

Tooth wear and erosion: Methodological issues in epidemiological and public health research and the future research agenda

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Background: This paper addresses methodological issues in the field of tooth wear and erosion research including the epidemiological indices, and identifies future work that is needed to improve knowledge about tooth wear and erosion. **Methods:** The paper is result of the work done at the meetings of the Special Interest Group “Tooth Surface Loss and Erosion” at the 2008, 2009 and 2010 conferences of the European Association for Dental Public Health, and the Workshop “Current Erosion indices- flawed or valid” which took place in Basel in 2007. **Results:** Although there is consensus about the definition and the diagnostic criteria of various forms of tooth wear, gaps in research strategies have been identified. A basic problem is that fundamental concepts of wear and erosion as an oral health problem, have not yet been sufficiently defined. To a certain extent, tooth wear is a physiological condition, and there is no consensus as to whether it can be regarded as a disease. Furthermore, the multitude of indices and flaws in existing indices, make published data difficult to interpret. **Conclusion:** Topics for the research agenda are: the initiation of a consensus process towards an internationally accepted index, and the initiation of data collection on the prevalence of various forms of wear on a population-based level. There should be an emphasis on promoting communication between basic and clinical sciences, and the area of Public Health Dentistry. Furthermore, the question of whether tooth wear is a public health problem remains open for debate.

Key words: tooth wear, erosion, epidemiology

Tooth wear is the loss of dental hard tissue due to various forms of physical and chemical impacts not involving bacteria and excluding trauma. The process is multifactorial (Addy and Shellis, 2006) and includes the effect of exogenous material forced over tooth substances, the impact of tensile and compressive forces during tooth flexure, the action of opposing teeth, and the chemical dissolution of tooth mineral. Considering that the lost tissue cannot regenerate, the wear process is of great clinical significance.

For epidemiological and public health purposes, it is essential to accurately define the condition under study. The clinical criteria of the various forms of tooth wear have been extensively described in the scientific literature tracing back to early case reports published such as that by Robinson (1946) or Stafne and Lovsted (1947). Pindborg (1970) systematically described the different forms of tooth wear in an extensive textbook, which is also the source of an established and often cited definition of dental erosion.

One subject of debate in this field is the fact that except for wedge-shaped defects, where the lesion form is eponymous, the terminology for the various forms of tooth wear refers to the aetiology. It has been argued that without a thorough clinical history, in other words if the condition is only diagnosed by visual examination, a specific aetiology cannot be determined (Fares *et al.*, 2009). Indeed, the current clinical criteria are based on

early case reports and general clinical experience. As an example, the currently accepted clinical criteria for dental erosion refer back to Eccles and Jenkins who gave a detailed and systematic description of lesions occurring in a small group of patients with known exposure to intrinsic or extrinsic acids (Eccles, 1979; Eccles and Jenkins, 1974). However, these criteria have never been systematically validated (Ganss, 2008).

Tooth wear: definition of subforms and clinical diagnostic criteria

Tooth wear as an umbrella term includes various subforms that are the result of the different physical and chemical impacts acting on tooth surfaces. In general, these impacts are classified as follows (Addy and Shellis, 2006; Bartlett and Smith, 2000; Ganss, 2006; Imfeld, 1996; Mair, 2000; Pickles, 2006):

Abrasion: Physical wear as a result of mechanical processes involving foreign substances or objects (two or three body wear).

Attrition: Physical wear as a result of the action of antagonistic teeth with no foreign substances intervening (two body wear).

Abfraction: Physical wear as a result of tensile and compressive forces in the cervical region due to flexing of teeth under occlusal loads, provoking microfractures in enamel and dentine (fatigue wear).

Erosion: Chemical wear as a result of extrinsic or intrinsic acids or chelators acting on plaque-free tooth surfaces.

The morphology and severity of the resulting tooth wear lesions may vary substantially depending on the predominant aetiological factor. Even if reaching the correct diagnosis may be difficult in individual cases, the following subforms and diagnostic criteria of tooth wear are defined (Bartlett and Smith, 2000; Ganss and Lussi, 2006):

Abrasion: The morphological changes due to abrasion can be diffuse or localised depending on the predominant impact. Due to the lower microhardness of dentine, abrasion mainly occurs on exposed root surfaces and on exposed coronal dentine. On occlusal surfaces, abrasion is difficult to distinguish from erosion.

