the different populations in the two studies.

Therefore, EPRS-M was proposed by inclusion of the buccal surfaces of maxillary central incisors to the previously proposed system (SEPRS). EPRS-M showed a reasonable sensitivity and specificity for detecting advanced erosive lesions in relation to EPRS in both the primary and permanent dentitions. In addition, there were no statistically significant differences between the prevalence figures obtained by both EPRS and EPRS-M among boys and girls in the examined three age groups. This might be explained by the fact that the erosion marker teeth surfaces which are proposed in EPRS-M are affected by dental erosion most consistently and thus provide good indicators for the individual's severity of dental erosion.

The modification of EPRS to EPRS-M has therefore provided another reasonable alternative for detecting and grading dental erosion by the use of the same erosion scale but utilizing fewer erosion marker teeth which is very time-efficient during the clinical diagnosis process. EPRS-M is therefore suggested to be used as a quick dental erosion

detection tool in future dental erosion research. However, it is suggested to apply EPRS-M as a quick initial detection tool and to consider recording of more erosion marker teeth whenever advanced erosive lesions are detected.

### ***Risk indicators of dental erosion***

Risk might be defined as “the probability that an event will occur within a given period of time [195]. The probability that a particular outcome (which is often a disease) will occur after exposure to a certain factor is often expressed by risk [195]. Risk factor is 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”[196]. Risk indicator could be defined as “a probable or putative risk factor, often detected in cross-sectional studies, that has not yet been confirmed by longitudinal studies”[196]. Therefore, the association strength identified in this study is limited to disease indicators as it is a cross-sectional study.

### ***Oral clinical variables***

Dental caries has been previously associated with the presence of dental erosion, but there are contradictory results in the literature. Some reports have found this association [53, 64, 124], while other reports could not find such association between these two oral health problems [125, 193, 197]. In this study (**Paper II**), there was no significant association between severity of dental erosion and caries experience.

Absence of dental fluorosis among the 18-19 year olds, but not in the younger groups, was significantly associated with severe dental erosion (**Paper II**). This finding may seem confusing, since it is expected that teeth with fluorosis would be more susceptible to erosion than teeth without fluorosis [198]. This might be explained by the fact that study participants with fluorosis had mostly resided in areas with high fluoride sources which is the principal cause of fluorosis. In addition, all participants reported daily intake of water which has fluoride contents of 1.5-2.8 ppm in Sanaa [199]. Therefore, the protection against dental erosion was probably gained from the known topical anti-demineralization effects of these fluoride sources rather than from having fluorosis [200]. This explanation could be



supported by a previous report from England which found that children in fluoridated districts were less likely to have dental erosion [54]. In addition, it's worthy to mention that most of the fluorosis cases among the participants in our study were mild (TFI-grade 1-3; **Paper II**) and therefore the enamel was still intact without fluorosis pitting that appear in advanced stages.

Teeth sensitivity was associated with severe/very severe erosive lesions among 5-6 years children in this study. This could be explained by the fact that severe/very severe erosive lesions occur when the lesion is approaching or extending into the dentine causing the sensitivity. In addition, primary teeth might be more prone to teeth sensitivity as their enamel layer is thinner and could be eroded faster than in permanent dentition [201]. Other tested oral clinical variables did not show associations with the existence of dental erosion.

### ***General health variables***

There was no significant association between severity of dental erosion and acid reflux/heartburn (**Paper II**) which are some of the reported manifestations of GER(D), although in the unadjusted association analysis among 5-6 years and 18-19 years participants the direction of association was positive but not significant. This might be due to the fact that a confirmed medical GER(D) diagnosis (i.e. by esophageal manometry or 24-hour monitoring of esophageal pH) was not obtained and acid reflux/heartburn as a reported symptom is considered physiological when limited to certain episodes per day [103, 104]. In addition, acid reflux might be confined to the esophagus without reaching to the oral cavity in these episodes [103]. However, the prevalence of dental erosion has in previous reports been found to be higher among patients suffering from gastroesophageal reflux disease GER(D) [103, 106, 202]. In one study conducted in Iceland, 33.7% of participants had severe erosive lesions extending into dentine and a significant association was reported between these lesions and GER(D) [106]. Other included medical variables did not show associations with the existence of dental erosion.

### ***Dietary habits***

Previous reports have shown that lemon-sucking or chewing were associated with dental erosive wear [203, 204]. This was confirmed by our results in **Paper II** where lime sucking

was found to have a significant association with severe dental erosion among 5-6 years children. The acidic nature of these fruits and its demineralization effect on enamel could explain their association with the presence of dental erosion. In addition, the habit of lime sucking provides direct contact between the acidic contents of the lime with the tooth surfaces for a longer period of time in comparison with the usual lemon/lime drinks. Moreover, the prevalent lime sucking habits among participants in this study (**Paper II**) might explain the presence of buccal grade 3 erosive lesions in **Paper I**.

Soft drinks and fruit juices are considered the major risk factors that are associated with dental erosion [6, 163]. The relationships between severe dental erosion and several types of soft drinks and fruit juices were explored in this study (**Paper II**), and the results showed significant associations between higher intake amount and frequency of these drinks and severe dental erosion. In addition, the results revealed that severe dental erosion was significantly associated with the combined total amount of consumed acidic beverages. Several previous reports have also confirmed the association between acidic drinks consumption and dental erosion [85, 93, 164, 205- 207]. This fact represents a challenge for the prevention efforts against dental erosion, because there has been a marked change in dietary habits with an apparent increase in consumption of these acidic drinks in developed and developing countries [208, 209]. On the other hand, the average soft drinks consumption among all participants in this study was moderate and lower than previously reported consumption rates in other studies [210-212]. This may explain why the prevalence rates of advanced erosive lesions were not high in this study (**Paper I**) and provide better chances for dental erosion prevention among the participants in this study by enhancing the already existing moderate soft drink consumption pattern.

Study participants aged 18-19 years who reported not being breastfed during infancy were more likely to have severe dental erosive lesions. Thus, the results suggest an association between absence of severe erosion in the permanent dentition and being breastfed during infancy. This finding might be explained by the hypothesis that breastfeeding during tooth development may promote the formation of teeth with mineral composition that is more resistant to acidic challenge. In addition, the majority of participants in this study reported being breastfed for six months or more by their mothers during infancy. This might provide

additional preventive measure against the existence of severe dental erosive lesions as breastfeeding for shorter duration was also associated with severe tooth wear in a previous study [213].

### ***Awareness of dental erosion among children and adolescents***

Awareness about dental erosion and its prevention methods among the study participants or their parents/guardians was poor in **Paper II**, and the majority of participants had not heard about dental erosion previously. Moreover, the results indicate that a very high percentage of those who had seen a dentist earlier have not received information about how to prevent dental erosion from their dentists. In this regard, the results in **Paper III** have also found that awareness about dental erosion was insufficient among dental professionals [214]. These results coincide with previous studies that found low awareness about dental erosion among children [150] and dental professionals [151]. This lack of knowledge about dental erosion might be attributed to the lack of effective awareness programs at schools and media. In contrast, recent studies from Norway found that the majority of 18 years old adolescents have heard about dental erosion [154] and that dentists' knowledge about dental erosion was up to date [215]. However, the prevalence of dental erosion was high among 18 years old Norwegians [124].

### ***Awareness of dental erosion among dental professionals***

Knowledge about dental erosion is commonly expected to be gained by dental professionals during the undergraduate education period. However, the results in **Paper III** showed that a large proportion of the study respondents have utilized their own studies to learn about dental erosion. This is probably due to insufficient coverage of the dental erosion subject in their taught undergraduate dental curriculum, or possibly because dental erosion subject was given a lower priority by those dental professionals during their undergraduate education. Another explanation might be that dental erosion prevalence in Sanaa is still not high which might be confirmed from the prevalence results in this study (**Paper I**), or that dental erosion is not given appropriate importance in the clinical setting. Therefore, dental erosion is recommended to be given greater attention in dental education in Sanaa by incorporating more details about this subject in the taught dental curriculum to prepare

Yemeni dental professionals for the early diagnosis and prevention of this worldwide emerging oral health problem [41].

High consumption of acidic drinks and the existence of certain systemic diseases such as gastroesophageal reflux are well-known risk factors for dental erosion development [26, 75, 86, 125, 216-218]. However, acidic drinks and systemic diseases were only recognised by half of the participants as contributing factors that may cause dental erosion. This indicates a lack of an essential knowledge among a relatively large proportion of dental professionals in Sanaa, who are mainly expected to provide the public with the necessary preventive advice about dental erosion [219, 220]. Consequently, it is anticipated that a large number of Yemeni dental erosion patients in Sanaa will not receive the required preventive advice from their own dentists, and would have low awareness about dental erosion as reported in other reports [150], which might also lead to a future increase in the prevalence of this oral health problem in Sanaa.

Enamel surface smoothening is recognised as one of the early important clinical signs during the diagnosis of dental erosion [13, 184, 208, 221]. However, this characteristic early dental erosion sign was recognised by only half of the respondents. Therefore, it is expected that early diagnosis and prevention of dental erosion might be overlooked by a significant proportion of the dental professionals in Sanaa. This coincides with the reported low awareness about dental erosion among dental professionals in another previous study [150].

Utilisation of a dental erosion index is important clinically for the diagnosis, grading of severity and progression of dental erosion [222]. Additionally, the progression in the severity of dental erosive lesions is recognised previously [36]. In this study (**Paper III**), a dental erosion index was not used by the majority of respondents. However, it is not clear from the data whether this was due to insufficient knowledge about dental erosion indices or it was the respondent's choice. In any event, this may lead to poor diagnosis which could affect both management measures and follow-up of existing dental erosive lesions, and subsequently may result in progression and deterioration. In contrary, another study from Norway has found that most of the dental professionals used an index during the diagnosis

of dental erosion [215]. The tested erosion grading system (EPRS-M) in **Paper I** may therefore provide a good tool to be used in the future by the dental professionals.

Recognition of dental erosion etiological factors with subsequent implementation of appropriate preventive approaches requires a proper dietary history taking [6]. Interestingly, the majority of respondents in the study reported that asking about dietary habits would help during the diagnosis and treatment planning of dental erosion. This would encouragingly improve the chances of detecting dental erosive lesions and recognising their etiological factors. The dental professionals are also encouraged to include the factors that were found associated with dental erosion in **Paper II** in their future dietary history taking in connection with dental erosion investigation.

There is no previously reported correlation in the literature between sugar consumption, the use of muscle relaxants, wearing night guards and biting on hard objects, on the one hand, and prevention of dental erosion, on the other. Nevertheless, a proportion of the respondents reported advising their dental erosion patients to take certain muscle relaxants and to reduce acidic drinks together with sugar consumption as a preventive strategy against dental erosion. Additionally, about half of the respondents reported giving advice to their dental erosion patients to wear night guards, to stop biting on hard objects and to frequently brush with fluoridated toothpaste. This might be explained by the inability to discriminate between abrasion/attrition and dental erosion [62, 205]. Similarly, the majority of respondents in a previous report believed that frequent sugar consumption has a significant role in the development dental erosive lesions [151] which also indicate confusion between dental erosion and dental caries.

Younger participants were more likely than older participants to recognise acidic drinks and certain systemic diseases as causative factors for dental erosive lesions, and to recommend the reduction of acidic drinks consumption to prevent dental erosion. Additionally, dental students were more likely than graduated dentists to use an index for grading the severity of dental erosive lesions during the clinical examination. This could be attributed to the fact that younger participants had possibly more current knowledge about dental erosion as they have gained this knowledge in a more recent time in comparison with graduated dentists who may have acquired this knowledge but started to forget it. This may clarify the

importance of the participation in continuing education courses for any certified dentist on the subject of dental erosion. Recently, such continuing education courses have started to be offered and available in Sanaa and all certified Yemeni dentists are therefore encouraged to participate actively in them.

In spite of the fact that many participants were not able to recognise dental erosive lesions at an early stage, they seem to be able to do so in the advanced stages when the erosive lesions became larger and clearer for identification. The results in Paper III have also shown that a large proportion of the participants preferred to manage dental erosion cases themselves while only referring severe cases to a specialist. This would suggest that in spite of the insufficient knowledge about detection of erosive lesions at an early stage, the respondents seem to have enough confidence and knowledge regarding dental erosion management approaches; this also coincides with a previous report from Norway where a large proportion of the dentists preferred to treat dental erosion cases themselves [215].

More interestingly, referral of dental erosion cases was more likely done by dental students rather than dentists, which could be explained by the fact that dental students might have self-perceived inadequate experience in dealing with dental erosion patients in comparison with the graduated dentists who are in turn expected to have more clinical experience.