Erosion: At early stages, erosive tooth wear appears as loss of the physiological surface lustre. In more advanced stages changes in the original tooth morphology occur. On smooth surfaces, the convex areas flatten and concavities can develop, the width of which clearly exceeds the depth. Lesions are located coronal to the enamel-cementum junction, with an intact border of enamel along the gingival margin. Occlusal erosion leads to a rounding of the cusps, grooves on the cusps and incisal edges, and restorations rising above the level of the adjacent tooth surfaces. In severe cases the entire occlusal morphology disappears.

Attrition: This form of tooth wear is characterised by antagonistic glossy plane facets with sharp margins that only occur on occluding surfaces. The occluding surfaces match in excursive jaw movements, usually with similar degrees of wear in both arches.

Wedge shaped defects: These defects are typically located at the enamel-cementum junction. Usually, the coronal part of a wedge-shaped defect has a sharp margin that cuts at right angles into the enamel surface, whereas the apical part runs out onto the root surface. In contrast to erosive defects, the depth of these defects clearly exceeds the width.

Epidemiological tools

Within the field of epidemiology, the need to record the presence and severity of a particular clinical diagnosis or finding often requires the use of a grading index. A suitable index should fulfil several requirements. For the operator it must be easy to both learn and use, so that sufficient inter- and intra-examiner reproducibility can be achieved after an acceptable calibration process. Subdivision into further grades must therefore not be too detailed. The findings must be easy for the clinical examiner to pass on to the person registering the wear, which is of particular importance for large-scale examinations or in field studies. For analytical approaches, one may need detailed documentation of findings whereas in large scale field studies a partial recording may be more applicable. In order to keep recorded index data comparable between studies, it would therefore be desirable to have a short and a long version of the same index. Finally, it would be advantageous if an index can be also used on study

casts, for instance for use in longitudinal analytical studies.

Many indices which more or less fulfil the described requirements have been developed all over the world. They vary considerably with respect to scale and grading as well as to the information provided, making comparison of recorded data difficult, if not impossible.

Two main contrasting strategies have been identified (Bardsley, 2008). The first approach intended to present a way of quantifying tooth wear, irrespective of the cause. Indices in this category stem mainly from the Tooth Wear Index (TWI) of Smith and Knight (1984). Essentially, the TWI provides a comprehensive system whereby buccal, cervical, lingual and occlusal/incisal surfaces of all teeth present are scored for wear, irrespective of how it occurred. Several modifications of the TWI have been published (Al-Malik *et al.*, 2001; Chadwick *et al.*, 2004; Donachie and Walls, 1996; Oilo *et al.*, 1987) that mainly use criteria for quantifying the amount of tissue loss expressed as the proportion of the sound tooth surface and as the degree of dentin exposure.

Other approaches intend to focus on subforms of tooth wear diagnosed by defined clinical criteria. Specific indices combine quantitative criteria (severity scores) with qualitative criteria for diagnosis. These erosion indices mainly originate from the index published by Eccles and Jenkins (1979). This index was presented as a comprehensive qualitative index, grading both site of erosion and severity. In essence it includes three classes, the latter with four subclasses with respect to the location of the lesion. The index has been refined or modified mainly with respect to the scoring component, whilst the clinical criteria have remained more or less unchanged. Erosion indices were for instance published by Fares *et al.* (2009), Larsen *et al.* (2000), Linkosalo and Markkanen, (1985), Lussi *et al.* (1991), and O'Sullivan (2000). Another approach has been to use the TWI in combination with the diagnostic criteria for erosion (Nunn *et al.*, 2003). A more recent development is the Basic Erosive Wear Index (BEWE) which is a partial scoring system (Bartlett *et al.*, 2008). In the BEWE index the most severely affected surface in a sextant is recorded and the cumulative score is a measure for the severity of the condition and aims to help guide the clinician in the management of erosive tooth wear.

Less attention has been paid to the indices for wedge-shaped defects (Lussi *et al.*, 1993), while a specific index for abrasion or attrition has not yet been published.

Epidemiological data

Few data exist about the prevalence of tooth wear and their subforms. Of these, most are studies on the prevalence of the condition in children and adolescents and only very few refer to forms of tooth wear in adults. In addition, most studies include small groups and/or are not representative of the general population. As already mentioned, the comparison of already published data is difficult because of the multitude of indices used, and in a number of studies the type of tooth wear is not clearly defined.