### ***Dental erosion clinical conceptual overview***

The findings in this thesis have confirmed the common occurrence of dental erosion among children and adolescents which coincides with the previous scientific literature [6]. In its early stages, dental erosion shall be expected to exist in any individual as was observed in the examined individuals in this study. Primary prevention is always the best approach, however, a good chance is still present to detect dental erosion at an early stage and initiate secondary preventive comprehensive clinical approach to avoid its progression that was also reported in previous studies [38, 52, 62]. The presence of an easy and time-efficient dental erosion clinical examination index such as EPRS-M may help and encourage dental professionals to consider detection of possible dental erosive lesions during any routine dental clinical examination. However, this needs to be augmented by a solid dental professional and community knowledge about dental erosion early clinical signs in general.

This highlights the role of the dental educational sector and official community authorities to support and spread the awareness about this oral health condition.

However, the actual current situation indicates that dental erosive lesions are mostly detected at advanced stages either by the dental professional or the patient himself due to the major tooth morphological changes that might be accompanied by more clinical symptoms such as pain and makes dental erosion detection much easier. Late detection is usually accompanied by greater dental professional responsibility and clinical efforts to identify the possible etiological factors that were found to be unique to each patient due to the multifactorial etiology of dental erosion. This necessitates a thorough clinical examination and history taking as well as good knowledge about all dental erosion associated factors which is ideally followed by a comprehensive preventive and management plan.

The efficient clinical dental examination and the awareness about dental erosion prevalence and etiological factors both among dental professionals and the community seems to be the key factors that may help in early detection and easier prevention of this oral health problem. Therefore, it's hoped that the findings in this thesis have provided a scientific addition towards better dental erosion clinical understanding and general awareness.

## 6. Conclusions

The results in this thesis provided good reference data and confirmed the hypothesis of the common presence of advanced erosive lesions among the participants in the first and third age groups but not in the middle age group. However, the hypothesis of more prevalent dental erosion among boys was not confirmed, while that a reduced number of erosion marker teeth would reasonably reflect the individual's erosion severity was confirmed. In addition, the other hypothesis that advanced dental erosion would be associated with consumption of acidic drinks and foods, and that awareness about dental erosion would be low among children, adolescents and dental professionals were all confirmed.

The following specific conclusions can be drawn from this thesis:

1. Advanced erosive lesions were common among the examined Yemeni children and older teenagers aged 5-6 and 18-19 years, while they were less common among younger teenagers aged 13-14 years. However, mild/moderate erosive lesions were present in the majority of examined individuals.
2. Girls aged 18-19 years had significantly the highest prevalence of advanced erosive lesions, while there were no significant differences in the prevalence of advanced erosive lesions between boys and girls aged 5-6 years and 13-14 years.
3. Palatal surfaces of maxillary anterior teeth should be given greater concern during diagnosis of dental erosion as they were found to be more commonly affected.
4. The sensitivity of SEPRS in detecting cases with advanced erosive lesions was found to be low in permanent dentition and reasonable in primary dentition among the examined participants while its specificity in detecting cases without advanced erosive lesions was very high in both primary and permanent teeth.
5. The proposed erosion partial recording system (EPRS-M) provides a reasonable and time-efficient erosion detection tool which is suggested to be used in future dental erosion research. However, it is suggested to apply EPRS-M as a quick initial



detection tool and to consider recording of more erosion marker teeth whenever erosive lesions are detected.

6. Dental erosion is a multifactorial condition and was associated with frequent acidic foods and soft drinks consumption, frequent lime sucking, teeth sensitivity and older age while presence of mild fluorosis and being breastfed were associated with lesser severity of dental erosion.
7. Dental caries and acid reflux/heartburn were not associated with the occurrence of advanced dental erosion in the examined groups.
8. Awareness about dental erosion and its prevention methods among the children and adolescents or their parents/guardians was poor, and the majority of participants had not heard about dental erosion previously.
9. Only half of the Yemeni dental professionals in Sanaa had in-depth knowledge about early stages of dental erosion, factors causing it and methods used to prevent it.
10. Knowledge about dental erosion and the approaches used in its early diagnosis were insufficient among many Yemeni dental professionals in Sanaa.
11. Younger Yemeni dental professionals showed better awareness about dental erosion causative factors and preventive methods.

## **7. Future perspectives and recommendations**

Based on the obtained dental erosion prevalence figures in this thesis it seems necessary to conduct further population-based dental erosion studies in Sanaa and other Yemeni governorates to investigate dental erosion prevalence among different age groups and the potential factors associated with its occurrence. The use of EPRS-M and EPRS in such studies is also recommended as these systems were clinically tested on three samples of Yemeni children and adolescents. However, to conduct such future population-based studies, there is an urgent need to increase the awareness about the importance of scientific research in the Yemeni community first, to gain the necessary cooperation from people that is essential to conduct these studies.

In addition, there is a need to plan for appropriate primary and secondary preventive programmes and to conduct studies that could test the effectiveness of such programmes in the prevention of dental erosion in the Yemeni community.

There is a need for further clinical investigations to explore, compare and modify the existing dental erosion recording systems on different populations to reach to a worldwide acceptable dental erosion recording system that would help in easier diagnosis and better comparability between the results obtained among different studies across the world.

The preventive effect of high water fluoride contents and breastfeeding on dental erosion that were found in this thesis encourages the inclusion of these practices in any future dental erosion preventive programs and needs further clinical investigations to clarify and confirm whether such relationships are consistent among different populations and to explore possible mechanisms by which such protective effects are gained.

The level of dental erosion awareness that was found among the children, adolescents and dental professionals in this study indicates the need for spreading and improving awareness and dental education about dental erosion and its preventive methods among the Yemeni children, adolescents and the dental professional community in Sanaa. Moreover, well-organized continuing education dental erosion courses are needed and graduated Yemeni dentists in Sanaa shall be encouraged to participate in such courses.

At the same time, the author is mindful of the severe difficulty of implementing oral health, educational and preventive studies in the circumstances and political instability that is currently prevailing in Yemen, although all these current circumstances were not present during the planning and implementation phases of this project. It is hoped, however, that these recommendations can be acted upon as soon as the circumstances permit.

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## 10. Appendices

### Appendix 1 - Clinical registration form (Paper I)

Age: ..... Male ☐ Female ☐ No. ....

#### Maxillary

Erosion  
(0-4)  
(X=Cervical defect)

Visible  
Plaque  
Index  
(X=  
plaque)

Gingival  
Bleeding  
Index  
(X= Bleeding after 10 sec.)

Primary

Permanent Teeth								Primary Teeth						
13	12	11	21	22	23		53	52	51	61	62	63		
Buccal														
Palatal														
Cervical defect														
Buccal														
Palatal														
Mesiobuccal														
Buccal														
Palatal														
Mesiobuccal														

#### Molars

Cupings  
(0-4)  
(X= Cervical defect, non-occluding tooth)

Permanent					Primary							
16	26	46	36		55	54	64	65	85	84	74	75
Cupings												
Occlusion												
Cervical defect												

No. of Cervical defects on premolars, second molars and lower anteriors

Anterior Open Bite: Yes ☐ No ☐

Visible Calculus: Yes ☐ No ☐



## DMFT/S, dmft/s Index

<i>Upper right</i>								<i>Upper left</i>							
	17	16	15	14	13	12	11	21	22	23	24	25	26	27	
			55	54	53	52	51	61	62	63	64	65			
B															
P															
M															
D															
O															
DMFT															

B= Buccal, P= Palatal, L= Lingual, M=Mesial, D=Distal, O= Occlusal

DMFT														
O														
D														
M														
L														
B														
			85	84	83	82	81	71	72	73	74	75		
	47	46	45	44	43	42	41	31	32	33	34	35	36	37
<i>Lower right</i>								<i>Lower left</i>						

0-Sound, 1-Decayed, 2-Filled, with decay, 3-Filled, no decay, 4-Missing due to caries, 5-Missing for other reason, 6-Fissure sealant, 7-Bridge abutment, special crown or veneer/implant, 8-Unerupted tooth(crown)/unexposed root, T-Trauma

## Fluorosis

Total No. of teeth:.....

### Fluorosis on anterior teeth

0	1	2	3	4	5	6	7	8	9

## Appendix 2 – Questionnaire 1 (English translation) - (Paper II)

<i>Tick the best option with (√)</i>	Never	One to several times/month	Once weekly	Two or more times weekly	Daily
<b>How often do you eat:</b>					
1. Sweets					
2. Ice cream					
3. Chips / Cheese doodles					
4. Cakes/ Buns/ Biscuits					
5. Cheeses					
6. Fresh fruits					
7. Chewing gum					
8. Do you suck lime					
9. Do you chew qat					
10. Do you smoke					

<i>Tick the best option with (√)</i>	Never	One to several times/month	Once weekly	Two or more times weekly	Daily
<b>How often do you drink:</b>					
11. Water					
12. Cola soft drinks					
13. Other carbonated soft drinks					
14. Fruit Juice (100%)					
15. Fruit drink (with water)					
16. Tea (with sugar)					
17. Tea (without sugar)					
18. Coffee (with sugar)					
19. Coffee (without sugar)					
20. Milk (with sugar)					
21. Milk (without sugar)					
22. Yogurt/ Labneh					

<b>How much do you drink a week of (last year):</b>	<b>Type of drink</b>	<b>Times per week</b>	<b>Number of glasses/cans / bottles each time</b>	<b>Milliliters per week</b>
23. Cola soft drinks				
24. Other soda				
25. Fruit Juice (100%)				
26. Fruit drink (with water)				
27. Energy drink				
28. Milk				

<i>Tick the best option with (√)</i>	Home	In school	Anywhere	Do not drink carbonated soft drink
29. Where do you drink soda				

<i>How do you drink: Tick the best option with (√)</i>	Swallows directly	Keeps the drink in your mouth and swallow after a while
30. Carbonated soft drinks		

<i>Do you: Tick the best option with (√)</i>	Never	Once or more/ month	Once or more/ week	Once/day	Several times/day	Always
31. Have mouth dryness during the day						
32. Have mouth dryness during the night						
33. Have sensitivity in your teeth						
34. Have pain in your teeth						
35. Have stomach pain						
36. Have acid reflux/heartburn						
37. Vomit						

<i>Tick the best option with (√)</i>	Yes	No
38. Do you play sports		

<i>How many hours do you often play sports Estimating an average of seasonal sports</i>	Number of times per week	Number of hours per day
39. Training		
40. Race / match		

<i>How many hours/day do you spend in front of the TV / Computer/ VCR/ Video games</i>	0-1 hours	2-3 hours	4-5 hours	More than 5 hours
41. On weekdays				
42. On weekends				

<i>43. What do you do during the day (can be two options)</i>					
Home	Kindergarten	School	Gymnasium	Work	Other

<i>Tick the best option with (√)</i>	Never	One to several times/ month	One to several times/ week	Once daily	More than once daily
44. How often do you clean your teeth					

<i>Tick the best option with (✓)</i>	<b>Tooth brush</b>	<b>Miswak</b>	<b>Finger</b>	<b>I don't wash my teeth</b>
<b>45. How do you clean your teeth</b>				

<i>Tick the best option with (✓)</i>	<b>Yes</b>	<b>No</b>
<b>46. Do you use tooth paste</b>		

<b>How many times per week do you have</b>	<b>47.Breakfast</b>	<b>48. School Lunch</b>	<b>49.Dinner</b>	<b>50.Snacks(including school)</b>

	<b>Yes</b>	<b>No</b>
<b>51. Mouth breathing</b>		
<b>52. Diabetes</b>		
<b>53. Asthma</b>		
<b>54. Other systemic diseases</b>		
<b>If yes, what?</b> .....		
<b>55. Medications</b>		
<b>If yes, what?</b> .....		
<b>56. Did you have breastfeeding?</b>		
<b>If yes, for how long?.....Months</b>		
<b>57. Have you ever heard about acidic tooth wear?</b>		
<b>58. Have you received any information about acidic tooth erosion from your dentist?</b>		
<b>59. Do you know how to prevent acidic tooth erosion?</b>		
<b>If yes, How?.....</b>		

<b>60. How often do you visit a dentist?</b>	<b>Regularly</b>	<b>When I have pain</b>	<b>Never</b>

### Appendix 3 – Questionnaire 1 (Arabic translation) - (Paper II)

ضع علامة (✓) تحت الخيار المناسب	لا أبدا	مره إلى عدة مرات في الشهر	مره في الأسبوع	مرتين أو أكثر في الأسبوع	يومية
كم مره عادةً تأكل:	1	2	3	4	5
1. الحلويات					
2. الأيس كريم					
3. الشبس أو البفك					
4. الكيك أو البسكويت أو الكعك					
5. الجبن					
6. الفواكه الطازجة					
7. العلكة أو اللبان					
8. هل تحب مص الليمون					
9. هل تتعاطى القات					
10. هل تدخن					

ضع علامة (✓) تحت الخيار المناسب	لا أبدا	مره إلى عدة مرات في الشهر	مره في الأسبوع	مرتين أو أكثر في الأسبوع	يومية
كم مره عادةً تشرب:	1	2	3	4	5
11. الماء					
12. مشروبات الكولا					
13. المشروبات الغازية الأخرى					
14. عصير فواكه صافي (بدون ماء)					
15. عصير الفواكه (مع الماء)					
16. الشاي (بدون سكر)					
17. الشاي (مع سكر)					
18. القهوة (بدون سكر)					
19. القهوة (مع سكر)					
20. الحليب (بدون سكر)					
21. الحليب (مع سكر)					

					22. الزبادي أو اللبنه
كم تشرب في الأسبوع (خلال السنة الماضية)	نوع الشراب	عدد المرات في الأسبوع	عدد الأكواب أو العلب أو الفوارير في المرة	مليتر في الأسبوع	
23. مشروبات الكولا					
24. مشروبات غازية أخرى					
25. عصير فواكه صافي					
26. عصير فواكه مع الماء					
27. مشروب طاقه					
28. حليب					

ضع علامة (√) تحت الخيار المناسب	في البيت	في المدرسة	في أي مكان	لا اشرب المشروبات الغازية
	1	2	3	4
29. أين تشرب المشروبات الغازية				

ضع علامة (√) تحت الخيار المناسب	أبلعها مباشرة	احتفظ بالمشروب في الفم قليلاً ثم أبلعه
	1	2
30. كيف تشرب عادة المشروبات الغازية		

هل لديك:	لا أبداً	مره إلى عدة مرات في الشهر	مره إلى عدة مرات في الأسبوع	مره في اليوم	عدة مرات في اليوم	دائماً
ضع علامة (√) تحت الخيار المناسب	1	2	3	4	5	6
31. جفاف في الفم أثناء النهار						
32. جفاف في الفم أثناء الليل						
33. حساسية في الأسنان						
34. ألم في الأسنان						
35. ألم في المعدة						
36. ارتجاع حمضي (حزاز)						
37. غثيان وطرش						

ضع علامة (√) تحت الخيار المناسب	نعم	لا
	1	2
38. هل تمارس الرياضة؟		
كم ساعة عادة تلعب الرياضة	عدد المرات في الأسبوع	عدد الساعات في اليوم
39. التمارين الرياضية		
40. السباق وكرة القدم		

كم ساعة في اليوم تقضيها أمام التلفزيون أو الكمبيوتر أو ألعاب الفيديو	1-0 ساعة	2-3 ساعات	4-5 ساعات	أكثر من 5 ساعات
	1	2	3	4
41. في الأيام العادية				
42. في إجازة الأسبوع (الخميس والجمعة)				

43. ماذا تفعل أثناء النهار ( يمكن اختيار عدة خيارات )					
اجلس في البيت	اذهب للحضانة	اذهب للمدرسة	اذهب للنادي	اذهب للعمل	غير ذلك

ضع علامة (√) تحت الخيار المناسب	لا أبداً	مره إلى عدة مرات في الشهر	مره إلى عدة مرات في الأسبوع	مره في اليوم	أكثر من مره في اليوم
	1	2	3	4	5
44. كم مره عادة تغسل أسنانك؟					

ضع علامة (√) تحت الخيار المناسب	بفرشاة الأسنان	بالمسواك	بالأصبع	لا اغسل اسناني
	1	2	3	4
45. كيف تغسل أسنانك؟				

ضع علامة (√) تحت الخيار المناسب	نعم	لا
	1	2
46. هل تستخدم معجون الأسنان		

كم مره في الأسبوع	47. تأكل الإفطار (تصطبج)	48. تتغذى	49. تتعشى	50. تأكل بين الوجبات

ضع علامة (√) تحت الخيار المناسب	نعم	لا
	1	2
51. هل تتنفس من الفم؟		
52. هل لديك مرض السكر؟		
53. هل لديك مرض الربو؟		
54. هل لديك أي أمراض أخرى؟		
إذا نعم، ما هي.....		
55. هل تتناول أي أدوية؟		
إذا نعم، ما هي.....		
56. هل رضعت من حليب الأم؟		
إذا نعم، لفترة ..... شهر.		
57. هل سمعت من قبل عن التآكل الحمضي للأسنان؟		
58. هل تم إخبارك من قبل طبيب الأسنان عن التآكل الحمضي للأسنان؟		
59. هل تعلم كيفية الوقاية من التآكل الحمضي للأسنان؟		
إذا كنت تعلم، كيف.....		

ضع علامة (√) تحت الخيار المناسب	بانتظام	عندما يكون لدي ألم في الأسنان	أبدأ
	1	2	3
60. كم مره عادة تزور طبيب الأسنان؟			



#### **Appendix 4 – Questionnaire 2 (Dentists) - (Paper III)**

Dear Colleague,

No:.....

Dental erosion is an increasing worldwide oral health problem which has gained considerable interest.

The objective of this research is to know the frequency of dental erosion cases in Sanaa city and the methods used by general dental practitioners to prevent dental erosion. The questionnaire is divided into two parts and simple to complete. This research is conducted by Dr. Amin Al-Ashtal- University of Bergen – Norway.

I appreciate your cooperation in advance.

##### **A- Part I - Demographic Information:**

1. Gender:  
.....Male  
.....Female
2. Age: .....
3. Nationality: .....
4. Date of graduation: .....
5. University of graduation: .....
6. Type of dental practice:  
..... Governmental clinical dental practice  
..... Private clinical dental practice

##### **B- Part II – General information about dental erosion:**

(Please choose only one option)

7. From where have you mainly learned about dental erosion:  
..... Dental school  
..... Continuing educational courses  
..... Own studies/experience/colleagues  
..... Media (newspapers, magazines, etc)

8. I see cases of dental erosion:
- ..... Daily
  - ..... Weekly
  - ..... Monthly
  - ..... Yearly
  - ..... More seldom / never
9. I see cases of dental erosion more commonly in:
- ..... Males
  - ..... Females
  - ..... Equally in males and females
10. I think the prevalence of dental erosion has:
- ..... Increased in comparison to the past 10 years
  - ..... Decreased in comparison to the past 10 years
  - ..... Not changed.
11. I believe that dental erosion is most frequently seen at:
- ..... Buccal surfaces of teeth
  - ..... Palatal surfaces of teeth
  - ..... Proximal surfaces of teeth
  - ..... All teeth surfaces are affected equally
12. The most frequently affected teeth by dental erosion are:
- .....Incisors
  - .....Premolars
  - .....Molars
  - .....All teeth are equally affected
13. I think dental erosion can be caused by:
- ..... Bruxism
  - ..... Acidic drinks
  - ..... Excessive teeth brushing with hard tooth brush
  - ..... All of the above

14. Other causes of dental erosion include:
- ..... Biting on hard objects such as nails, pens and nuts
  - ..... High sugar consumption
  - ..... Systemic diseases (e.g. eating disorders, stomach reflux)
  - ..... All of the above
15. The main clinical sign of early stage of dental erosion is:
- .....Shortening of teeth
  - .....Facial muscle tension
  - .....Smoothering of enamel surfaces
  - .....All of the above
16. During the diagnosis of dental erosion:
- ..... I depend on the clinical signs of dental erosion without using a special index to grade the severity of dental erosion.
  - ..... I prefer to use a special index to grade the severity of dental erosion.
17. During the diagnosis of dental erosion:
- ..... I believe that asking about dietary habits will help in the diagnosis and treatment plan of the case.
  - ..... I believe that asking about dietary habits will not help in the diagnosis and treatment plan of the case.
18. To prevent dental erosion I advise my patients to:
- .....Reduce acidic drinks consumption
  - .....Take some muscle relaxant drugs
  - .....Reduce sugar consumption
  - ..... All of the above

19. Additional preventive measures against dental erosion may include:

- .....Use tooth paste with fluoride
- .....Wear night guard
- .....Stop biting on hard objects
- .....All of the above

20. After diagnosis of dental erosion cases:

- ..... I prefer to treat all cases myself.
- ..... I prefer to refer all cases to a specialist.
- ..... I prefer to refer only severe cases to a specialist.

Thank you very much for your help and cooperation.

If you have any questions or inquiries, please contact:

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Professor Ridwaan Omar phone: 00965 249836765, e-mail: [romar.k@hsc.edu.kw](mailto:romar.k@hsc.edu.kw)

## **Appendix 5 – Questionnaire 2 (Dental students) - (Paper III)**

Dear Colleague,

No:.....

Dental erosion is an increasing worldwide oral health problem which has gained considerable interest.

The objective of this research is to know the frequency of dental erosion cases in Sanaa city and the methods used by general dental practitioners to prevent dental erosion. The questionnaire is divided into two parts and simple to complete. This research is conducted by Dr. Amin Al-Ashtal- University of Bergen – Norway.

I appreciate your cooperation in advance.

### **A- Part I - Demographic Information:**

1. Gender:  
.....Male  
.....Female
2. Age: .....
3. Nationality: .....

### **B- Part II – General information about dental erosion:**

(Please choose only one option)

4. From where have you mainly learned about dental erosion:  
..... Dental school  
..... Continuing educational courses  
..... Own studies/experience/colleagues  
..... Media (newspapers, magazines, etc)
5. I see cases of dental erosion:  
..... Daily  
..... Weekly  
..... Monthly  
..... Yearly  
..... More seldom / never

6. I see cases of dental erosion more commonly in:
- ..... Males
  - ..... Females
  - ..... Equally in males and females
7. I think the prevalence of dental erosion has:
- ..... Increased in comparison to the past 10 years
  - ..... Decreased in comparison to the past 10 years
  - ..... Not changed.
8. I believe that dental erosion is most frequently seen at:
- ..... Buccal surfaces of teeth
  - ..... Palatal surfaces of teeth
  - ..... Proximal surfaces of teeth
  - ..... All teeth surfaces are affected equally
9. The most frequently affected teeth by dental erosion are:
- .....Incisors
  - .....Premolars
  - .....Molars
  - .....All teeth are equally affected
10. I think dental erosion can be caused by:
- ..... Bruxism
  - ..... Acidic drinks
  - ..... Excessive teeth brushing with hard tooth brush
  - ..... All of the above
11. Other causes of dental erosion include:
- ..... Biting on hard objects such as nails, pens and nuts
  - ..... High sugar consumption
  - ..... Systemic diseases (e.g. eating disorders, stomach reflux)
  - ..... All of the above

12. The main clinical sign of early stage of dental erosion is:
- .....Shortening of teeth
  - .....Facial muscle tension
  - .....Smoothing of enamel surfaces
  - .....All of the above
13. During the diagnosis of dental erosion:
- ..... I depend on the clinical signs of dental erosion without using a special index to grade the severity of dental erosion.
  - ..... I prefer to use a special index to grade the severity of dental erosion.
14. During the diagnosis of dental erosion:
- ..... I believe that asking about dietary habits will help in the diagnosis and treatment plan of the case.
  - ..... I believe that asking about dietary habits will not help in the diagnosis and treatment plan of the case.
15. To prevent dental erosion I advise my patients to:
- .....Reduce acidic drinks consumption
  - .....Take some muscle relaxant drugs
  - .....Reduce sugar consumption
  - ..... All of the above
16. Additional preventive measures against dental erosion may include:
- .....Use tooth paste with fluoride
  - .....Wear night guard
  - .....Stop biting on hard objects
  - .....All of the above

17. After diagnosis of dental erosion cases:

..... I prefer to treat all cases myself.

..... I prefer to refer all cases to a specialist.

..... I prefer to refer only severe cases to a specialist.

Thank you very much for your help and cooperation.

If you have any questions or inquiries, please contact Dr. Amin Al-Ashtal – Phone: 711437126. E-mail: [aminashtal19@gmail.com](mailto:aminashtal19@gmail.com)

Professor Ann-Katrin Johansson – Phone: 004755586699, e-mail: [Ann-katrin.Johansson@iko.uib.no](mailto:Ann-katrin.Johansson@iko.uib.no)

Professor Ridwaan Omar phone: 00965 249836765, e-mail: [romar.k@hsc.edu.kw](mailto:romar.k@hsc.edu.kw)



## **Appendix 6 – Informed consent (English translation) - (Papers I & II)**

Invitation for participation in a scientific research

This is a request to participate in a scientific study about acid erosion of teeth – How often it occurs?

We would like to find answers to this question by investigating a group of Yemeni children and adolescents in Sanaa city.

Acid erosion of teeth is caused by soft drinks and juice consumption or acid reflux associated with indigestion. It is not always easy to find specific reasons for this acid damage to teeth. Indeed some people may get this damage to teeth easier than others even at normal rate of acidic beverages consumption.

The purpose of this study is to determine how many people have such acid damage and to find factors that affect their development. We want to use and scientifically publish the results of this study without identification of the participants.

Teeth will be examined the same way that you are familiar with during your past regular dental check-ups. Some questions will be asked about diet, habits and drinks consumption. The additional time needed for the whole procedure will be approximately 15-20 minutes. Questionnaire responses and findings from dental examination is the information collected about you. All information collected will be treated confidentially.

If diagnosis of dental erosion was made for your teeth, you will be offered free treatment and preventive advice.

Establishing knowledge about the prevalence and risk factors of dental erosion will help health authorities to implement effective preventive programs and reduce the incidence of dental erosion in the community.

Participation in this study is completely voluntary, and you can withdraw at any time without giving any reason, and you will get the same treatment as those who do not participate in the study.

If you want to participate we ask you to give your written consent.

This research project was approved by the Regional Committee for Medical and Health Research Ethics, Western Norway (Ref. 2013/981/REK Vest) and the Research Ethical Committee at the Faculty of Dentistry, University of Science and Technology in Yemen (Ref. 10/2013).

Information from clinical examination will be transferred into registration form in which the name will be replaced by number. The same number is used in the questionnaire. This information is stored separately and confidentially at the faculty of medicine and dentistry where data will be processed.

If you have questions about this study you can contact:

- Dr. Amin Al-Ashtal phone: 711437126, e-mail: [aminashtal19@gmail.com](mailto:aminashtal19@gmail.com)
- Professor Ann-Katrin Johansson phone: 004755586699, e-mail: [Ann-katrin.Johansson@iko.uib.no](mailto:Ann-katrin.Johansson@iko.uib.no)
- Professor Ridwaan Omar phone: 00965 249836765, e-mail: [romar.k@hsc.edu.kw](mailto:romar.k@hsc.edu.kw)

The study is conducted by Dr. Amin Al-Ashtal, Faculty of Medicine and Dentistry, Department of Clinical Dentistry, University of Bergen, Norway in collaboration with the Faculty of dentistry at University of Science and Technology and center for international health at the Faculty of medicine and dentistry at University of Bergen.

## **Informed Consent (for children)**

### **Consent statement**

I have read the information and understand that participation is voluntary and that I can withdraw my child at any time without giving any reason. I agree that my child participate in the study and if he/she has acid erosion of teeth, I wish him/her to be treated.

Name:..... Date:.....

Signature:.....

## **Informed Consent (for adolescents)**

### **Consent statement**

I have read the information and understand that participation is voluntary and that I can withdraw myself at any time without giving any reason. I agree to participate in the study and if I have acid erosion of teeth, I wish to have treatment.

Name:..... Date:.....

Signature:.....

## Appendix 7 – Informed consent (Arabic translation) - (Papers I & II)

### دعوه للمشاركة في بحث علمي

هذه دعوه للمشاركة في بحث علمي عن التآكل الحمضي للأسنان – ما هو معدل حدوثه؟

نود أن نجد إجابات لهذا السؤال وذلك بالقيام ببحث علمي بين مجموعه من الأطفال والبالغين اليمنيين.

سبب التآكل الحمضي للأسنان هو استهلاك المشروبات الغازية والعصائر أو الارتجاع الحمضي المصاحب لسوء الهضم. ليس من السهل دائما العثور على أسباب محددة لهذا الضرر الحمضي على الأسنان. بالطبع قد يكون بعض الناس أكثر عرضه للأصابة بهذا الضرر في أسنانهم حتى لو كان معدل استهلاكهم للمشروبات الحمضية طبيعياً.

الهدف من هذه الدراسة هو تحديد عدد الناس الذين لديهم هذا التآكل الحمضي ومعرفة العوامل المساعدة على حدوثه.

نود أن نستخدم وننشر علمياً نتائج هذه الدراسة بدون ذكر أسماء المشاركين فيها.

سوف يتم فحص أسنانك بنفس الطريقة المعتادة سابقاً لفحص الأسنان. وسوف يطلب منك الإجابة على بعض الأسئلة عن التغذية والعادات الغذائية وعن استهلاك بعض المشروبات وقد يتم أخذ صور لأسنانك إذا كان ذلك ضرورياً. سوف يستغرق الإجراء بأكمله 15-20 دقيقة اضافية لإكماله.

المعلومات التي سوف يتم جمعها هي إجاباتك على أسئلة الاستبيان وصورة الأسنان و نتائج الفحص السني. سوف يتم التعامل مع هذه المعلومات بشكل سري.

في حال تم تشخيص وجود تآكل حمضي في أسنانك , سوف يعرض عليك علاج مجاني ونصائح وقائية مجانية.

الحصول على معلومات حول معدل انتشار التآكل الحمضي للأسنان والعوامل المؤثرة عليه سوف يساعد الجهات الصحية على تنفيذ برامج وقائية فعالة وعلى الحد من نسبة حدوث التآكل الحمضي للأسنان في المجتمع.

المشاركة في هذه الدراسة اختياري ويمكنك الانسحاب في أي وقت بدون ذكر أسباب وسوف تحصل على نفس العلاج الذي يقدم لغير المشاركين في هذه الدراسة.

إذا أردت المشاركة يرجى الموافقة على ذلك كتابياً.

هذا المشروع البحثي تم إقراره من (اللجنة الإقليمية لأخلاقيات الأبحاث الطبية والصحية بالنرويج ومن لجنة أخلاقيات البحث العلمي بجامعة العلوم والتكنولوجيا باليمن)

سوف يتم نقل معلومات الفحص السريري إلى استمارة فحص وسيتم استبدال الاسم برقم. نفس الرقم سوف يتم استخدامه في الاستبيان. هذه المعلومات سوف يتم تحليلها وحفظها بشكل سري في كلية طب الأسنان- جامعة بيرجن بالنرويج حيث سيتم تحليل البيانات.

إذا كان لديك أي استفسارات حول هذه الدراسة يمكنك التواصل مع:

- د. أمين الأشطل تلفون: 711437126 , إيميل: [aminashtal19@gmail.com](mailto:aminashtal19@gmail.com)
- أ.د. آن كاترين يوهانسون تلفون: 004755586699 , إيميل: [Ann-katrin.Johansson@iko.uib.no](mailto:Ann-katrin.Johansson@iko.uib.no)
- أ.د. رضوان عمر تلفون: 00965 2498 36765 , إيميل: [romar.k@hsc.edu.kw](mailto:romar.k@hsc.edu.kw)

هذه الدراسة يتم إجرائها في جامعه العلوم والتكنولوجيا بالتعاون مع قسم طب الأسنان السريري ومركز الصحة العالمية في كلية الطب وطب الأسنان بجامعة برجن بالنرويج.

### بيان الموافقة ( الأطفال )

لقد قرأت المعلومات أعلاه وعلمت إن المشاركة اختياريه وانه يمكنني الانسحاب في أي وقت بدون ذكر أي أسباب.  
أنا أوافق على مشاركة ابني/ابنتي في هذه الدراسة وارغب أن يقدم له/ لها العلاج مجاناً إذا تم تشخيص وجود تآكل حمضي في الأسنان.

الاسم..... التاريخ..... التوقيع.....

### بيان الموافقة ( البالغين )

لقد قرأت المعلومات أعلاه وعلمت إن المشاركة اختياريه وانه يمكنني الانسحاب في أي وقت بدون ذكر أي أسباب.  
أنا أوافق على المشاركة في هذه الدراسة وارغب أن يقدم لي العلاج مجاناً إذا تم تشخيص وجود تآكل حمضي في الأسنان.

الاسم..... التاريخ..... التوقيع.....

## **11. Original Papers (I-III)**



**Paper I****Dental erosion in groups of Yemeni children and adolescents and the modification of an erosion partial recording system**

**Amin Al-Ahstal**, Anders Johansson, Ridwaan Omar, Ann-Katrin Johansson

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# Dental erosion in groups of Yemeni children and adolescents and the modification of an erosion partial recording system

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**Background.** The prevalence of dental erosion is rising especially among children and adolescents and its grading needs further investigation.

**Aims.** To determine the prevalence and severity of dental erosion in groups of Yemeni children and adolescents, and to clinically compare an erosion partial recording system (EPRS) with a proposed modified-simplified version (EPRS-M).

**Design.** Of 6163 individuals aged 5–6, 13–14 and 18–19 years, 911 were randomly selected, of which 668 participated in the study. Dental erosion was graded using EPRS. EPRS-M was proposed, and its sensitivity and specificity was calculated in relation to EPRS.

**Results.** Prevalence of erosion extending into dentine on at least one tooth was 6.8% among 5- to 6-year-olds, 3.0% among 13- to 14-year-olds and 14.6% among 18- to 19-year olds. The highest prevalence was 19.2% among girls aged 18–19 years which was significantly higher than boys (10.4%) in the same age group ( $P = 0.044$ ). Sensitivity and specificity for EPRS-M in relation to EPRS were 85.7% and 100% for primary teeth, and 84.1% and 100% for permanent teeth.

**Conclusions.** Dental erosion was common among children and older teenagers and highest among older girls but less common among younger teenagers. The tested accuracy of EPRS-M qualifies it to be used as an initial quick detection tool in future dental erosion research.

## Introduction

The scientific community has given dental erosion greater attention during the last two decades than previously. Studies have shown an association between its occurrence and changes in lifestyle and especially dietary habits<sup>1,2</sup>.

In both developed and developing countries as well as in different age groups, varied prevalence rates of dental erosion have been reported. Among 3- to 6-year-olds, erosive lesions extending into dentine ranged from 1 to 34%<sup>3–5</sup>, and among 12- to 14-year-olds, the range was 1–53%<sup>3,4,6,7</sup>. Studies that recruited older participants aged 18–21 years have reported prevalence rates of erosion into dentine to be 13–22%<sup>4,8</sup>. Thus, dental erosion is not uncommon and dental practitioners who treat children and adolescents would

frequently be expected to deal with dental erosion cases in their clinical practice.

While a clear majority of these studies reported higher prevalence of dental erosion among boys<sup>3,6,8</sup>, some studies found the prevalence to be greater among girls<sup>5,9</sup>. On the other hand, a study conducted in Brazil reported no significant difference in the prevalence of dental erosion between boys and girls aged 15–19 years<sup>10</sup>.

Researchers have applied different indices for grading the severity of dental erosion using both full mouth recording<sup>11</sup> and partial recording utilizing marker teeth<sup>3,4</sup>. In the clinical as well as the research setting, the available time for the clinical examination is often short which necessitates the availability of an easily used and time-efficient method for the assessment of dental erosion.

In spite of improvements in knowledge, much remains unknown or unresolved as regards dental erosion in general. In regard to its occurrence across different regions of the world, information is sparse and there are no previous data about the prevalence of dental erosion from Yemen. In addition, a recent

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study among Yemeni dental professionals and dental students in Sanaa showed that the awareness of dental erosion is low<sup>12</sup>.

Therefore, the aim of this study was to investigate the prevalence and severity of dental erosion in three groups of Yemeni children and adolescents, and to clinically compare an erosion partial recording system (EPRS) with a proposed modified version (EPRS-M). It was hypothesized that dental erosion would be common among children and adolescents and more so among boys, and that a reduced number of erosion marker teeth would reasonably reflect the individual's erosion severity.

### Materials and methods

The study was conducted at the University of Science and Technology – Dental College (UST-DC), Sanaa, Yemen.

#### Selection of subjects

The sampling frame comprised all children and adolescents aged 5–6, 13–14 and 18–19 years who visited UST-DC in the period from September 2012 to June 2013 ( $N = 6163$ ). Sample size calculations were based on simple random sampling and were performed for each age group separately by assuming a prevalence of dental erosion extending into dentine of 15% in the 5- to 6-years and 13- to 14-years age groups and 20% in the 18- to 19-years age group with precision of 0.05 and design effect of 1. The assumed percentages were based on the mean of percentages from other countries that ranged from 1 to 34%<sup>3–6,13–16</sup>, because there is no previous study on erosion from Yemen. Therefore, a minimum number of 196, 196 and 246 individuals were required for the ages 5–6, 13–14 and 18–19 years, respectively. According to the sample size estimation and using a computer, three random samples were drawn comprising 5–6 years ( $n = 280$ ), 13–14 years ( $n = 280$ ) and 18–19 years ( $n = 351$ ) groups, with a total of 911 individuals. The parents of enrolled children and the adolescents were contacted by phone and invited to come for a check-up

appointment and participate in the study. A total of 668 accepted to participate with 51.6% being males. Of those, 206 children were in the 5- to 6-years age group, 202 in the 13- to 14-years age group and 260 in the 18- to 19-years age group. Those who accepted to participate were scheduled for clinical examination during the period from October 2013 to June 2014.

#### Clinical examination and calibration

All clinical examinations were conducted by the principal investigator (AA). Calibration for dental erosion was carried out before the start of the study with a more experienced researcher (AKJ) and consisted of in-office three repeated examinations of 95 dental casts followed by clinical examinations of children and adolescents ( $n = 37$ ) at the Department of Clinical Dentistry, University of Bergen and UST-DC. Intra-examiner agreement for AA and inter-examiner agreement between AA and AKJ were tested at tooth surface level after performing two successive blind assessments with an interval of 3 weeks on 23 randomly selected casts with a total of 368 tooth surfaces.

#### Assessment of dental erosion on anterior and posterior teeth

Clinical examination was performed in a modern, standard dental clinical setting. Dental erosion was graded first with a partial recording system on the buccal and palatal surfaces of all maxillary anterior teeth, (13–23 or 53–63, totally 12 tooth surfaces) using the scale of Johansson *et al.*<sup>13</sup> (Table 1). Dental erosion was then graded on occlusal surfaces/cupings of all first permanent molars or all primary molars, totally four permanent or eight primary tooth surfaces, using the scale of Hasselkvist *et al.*<sup>4</sup> (Table 2).

#### Dental erosion by the EPRS

The two scales on anterior and posterior teeth (Tables 1 and 2) were combined into one scale according to Hasselkvist *et al.* (2016)<sup>17</sup> (Table 3) to form the 'EPRS' and technically

**Table 1. Ordinal scale for grading severity of dental erosion on buccal and palatal surfaces of maxillary anterior teeth<sup>13</sup>.**

Grade	Criteria
0	No visible changes, developmental structures remain, macro-morphology intact
1	Smoothed enamel. Developing structures have vanished completely or partially. Enamel surface is shiny, matt, irregular, 'melted', rounded or flat. Macro-morphology generally intact
2	Enamel surface as described in grade 1. Macro-morphology clearly changed. Faceting or concavity formation within the enamel. No dentinal exposure
3	Enamel surface as described in grades 1 and 2. Macro-morphology greatly changed (close to dentinal exposure of large surfaces) or dentin surface exposed by $\leq 1/3$
4	Enamel surface as described in grades 1, 2 and 3. Dentin surface exposed by $>1/3$ or pulp visible through the dentine

Approximal erosion and presence of 'shoulder' should be recorded.

**Table 2. Ordinal scale for grading cuppings on occlusal surfaces of first permanent molars and all primary molars<sup>4</sup>.**

Grade	Criteria
0	No cupping/intact cusp tip
1	Rounded cusp tip*
2	Cupping $\leq 1$ mm
3	Cupping $> 1$ mm
4	Fused cuppings: at least two cuppings are fused together on the same tooth

\*Changed morphology compared to the assumed original anatomy at the time of eruption.

using the same clinical registrations as above. In this system, the highest recorded grade for erosion on maxillary anterior teeth and cuppings on molars was used to classify the cases into: no erosion (grade 0); mild erosion (grade 1); moderate erosion (grade 2); severe erosion (grade 3); and very severe erosion (grade 4) (Table 3). The marker teeth surfaces used in EPRS include buccal and palatal surfaces of maxillary anterior teeth (tooth number 13–23 or 53–63) and occlusal surfaces of molars (tooth number 16, 26, 36, 46 or 54, 55, 64, 65, 74, 75, 84, 85) which comprise 16 permanent and 20 primary teeth surfaces, respectively. According to this system, a case would, for example, be classified as having severe erosion (grade 3) if the maximum recorded erosion grade on all maxillary anterior teeth or cupping grade on molars was 3 with the rest of recordings being 3 or less.

#### *Dental erosion by the modified erosion partial recording system*

The modified erosion partial recording system (EPRS-M) is proposed in this article as a further simplification of EPRS and utilizes the same erosion scale (Table 3) but on different marker teeth surfaces. EPRS-M was calculated using the earlier recorded clinical erosion registrations. In the permanent dentition, EPRS-M utilizes the highest grade recorded from the buccal and palatal surfaces of

**Table 3. The scale of the 'erosion partial recording system' (EPRS) on the anterior and posterior teeth<sup>17</sup>.**

Grade	Severity	Teeth	Criteria
0	No erosion	Anterior teeth Molars	No visible changes, developmental structures remain, macro-morphology intact No cupping/intact cusp tip
1	Mild erosion	Anterior teeth Molars	Smoothed enamel. Developing structures have vanished completely or partially. Enamel surface is shiny, matt, irregular, 'melted', rounded or flat. Macro-morphology generally intact Rounded cusp tip*
2	Moderate erosion	Anterior teeth Molars	Enamel surface as described in grade 1. Macro-morphology clearly changed. Faceting or concavity formation within the enamel. No dentinal exposure Cupping $\leq 1$ mm
3	Severe erosion	Anterior teeth Molars	Enamel surface as described in grades 1 and 2. Macro-morphology greatly changed (close to dentinal exposure of large surfaces) or dentin surface exposed by $\leq 1/3$ Cupping $> 1$ mm
4	Very severe erosion	Anterior teeth Molars	Enamel surface as described in grades 1, 2 and 3. Dentin surface exposed by $>1/3$ or pulp visible through the dentine Fused cuppings: at least two cuppings are fused together on the same tooth

\*Changed morphology compared to the assumed original anatomy at the time of eruption.

maxillary central incisors and the occlusal surfaces of mandibular first molars (tooth number 11, 21, 36, 46), thus in total six surfaces. On primary teeth, EPRS-M utilizes the highest grade recorded on the buccal and palatal surfaces of maxillary central incisors and all first molars (tooth number 51, 61, 54, 64, 74 and 84), in total eight surfaces.

In all erosion registrations, tooth surfaces that were clinically impossible to grade, for example missing or with large restorations/caries, were excluded. After clinical examination, the results of the oral health examination were conveyed to the parent/participant and any necessary preventive advice was given. Necessary further treatment was provided free of charge by scheduling the participant for another appointment.

#### *Ethical considerations*

The study protocol was approved by the Regional Committee for Medical and Health Research Ethics, Western Norway (Ref. 2013/981/REK Vest) and the Research Ethical Committee at the Faculty of Dentistry, UST in Yemen (Ref. 10/2013). Participation in the study was voluntary and without any compensation. An informed consent was signed by all participants or their parents/guardians before conducting the study.

#### *Statistical analysis*

The study data were analyzed using SPSS version 22 (IBM Corporation, Armonk, NY, USA). Response rates and gender distribution were calculated. Inter- and intra-examiner concordances between the researchers were tested by percentage agreement and Cohen's kappa. Descriptive statistics were conducted to assess percentage distribution of recorded dental erosion grades. Chi-square test was used to compare between groups. Spearman's correlation was used to assess the correlation between the severity of erosion and other variables. McNemar's test was used to compare between prevalence of advanced erosive lesions obtained by EPRS and EPRS-M. Statistical significance was set at  $P < 0.05$ .

The 'EPRS' (Table 3) was used to determine the prevalence of severe/very severe dental erosion at the individual level and at surface level. EPRS-M, which is proposed as a simplification of the above-mentioned EPRS, was calculated. Sensitivity and specificity of EPRS-M were calculated by cross-tabulation in relation to the EPRS.

#### **Results**

The overall participation rate in the study was 73.3% (668/911 individuals). The dropout was 243 individuals and for the following reasons: did not show up for their appointment ( $n = 63$ ), being sick ( $n = 9$ ), time constraints ( $n = 102$ ), not signing the consent ( $n = 45$ ), was away on travel ( $n = 24$ ).

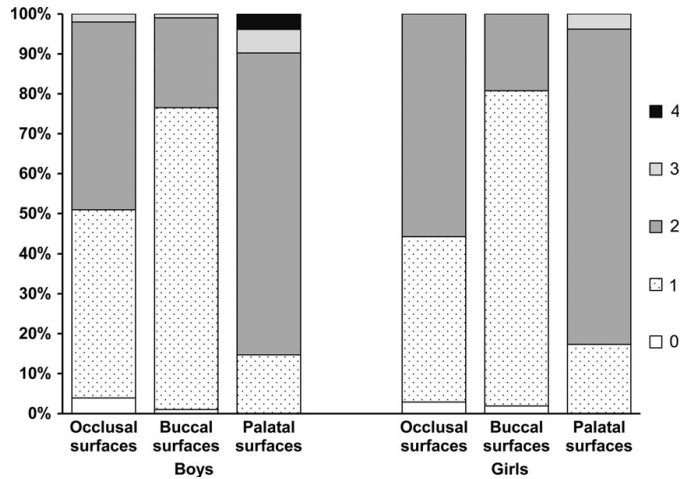
Intra-examiner concordance and Cohen's kappa for all examined tooth surfaces during the calibration were 81.7% and 0.70%, respectively. The inter-examiner concordance and corresponding Cohen's kappa were 76.4% and 0.66%, respectively. The deviations in all cases of disagreement were one scale unit except in one case where it was two scale units. The disagreements were only in mild and moderate enamel erosion (grades 1 and 2).

#### *Clinical examination*

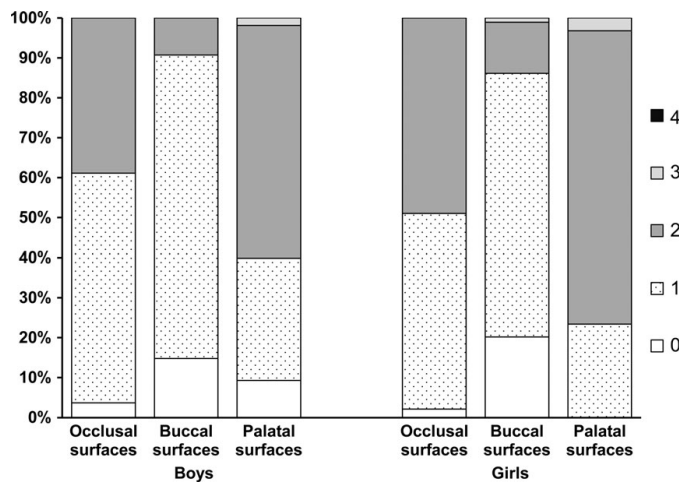
*Dental erosion on anterior and posterior teeth.* The percentage distribution of erosion grades on all buccal and palatal surfaces of maxillary anterior teeth in the three age groups are illustrated in Figs 1–3. In all three groups, the palatal surfaces of anterior teeth were the only surfaces affected by very severe erosion (grade 4), while severe erosion (grade 3) was the highest grade seen on the buccal surfaces of maxillary anterior teeth (Table 3).

Distribution of cuppings on occlusal surfaces of first permanent molars and all primary molars in all age groups is shown in Figs 1–3. The highest cupping grade found in all age groups was grade 3 (severe erosion) (Table 3). There was a statistically significant but weak positive correlation between the mean erosion grade on maxillary anterior

**Fig. 1.** Percentage distribution of the erosion grades (Table 1) on buccal and palatal surfaces of primary maxillary anterior teeth and occlusal surfaces of primary molars (Table 2) among boys and girls in the 5- to 6-years age group ( $n = 206$ ).



**Fig. 2.** Percentage distribution of the erosion grades (Table 1) on buccal and palatal surfaces of permanent maxillary anterior teeth and occlusal surfaces of permanent first molars (Table 2) among boys and girls in the 13- to 14-years age group ( $n = 202$ ).



teeth and mean cuppings grade on primary molars ( $r = 0.14$ ,  $P = 0.039$ ) in the 5- to 6-years age group, but not so with the permanent molars in the 13- to 14-years and 18- to 19-years age groups.

**Dental erosion by EPRS.** Using EPRS, the prevalence of advanced erosive lesions (severe and very severe erosion; grades 3 and 4) (Table 3) at the individual level among all participants was 8.7%, while at the level of age groups it was 6.8% among 5- to 6-year-olds, 3.0% among 13- to 14-year-olds and

14.6% among 18- to 19-year-olds. The distribution of erosion grades among boys and girls separately in the three age groups is illustrated in Fig. 4. Girls in the 18- to 19-years age group had the highest prevalence of advanced erosive lesions according to EPRS (19.2%, Fig. 4), and this was significantly higher than in boys (10.4%) in the same age group ( $P = 0.044$ ). There were no significant differences between boys and girls in the prevalence of advanced erosive lesions in the 5- to 6-years and 13- to 14-years age groups. The prevalence of mild and moderate erosion,

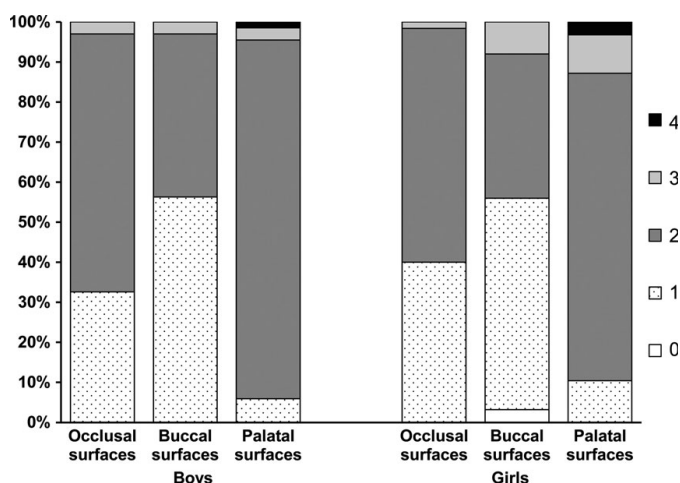


Fig. 3. Percentage distribution of the erosion grades (Table 1) on buccal and lingual surfaces of permanent maxillary anterior teeth and occlusal surfaces of permanent first molars (Table 2) among boys and girls in the 18- to 19-years age group ( $n = 260$ ).

that is within enamel (grades 1 and 2; Table 3; Fig. 4), was at individual level among all participants 91.3%, while at the level of age groups it was 93.2% among 5- to 6-year-olds, 97.0% among 13- to 14-year-olds and 85.4% among 18- to 19-year-olds.

At surface level, of all erosion graded teeth surfaces ( $n = 11,372$ ), there were 2040 surfaces (17.9%) with grade 0 erosion, 6077 surfaces (53.4%) with grade 1 erosion, 3091 surfaces (27.2%) with grade 2 erosion, 136 surfaces (1.2%) with grade 3 erosion and 28 surfaces (0.25%) with grade 4 erosion.

**Dental erosion by EPRS-M.** In addition to calculation of the prevalence of advanced erosive lesions by EPRS, the prevalence was also calculated by EPRS-M for the purpose of comparison. Using EPRS-M, the overall prevalence of severe/very severe erosion was 7.3%, while at the level of age groups it was 5.8% among 5- to 6-year-olds, 3% among 13- to 14-year-olds and 11.9% among 18- to 19-year-olds. The distribution of erosion grades among boys and girls separately in the three age groups by EPRS-M is illustrated in Fig. 5. A comparison between the prevalence figures of advanced erosive lesions obtained by EPRS and those obtained by EPRS-M is presented in Table 4. There were no significant differences between

prevalence figures obtained by EPRS and EPRS-M among boys and girls in the three age groups (Table 4). Sensitivity and specificity of EPRS-M in predicting prevalence of severe/very severe erosion in relation to EPRS were 85.7% and 100% for primary teeth, and 84.1% and 100% for permanent teeth.

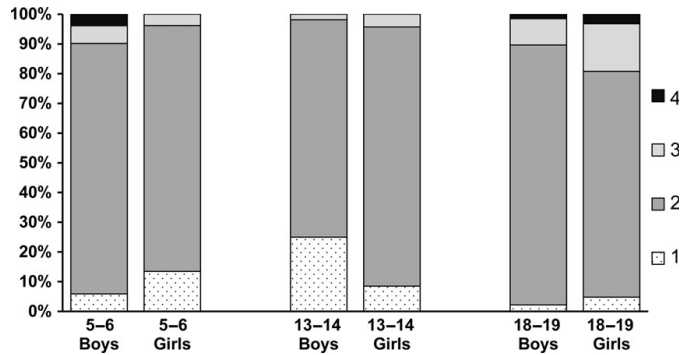
## Discussion

This is the first study that investigated the occurrence of dental erosion among three groups of Yemeni children and adolescents. In addition, the accuracy of the proposed EPRS-M was clinically tested in comparison with EPRS.

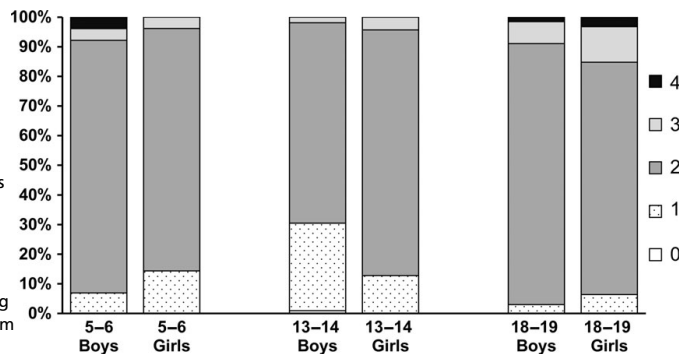
Dental erosion was graded using an EPRS<sup>17</sup> which is a combination of two scales<sup>4,13</sup>. These scales enable the detection of dental erosion changes at an early stage and have been successfully used in previous studies<sup>4,13,17-19</sup>. Partial recording was preferred over full-mouth recording because these teeth have been shown to be good markers and most consistently affected by dental erosion in previous studies<sup>4,13,20-22</sup>. In addition, the partial recording enables efficient use of time.

The study was mainly concerned with the prevalence of advanced dental erosion extending into dentine (grades 3 and 4). This is because at these levels dental erosion might be

**Fig. 4.** Percentage distribution of the combined recorded erosion grades on the marker teeth/surfaces including buccal and palatal surfaces of maxillary anterior teeth (tooth numbers 13–23 or 53–63) and cuppings on occlusal surfaces of all first permanent molars and all primary molars among boys and girls in the three age groups ( $n = 668$ ) according to erosion partial recording system (EPRS) (Table 3).



**Fig. 5.** Percentage distribution of the combined recorded erosion grades on the marker teeth/surfaces including buccal and palatal surfaces of maxillary central incisors (tooth numbers 11,21) and cuppings on occlusal surfaces of mandibular first permanent molars and all primary first molars (Table 3) among boys and girls in the three age groups ( $n = 668$ ) according to modified erosion partial recording system (EPRS-M).



**Table 4.** Comparison between prevalence figures of advanced erosive lesions at individual level obtained by EPRS and EPRS-M among boys and girls in the three age groups.

Age (years)	Gender	EPRS (%)	EPRS-M (%)	P-value
5-6	Boys	9.8	7.8	0.50
	Girls	3.8	3.8	1.0
13-14	Boys	1.9	1.9	1.0
	Girls	4.3	4.3	1.0
18-19	Boys	10.4	8.9	0.50
	Girls	19.2	15.2	0.063

EPRS, erosion partial recording system; EPRS-M, modified erosion partial recording system.

considered pathological in children and adolescents and often begins to cause aesthetic concerns or clinical symptoms while the lower grades might be considered physiological<sup>23</sup>; indeed, these lower grades were present in the majority of participants on at least one tooth surface. In addition, grading of dental erosion extending into dentine (grades 3 and 4) was

found to be more accurate during the grading calibration than the lower grades. Not surprisingly, the few intra-examiner and inter-examiner disagreements that occurred were confined to the enamel erosion (grades 1 and 2).

In this study, advanced erosive lesions were common especially among 5- to 6-year children and 18- to 19-year adolescents, although the prevalence rates of such lesions were lower than those found in previous reports, with prevalence figures of erosive lesions extending into dentine ranging from 16–51% in neighbouring countries such as Jordan and Saudi Arabia<sup>3,13,24</sup> and from 13–32% in western countries such as Sweden and Norway<sup>4,21</sup>. In the countries mentioned, dental erosion has been associated with a modern lifestyle and a high consumption of soft drinks. However, a modern lifestyle has only more recently arrived in Yemen and carbonated soft drink consumption is not yet popular. In addition, the struggling economic situation in Yemen

might result in limited consumption of carbonated soft drinks in comparison with other countries<sup>25</sup>.

Dental erosion has been reported to be higher among boys in some studies<sup>11,19</sup>, while others reported higher prevalence among girls<sup>9,26</sup>. In contrast, no significant differences were found between boys and girls regarding the prevalence of dental erosion in some reports<sup>10,27</sup>. In our study, girls had significantly higher prevalence than boys only in the 18- to 19-year age group while no significant differences were found between boys and girls in the two younger age groups. This might indicate higher acidic diet consumption among girls in the older age group.

In previous studies, cuppings on occlusal surfaces of molars were correlated with the severity of dental erosion on maxillary anterior teeth and were suggested to be markers for the onset of dental erosion<sup>4,28</sup>. The present study confirmed this significant correlation but in the primary dentition only. In addition, the palatal surfaces of maxillary anterior teeth were found to be the only surfaces affected by very severe dental erosion which is in agreement with previous reports<sup>6,13,29</sup>. The reason for this localization of the most severe erosive damage has also been discussed earlier, and several factors were found to be involved including, for example, the pellicle layer which was found to be thinnest on the palatal surfaces of maxillary anterior teeth<sup>18,30</sup>. In addition, previous report has suggested that the tongue has an abrasive effect on the palatal surfaces which, in combination with the erosive components such as acidic drinks and various other acidic dietary items that are in close proximity intraorally to the palatal surfaces of teeth, may form an increased erosive potential in comparison with other sites in the oral cavity<sup>30</sup>.

In an attempt to provide an easy and time-saving method for the assessment of dental erosion in future research, the EPRS-M was proposed in this article and was clinically evaluated in relation to the erosion partial recording system (EPRS)<sup>17</sup>. Both EPRS and EPRS-M utilize the same erosion grading scale, although EPRS-M requires the examination of much fewer marker teeth and thus would be greatly time-saving. At the same

time, EPRS-M had reasonably high sensitivity and specificity in the detection of advanced erosive lesions and resulted in prevalence figures of no significant difference in comparison with EPRS. This could be attributed to the fact that the teeth surfaces proposed in EPRS-M are the most consistently affected by dental erosion and thus serves as marker surfaces for more severe erosive damage.

In a previous study, another modification of EPRS was proposed, namely the simplified erosion partial recording (SEPRS)<sup>4</sup>, which did not include the buccal surfaces of maxillary anterior teeth in the examined marker teeth. SEPRS had very high sensitivity and specificity in relation to EPRS in a Swedish population. Nevertheless, SEPRS did not produce the same high sensitivity and specificity on the Yemeni population in this study, which was due to a different prevailing location of erosive wear lesions, with buccal surfaces of maxillary anterior teeth being more often affected than in the Swedish sample. Therefore, a different modification of EPRS that produce reasonably higher sensitivity and specificity in relation to EPRS was needed.

In this context, it was found that the modification of EPRS to EPRS-M provided a useful alternative for the detection of advanced erosive lesions using the same erosion scale but utilizing fewer marker teeth and surfaces in the grading system. EPRS-M had the added benefit of being reliable as a quick erosion detection tool in future dental erosion research. However, it is suggested that EPRS-M be applied as an initial detection tool and that recording of additional marker teeth be considered whenever erosive damage is detected. Both EPRS and EPRS-M could be similarly used by paediatric dentists as simple and quick tools for grading of dental erosion among children and adolescents.

The results of this study provide reference data and confirm the common occurrence of dental erosion among the children and older teenagers examined; the occurrence of erosion among younger teenagers was less common. The tested accuracy of the EPRS-M qualifies it to be used as an initial quick detection tool in future dental erosion research, especially for epidemiological studies



where time efficiency in the clinical examination is a basic requirement and a cornerstone for their successful conduct.

The major limitation of this study is that selection of participants was performed in a population who attended only one dental hospital located in Sanaa city at UST-DC. However, UST-DC is the largest dental care provider in Yemen and offers free of charge dental care to children and adolescents which makes it the preferred choice for most people from all socio-economic levels. Therefore, although we consider the population attending UST-DC to be relatively representative for children and adolescents in Sanaa as a whole and probably Yemen also, we agree that some selection bias cannot be excluded. Indeed, it would have been preferable to use schools from different parts of Sanaa as the sampling frame but for several practical and cultural reasons this was not possible.

It is recommended to conduct further population-based dental erosion studies in Sanaa and other places in Yemen. In addition, it seems necessary to initiate planning for dental erosion preventive programmes in the Yemeni community and to conduct future studies that test their effectiveness. Generally, there is also need for a universally accepted dental erosion grading system that could be used both in research and clinic. The system used in this study could form a basis for such a development.

#### Why this paper is important to paediatric dentists

- The paper adds knowledge and understanding about the occurrence and distribution of dental erosive lesions among children and adolescents, who are commonly examined by paediatric dentists.
- The paper presents a user-friendly, clinically-relevant erosion scale and system for grading of dental erosion according to two partial recording systems (EPRS and EPRS-M) that could equally be used by paediatric dentists for quick and reliable grading of dental erosion among both children and adolescents.

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#### Conflict of interest

The authors declare no conflict of interest.

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## Paper III

### **Awareness and knowledge of dental erosion among Yemeni dental professionals and students**

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RESEARCH ARTICLE

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# Awareness and knowledge of dental erosion among Yemeni dental professionals and students

Amin Al-Ashtal<sup>1\*</sup>, Anders Johansson<sup>2</sup>, Ridwaan Omar<sup>3</sup> and Ann-Katrin Johansson<sup>1</sup>

## Abstract

**Background:** This study explored Yemeni dentists' and dental students' knowledge about the associated factors, approaches to diagnosis and preventive methods of dental erosion (DE), as well as any associations between DE awareness and some potentially related variables.

**Methods:** A self-administered questionnaire was distributed to general dental practitioners ( $n = 323$ ) in Sanaa and to fifth year dental students ( $n = 97$ ) at the University of Science and Technology, Sanaa, Yemen during the period from July to November 2013. Descriptive and logistic regression analyses were conducted.

**Results:** Overall response rate was 79 %. Results indicated that 61 % of respondents learned about DE from dental school, 27 % from their own studies and the rest from continuing education courses and the media. DE was reportedly most frequently seen on incisors by 46 % of respondents and on premolars and molars by 24 %. While 48 % reported DE to be more common in male patients, no gender differences were reported by 20 % of respondents. Acidic drinks were believed to be causative factors for DE by 41 % of dentists and 52 % of students, while 90 % of respondents believed that patients' dietary history is important during DE diagnosis. As preventive measures for DE, reduction of acidic drink consumption was advised by 51 % of respondents while only 37 % advised their patients to use fluoridated toothpastes. Younger respondents ( $\leq 35$  years) were more likely to identify the commonly-known causative factors for DE ( $P = 0.024$ ). Twenty-seven percent of the respondents reportedly used an index to grade DE. Dental students were more likely than dentists to use such an index ( $P < 0.001$ ) and to more frequently advise their patients to reduce intake of acidic drinks ( $P = 0.02$ ) compared to dentists.

**Conclusions:** In-depth knowledge about causative factors, diagnosis and preventive methods of DE was apparent among only half the respondents and approaches to early diagnosis were insufficient. There would appear to be an urgent need for enhancing awareness and knowledge about DE within the Yemeni dental community.

**Keywords:** Awareness, Dental erosion, Dental students, Dentists, Knowledge, Yemen

## Background

Dental erosion has gained considerable attention from researchers during the last two decades [1, 2]. A high, but often varying, prevalence of dental erosive lesions has been reported especially in young populations [3–9]. Today, it is well-established that dental erosion is an oral health problem with a multifactorial background [1, 10]. It is important that dental professionals are able to diagnose the condition as early as possible, to identify the possible etiology of the erosive damage and also to

understand the specific host defense factors of importance in each case. All this requires a careful and systematic evaluation of each patient by the dental professional, and particularly one who has a sufficiently good knowledge about tooth wear in general and about erosion specifically. In this regard, reports from Brazil and the United Kingdom showed that awareness of dental erosion among dental professionals was inadequate [11, 12].

Clinical diagnosis of dental erosion is considered difficult for dental practitioners [13–15]. This is further complicated by the fact that the condition is not well-known in the community [16] and most patients do not seek treatment for erosive lesions until the condition is at an advanced stage, when symptoms such as hypersensitivity

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or a perceived need for restorative therapy prompt the patient to seek treatment [17]. At the same time, there is clear evidence that an erosive process on a tooth will continue if the actual risk factors/behaviors persist and adequate preventive measures are not carried out [18]. Therefore, it is important to identify patients with dental erosion as early as possible. The diagnosis of dental erosion should also include the grading of its severity and if possible an assessment of its progression based on an evaluation of risk factors and behaviors present in each patient [18].

Early diagnosis of dental erosion depends mainly on the ability of the clinician to detect its pathognomonic features in enamel. However, a study conducted in a Brazilian dental school in 2011 showed that knowledge about dental erosion was not widely evident among students, patients and faculty members [12]. Of the 300 participants enrolled in the study, about a quarter of faculty members and over 60 % of dental students considered themselves unprepared to diagnose dental erosion. In other studies, patients were only occasionally or rarely advised by their dentists about any presence of dental erosion [11, 19].

For the previous reasons and since no information on the subject is currently available about Yemeni dental professionals, this study aimed to explore awareness and knowledge about dental erosion among a group of Yemeni dentists and dental students, and to assess associations between dental erosion awareness and some potentially related variables.

## Methods

This cross-sectional study was carried out in Sanaa, the capital of Yemen, with a population of nearly two million.

### Sample

Contact information of all members of the Yemeni Dental Association based in Sanaa was obtained from the Association, which included dental practitioners working in the government sector ( $n = 86$ ) and in private dental clinics ( $n = 237$ ). Another list of all enrolled dental students ( $n = 97$ ) in year five (final year) was obtained from the Dental College administration at the University of Science and Technology (UST). These comprised a total of 420 and were all invited to participate in the study during the period from July to November 2013.

### Questionnaire

The questionnaire was developed in English (Additional file 1). It comprised four parts and contained 20 close-ended questions. The first part inquired about demographic information including sex, age, nationality, work sector, and for dentists, their date and place of graduation. The second part included questions about

participants' knowledge about dental erosion including its common clinical features and distribution among males and females. The third part enquired about dentists' knowledge about dental erosion diagnosis, perceived etiological factors, and its clinical features. The last part of the questionnaire explored the preferred and applied dental erosion preventive methods used by participants.

The questionnaire was personally distributed to and collected from all participants by the principal investigator (AA). The aim of the study was explained to all invited participants and they were informed that participation in the study was voluntary and that return of the questionnaire was considered acceptance to participate. Participants who failed to return the questionnaire received two phone reminders after two and four weeks before they were reported as non-respondents.

### Pilot study

Prior to the start of the study, the questionnaire was piloted with ten Yemeni dentists and modified as needed.

### Statistical analysis

Data were analyzed using SPSS version 20.0 (IBM Corporation, Armonk, NY, USA). Response rates and gender distribution were calculated. Descriptive statistics were conducted to assess frequencies of answers in each part of the questionnaire relating to the level of awareness and knowledge of dental erosion. Logistic regression analysis was performed to examine possible associations between answers to questions on acidic drinks, systemic diseases and dental erosion preventive methods (dependent variables) and selected independent variables that included sex, age, nationality, country of graduation, type of participant (dentist or student), and referrals of erosion cases. Unadjusted (crude) odds ratios were calculated by conducting a separate logistic regression analysis for each selected variable. Then, a logistic regression analysis model was constructed by including all selected variables in the model to obtain adjusted odds ratios. Logistic regression models were constructed first for the whole sample, then for dentists and students separately. The results of possible associations were presented as OR (95 % CI) and  $P$  values. Statistical significance was set at  $P < 0.05$ .

### Ethical considerations

The study protocol was approved by the Regional Committee for Medical and Health Research Ethics, Western Norway (Ref. 2013/981/REK Vest) and the Research Ethical Committee at the Faculty of Dentistry, University of Science and Technology in Yemen (Ref. 10/2013). Participation in the study was voluntary and without any compensation to respondents. Verbal consent was obtained from all participants. In addition, participants

were informed that filling and return of the questionnaire would be considered as confirmation of acceptance to participate in the study. To ensure respondents' anonymity, the questionnaire was number coded and identification information such as participant's name or address was not required.

## Results

### Sample and respondents' distribution

Of the total of 420 dentists and dental students invited to participate in the study, 332 agreed to do so and returned their completed questionnaires, giving an overall response rate of 79.0 % (332/420), while 72 dentists and 16 dental students did not return the questionnaire and were considered non-respondents. Group response rates were 77.7 % (251/323) among dentists and 83.6 % (81/97) among dental students. Respondents comprised 75.6 % (251/332) dentists and 24.4 % (81/332) dental students with age range between 21 and 58 years. Sample distribution and demographic data of respondents are shown in Table 1.

### Awareness and knowledge regarding dental erosion

More than half the respondents (60.5 %, 201/332) reported that they learned about dental erosion from dental school, 26.5 % (88/332) from their own studies and the rest from continuing education courses and the media (Table 2). According to participants' opinions, dental erosion cases were seen more commonly in male patients by 48.2 % (160/332) of respondents and in female patients by 29.2 % (97/332), while the rest of the participants reported no gender differences among their patients.

Regarding the location of dental erosion, lesions were believed to be seen most frequently on buccal surfaces of teeth by 51.5 % (171/332) of respondents, on palatal surfaces by 16.3 % (54/332), and equally on all tooth surfaces by the remaining respondents. In terms of tooth type, 46.1 % (153/332) of participants reported that erosive lesions are most frequently found on incisors, 23.8 % (79/332) on premolars and molars, 20.2 % (67/332) equally on all teeth, while 9.9 % (33/332) did not answer the question.

### Knowledge regarding dental erosion causative factors

Forty-one percent (103/251) of dentists and 51.9 % (42/81) of dental students stated that acidic drinks

**Table 2** Distribution of respondents according to their stated source(s) of knowledge about dental erosion

Source of knowledge	Dentists	Students	Total
Dental school	154 (61.4 %)	47 (58.0 %)	201 (60.5 %)
Continuing education	10 (4.0 %)	6 (7.4 %)	16 (4.8 %)
Own studies	63 (25.1 %)	25 (30.9 %)	88 (26.5 %)
Media	0 (0.0 %)	1 (1.2 %)	1 (0.3 %)
Not answered	24 (9.6 %)	2 (2.5 %)	26 (7.8 %)
Total	251 (100 %)	81 (100 %)	332 (100 %)

are causative factors for dental erosion. On the other hand, 11.6 % (29/251) of dentists and 16.0 % (13/81) of dental students believed that bruxism and excessive tooth brushing with a hard toothbrush can cause dental erosion. Adjusted logistic regression analysis showed that younger respondents ( $\leq 35$  years) were more likely to regard acidic drinks as causative factors for dental erosion than older respondents ( $OR = 3.18$ ;  $P = 0.009$ ) (Table 3).

Less than half the dentists and dental students (41.0 % (103/251) and 45.7 % (37/81), respectively) identified systemic diseases such as gastric reflux and eating disorders as causative factors for dental erosion. These factors were significantly more likely to be identified by male than female dental students ( $OR = 3.17$ ;  $P = 0.015$ ), while there was no significant association between sex and knowledge about these causative factors in the dentists group ( $P = 0.26$ ). Furthermore, results from adjusted logistic regression showed that younger participants ( $\leq 35$  years) were significantly more likely to identify

**Table 3** Associations between selected independent variables and knowledge of acidic drinks (dependent variable) as causative factors for dental erosion (logistic regression)

Independent variables	Adjusted OR (95 % CI)	P-value
Sex		
Male	1.42 (0.89 – 2.28)	0.14
Female (Ref.)		
Age		
$\leq 35$ years	<b>3.18 (1.33 – 7.57)</b>	<b>0.009</b>
$\geq 36$ years (Ref.)		
Nationality		
Yemeni	0.82 (0.41 – 1.64)	0.59
Foreign (Ref.)		
University		
Yemeni	0.80 (0.37 – 1.71)	0.57
Foreign (Ref.)		
Referral		
Yes	<b>0.41 (0.20 – 0.82)</b>	<b>0.012</b>
No (Ref.)		

**Table 1** Distribution and demographic data of respondents

Type of participant	N	Males	Females	Mean age	SD
Dentists	251	134 (53.4 %)	117 (46.6 %)	31.2	5.5
Dental students	81	38 (46.9 %)	43 (53.1 %)	23.7	2.3
Total	332	172 (51.8 %)	160 (48.2 %)	29.3	5.9

systemic diseases, such as gastric reflux, as causative factors for dental erosion (OR = 2.7;  $P = 0.024$ ) (Table 4). However, high sugar consumption was reported to contribute to dental erosion by 4.8 % (12/251) of dentists and 4.9 % (4/81) of dental students, while 12.0 % (30/251) of dentists and 19.8 % (16/81) of dental students thought that biting on hard objects such as pens and fingernails can cause dental erosion.

#### Clinical signs of dental erosion

Smoothing of enamel surfaces was recognized as an early clinical sign of dental erosion by 57.0 % (143/251) of dentists and 49.4 % (40/81) of dental students. During the clinical diagnostic process for dental erosion, 21.1 % (53/251) of dentists and 44.4 % (36/81) of dental students preferred to use an index to grade its severity, a difference in usage patterns that was significant (OR = 2.98;  $P < 0.001$ ) (Table 5). Most dentists (75.7 %, 190/251) and students (53.1 %, 43/81), however, relied instead on the general signs of dental erosion without resort to an index during the clinical diagnostic phase.

Most dentists (90.8 %, 228/251) and dental students (85.2 %, 69/81) believed that asking about dietary habits during history taking could help in the diagnosis and treatment-planning phase for dental erosion. There was no significant difference between dentists and dental students regarding this practice ( $P = 0.15$ ).

**Table 4** Associations between selected independent variables and knowledge of systemic diseases (dependent variable) as causative factors for dental erosion (logistic regression)

Independent variables	Adjusted OR (95 % CI)	P-value
Sex		
Male	1.08 (0.68 – 1.72)	0.73
Female (Ref.)		
Age		
≤35 years	<b>2.71 (1.14 – 6.46)</b>	<b>0.024</b>
≥36 years (Ref.)		
Nationality		
Yemeni	0.69 (0.35 – 1.35)	0.28
Foreign (Ref.)		
University		
Yemeni	0.71 (0.33 – 1.52)	0.39
Foreign (Ref.)		
Referral		
Yes	0.78 (0.41 – 1.50)	0.47
No (Ref.)		

#### Dental erosion preventive methods

Reduction of acidic drink consumption was advised by 47.0 % (118/251) of dentists and 61.7 % (50/81) of dental students as a preventive method against progression of dental erosion. Younger respondents (≤35 years) were significantly more likely to give this preventive advice to their patients (OR = 2.9;  $P = 0.012$ ) (Table 6). A small percentage of dentists (5.6 %, 14/251) and dental students (2.5 %, 2/81) believed that taking muscle relaxants would have a preventive role against progression of dental erosion.

The use of fluoridated toothpastes was advised by 37.5 % (94/251) of dentists and 37.0 % (30/81) of dental students as an additional preventive measure against dental erosion, while 10.8 % (27/251) of dentists and 4.9 % (4/81) of dental students advised their patients to wear a night guard to prevent progression of dental erosion. A small percentage of dentists (0.8 %, 2/251) and dental students (8.6 %, 7/81) believed that stopping biting on hard objects would help in the prevention of dental erosion.

#### Treatment of dental erosion

A minority of dentists (27.1 %, 68/251) and dental students (19.8 %, 16/81) preferred to treat all cases of dental erosion themselves, with 58.2 % (146/251) of dentists and 54.3 % (44/81) of dental students preferring to refer severe cases of dental erosion to a specialist. At the same time, dental students (25.9 %, 21/81) were significantly more likely to refer all cases of dental erosion to a specialist than were dentists (11.2 % (28/251)) (OR = 2.78;  $P = 0.002$ ) (Table 5). Furthermore, participants who preferred to refer all cases of dental erosion were significantly less likely to have identified acidic drinks as a causative factor for dental erosion (OR = 0.41;  $P = 0.012$ ) (Table 3).

#### Discussion

What may be considered in-depth knowledge about causative factors, diagnosis, preventive methods, as well as approaches to early diagnosis of dental erosion was found among only half the respondents. Nevertheless, and encouragingly so, most dentists and dental students believed that enquiry about the dietary history of their patients helped in the diagnosis of dental erosion. The majority of participants reported not using an index for grading the severity of dental erosion which arguably could negatively affect the chances of early dental erosion detection, progression recording, and giving appropriate preventive advice.

Our study was conducted in Sanaa, which is the capital of Yemen, with a population of nearly 2 million, and is where most dental professionals from all governorates of the country prefer to work [20]. The number of



**Table 5** Associations between participants' answer choices with respect to various questions about dental erosion (dependent variable) and type of participant (independent variable) (unadjusted logistic regression)

Answer choice	Participant	OR (95 % CI)	P-value
Acidic drinks can cause dental erosion	Dental student	1.54 (0.93 – 2.55)	0.09
	Dentist (Ref.)		
Systemic diseases such as gastric reflux can cause dental erosion	Dental student	1.20 (0.73 – 2.00)	0.46
	Dentist (Ref.)		
Enamel smoothening is the early clinical sign of dental erosion	Dental student	0.73 (0.44 – 1.21)	0.23
	Dentist (Ref.)		
I prefer to use an index to grade the severity of dental erosion	Dental student	<b>2.98 (1.75 – 5.09)</b>	<b>&lt;0.001</b>
	Dentist (Ref.)		
Asking about dietary habits will help in the diagnosis and treatment plan of the case	Dental student	0.58 (0.27 – 1.22)	0.15
	Dentist (Ref.)		
To prevent dental erosion, I advise my patients to reduce acidic drinks consumption	Dental student	<b>1.81 (1.08 – 3.03)</b>	<b>0.022</b>
	Dentist (Ref.)		
Additional preventive methods against dental erosion include the use of fluoridated tooth paste	Dental student	0.98 (0.58 – 1.65)	0.95
	Dentist (Ref.)		
I prefer to refer all cases of dental erosion to a specialist	Dental student	<b>2.78 (1.47 – 5.25)</b>	<b>0.002</b>
	Dentist (Ref.)		

specialists in Sanaa are very few and were excluded from the study, while general dental practitioners working in governmental and private dental clinics were included as they can generally be expected to be diagnosing and treating dental erosion cases regularly [9, 21, 22].

**Table 6** Associations between selected independent variables and the recommendation of acidic drink reduction (dependent variable) as a preventive measure against dental erosion (logistic regression)

Independent variables	Adjusted OR (95 % CI)	P-value
Sex		
Male	0.93 (0.58 – 1.47)	0.77
Female (Ref.)		
Age		
≤35 years	<b>2.92 (1.26 – 6.77)</b>	<b>0.012</b>
≥36 years (Ref.)		
Nationality		
Yemeni	0.81 (0.41 – 1.61)	0.56
Foreign (Ref.)		
University		
Yemeni	0.92 (0.43 – 1.94)	0.83
Foreign (Ref.)		
Referral		
Yes	0.70 (0.37 – 1.32)	0.28
No (Ref.)		

Final year dental students were included as a comparison group as they are likely to have more up-to-date theoretical knowledge of dental erosion compared to dentists, but who in turn have more clinical experience. This also potentially allowed us to gauge the value of continuing education courses for practising dental professionals [23]. The questionnaires were distributed to and collected from all participants in person because the postal system in Sanaa is not reliable and most dentists do not have a postal address.

To ensure a high response rate, several measures were carried out in line with a Cochrane systematic review of questionnaire investigations [24]. Thus, the questionnaire was anonymous, short, developed in English, which is the language of instruction for dental education in Yemen, and included no questions of a sensitive nature. University sponsorship of the study was mentioned together with a brief explanation about the study aims. In addition, two phone reminders after 2 and 4 weeks were given to participants who failed to return the questionnaire, and this increased the response rate [24].

The relatively high response rate achieved in this study was probably in part due to the implementation of the above-mentioned strategies. However, the higher response rate among dental students in comparison with dentists might be attributed to the fact that they are still in an academic environment, in which the importance of research might be more recognized. At the same time, anonymity of the study and lack of information about non-respondents prevented reasonable non-response analysis

from being conducted. Also, dependence on anamnestic information may be considered another limitation [25].

Dental professionals are generally expected to have gained knowledge about dental erosion during their undergraduate dental education. A large number of our dentist respondents, however, seem mainly to have learned about dental erosion from their own studies. This could be attributed either to poor coverage of the subject in their undergraduate curricula, or to a low priority they may have given to the subject as students. Another possibility may be that dental erosion is still not so prevalent in Sanaa or that dental erosion is somewhat overlooked in the clinical setting. Therefore, it is recommended that dental erosion is given more importance in dental education in Sanaa by revising the dental curriculum and adding more emphasis on the subject in order to better address this oral health problem that is increasing worldwide [26].

Frequent consumption of acidic drinks and the presence of systemic diseases such as gastroesophageal reflux disease are well-established risk factors for the development of dental erosion [27–33]. In spite of this, less than half the participants recognized acidic drinks and systemic diseases as factors that can cause dental erosion. This suggests a shortfall in important knowledge among many dental professionals in Sanaa, who would be the main public providers of necessary preventive care and management of dental erosion [34, 35]. Consequently, it is likely that not all dental erosion patients will receive adequate preventive advice from their dentists. This could result in low awareness about dental erosion among patients in Sanaa as was reported in other countries [11].

Smoothening of the enamel surface is considered one of the important early clinical signs in the diagnosis and grading of severity of dental erosion [15, 36–38]. Nevertheless, only about half of the participants recognized this as a characteristic feature of dental erosion in its early stage. Therefore, it is clear that diagnosis and prevention of dental erosion in its early stages might be overlooked by a large proportion of the participants in this study. A similarly low awareness about dental erosion among dental professionals was also reported elsewhere [11].

The use of a grading index is essential for recording the presence, severity and progression of dental erosion in the clinical setting [39]. In addition, the severity of existing dental erosion cases is known to progress steadily [40]. In this study, the majority of respondents did not use such an index. Whether this was due to lack of knowledge about dental erosion indices or the practitioner's choice is unclear from our data, but in any event it might well lead to inadequate diagnosis in the early stages, thus affecting both interventional measures and follow-up of dental erosion patients, with subsequent

unpredictable progression and deterioration. This is in contrast with another study from Norway where it was found that most of the dentists used a grading index during dental erosion diagnosis [41].

Identification of dental erosion etiological factors and subsequent implementation of suitable preventive approaches frequently depend on proper dietary history taking [1]. Encouragingly, the majority of dentists and dental students in this study believed that asking about dietary habits would help in the diagnosis and decision making about treatment of dental erosive lesions. This would likely increase the chances of detecting erosive lesions and identifying their etiological factors.

A correlation between use of muscle relaxants, sugar consumption, biting on hard objects and wearing night guards, on the one hand, and dental erosion prevention, on the other, has not been reported in the literature. Surprisingly, a proportion of participants advised their erosion patients to take some muscle relaxants and to reduce sugar and acidic drink consumption to prevent dental erosion. Moreover, nearly half the respondents advised their patients to stop biting on hard objects, to wear night guards and to brush with fluoridated toothpaste. This could be due to the difficulty encountered in distinguishing between dental attrition, abrasion and erosion [18, 42]. In addition, the majority of participants in a previous study believed that sugar consumption has a role in the development of dental erosion [12] which suggests confusion between dental erosion and dental caries.

Younger respondents were more likely than older respondents to identify acidic drinks and systemic diseases as causative factors for dental erosion, as well as to advise their patients to reduce acidic drinks consumption as a preventive method. Similarly, dental students were more likely than dentists to grade the presence of erosion using an index during the clinical examination. This might be attributed to younger respondents having more current knowledge about dental erosion because of their more recent dental education. At the same time, this may indicate a need for dentists to participate in continuing education courses focused on tooth wear and especially dental erosion. Such courses have started to be available in Sanaa and dental professionals should be encouraged to participate in them actively.

Although many participants could not recognize dental erosion cases at an early stage, they seem to be able to do so in the later stages when the lesions became more apparent or closer to dentinal exposure and thus easier to detect. Indeed the results showed that a large proportion of respondents preferred to treat dental erosion cases themselves and refer only severe cases to a specialist. This may suggest that, while they lack adequate knowledge about detection of early erosion, they have enough knowledge and confidence regarding dental

erosion treatment approaches, and concurs with a previous study conducted in Norway where the majority of dentists preferred to treat their dental erosion patients themselves [41].

Interestingly, dental students were more likely than dentists to refer all dental erosion cases to a specialist. This could be due to their self-perceived insufficient experience in dealing with dental erosion cases compared to their independently practising colleagues.

## Conclusions

Given the limitations and difficulties of collecting information with this type of study, the results suggest that only half of the dental professionals in Sanaa appear to have adequate knowledge about dental erosion in its early stages, its causative factors and preventive methods. In addition, self-perceived knowledge of dental erosion and approaches to its early diagnosis were insufficient among many participants. Not surprisingly, younger participants have better awareness about the causative factors of dental erosion and its preventive methods. In light of these findings, there appears to be an urgent need for improving awareness and education about dental erosion within the Yemeni dental community. This could be achieved by strengthening the subject both during dental education for dental students and in continuing education courses for dental professionals.

## Additional file

**Additional file 1: Questionnaire on awareness and knowledge of dental erosion.** (PDF 218 KB)

## Abbreviations

DE: Dental erosion; UST: University of Science and Technology.

## Competing interests

The authors declare that they have no competing interests.

## Authors' contributions

AA carried out the study design, data collection, data analysis and writing of the article. AJ contributed to the data analysis, study planning, interpretation of the data and writing of the manuscript. RO was involved in the study planning, interpretation of data, writing and review of the manuscript. AKJ was involved in study planning, interpretation of the data, critical review and writing of the manuscript. All authors have read and approved the final manuscript.

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