Based on the available literature, between 5 and 100% of children and adolescents, and between 76 and 100% of adults have erosive tooth wear (for review see

e.g. Jaeggi and Lussi, 2006; Van't Spijker *et al.*, 2009). Particularly in the primary dentition, erosive wear appears to be relatively prevalent (Al-Majed *et al.*, 2002; Ganss *et al.*, 2001; O'Brien, 1994; Wiegand *et al.*, 2006), and there is some evidence that erosive wear in the primary dentition is predictive for erosive wear in the permanent dentition (Ganss *et al.*, 2001; Harding *et al.*, 2010). Clinical experience indicates that tooth wear is common and many authors suggest that the prevalence of the condition is increasing even though the evidence for that assumption is lacking.

Only very few incidence studies have been published and little information about progression of tooth wear is available. Incidence studies in older children indicate a significant overall increase in erosive lesions from age 11 to age 15 (Dugmore and Rock, 2003; Ganss *et al.*, 2001). However, a study with multiple examinations of a cohort in the same age range revealed that the development of new lesions was not linear but decreased within the examination period (El Aidi *et al.*, 2010). No information about the incidence of the condition in older age groups is available.

Regarding physiological wear, it seems reasonable to assume that tooth surface loss will increase with age due to the various chemical and physical impacts associated with continuous function. The situation is much less clear for pathological levels of wear (Bartlett and Dugmore, 2008). Specific habits and conditions in an individual may cause episodic onset and progression of lesions, that many be followed by periods of arrest. However, in subjects with wear, the number of affected tooth surfaces increases over time (Lussi and Schaffner, 2000) and, once established, lesions may increase in severity (El Aidi *et al.*, 2008).

Main problems identified

Is tooth wear and its subforms an oral disease, and is it a public health problem?

Even though the first detailed indices for tooth wear and erosion were published 30 years ago, there are still many flaws and shortcomings associated with these indices. Tooth wear is a common phenomenon seen in daily clinical practice, but the scientific basis for assessing the impact of the condition on overall oral health at a population-based level is still very limited. This is due to the fact that not only epidemiological indices, but also most notably, fundamental concepts relating to tooth wear have not yet been sufficiently discussed and clarified. The question of when 'tooth wear and its subforms' can be regarded as an oral health problem is therefore still not answered.

Tooth wear and its subforms are listed in the WHO International Statistical Classification of Diseases and Related Health Problems (10th Revision, Version for 2007) which implies that the condition is regarded as an oral disease. Particularly in the UK, the condition has received significant attention as an oral health problem and most of the larger scale prevalence studies originate from the surveys initiated by the National Health Service (Dugmore and Rock, 2003; Dugmore and Rock, 2004; Nunn *et al.*, 2003; O'Brien, 1994; Walker *et al.*, 2000).

Anthropologists, however, consider human tooth wear a normal physiological phenomenon caused by various physical impacts over a life span (Kaifu *et al.*, 2003). Clinical experience suggests that tooth surface loss occurs sooner or later in all individuals. Tooth wear, in its various forms, is therefore considered a common feature in contemporary humans. Unlike caries, which under ideal circumstances should not occur at all, tooth wear should therefore not automatically be regarded as an oral disease. Smith and Knight (1984) made one of the few attempts to distinguish between physiological and pathological wear: "*Tooth wear can be regarded as pathological if the teeth become so worn that they do not function effectively or seriously mar the appearance before they are lost for other causes or the patient dies. The distinction of acceptable and pathological wear at a given age is based upon the prediction of whether the tooth will survive the rate of wear*".

To date, however, no indices have scores that take into consideration the age of the patient, or include other criteria for identifying pathological forms of wear.

The question of whether the various forms of tooth wear are a dental public health problem seems to be crucial because depending on the answer, different preventive strategies and measures will be appropriate. There is only limited information available about the prevalence and incidence of the condition on a population-based level. The published data, however, indicate that erosion and tooth wear clearly contribute to oral health problems and it has been suggested that a small proportion, in the order of 2-10% of the population, present higher levels of tooth wear than the majority (Bartlett and Dugmore, 2008). Due to flaws in comparing current epidemiological approaches it is difficult to draw any broad conclusion, all the more so as there are large differences in the prevalence between different countries.

Main problems related to current epidemiological tools

Many indices have been developed all over the world. Most research groups working in the field have developed their own approach, or at least their own modification of an existing index. The consequence of this is a considerable variety of different indices with respect to scale, grading and information provided, making comparison of data difficult, if not impossible.

Important parameters for index quality are reliability, sensitivity and specificity, and validity (Berg *et al.*, 2008). So far, existing tooth wear and erosion indices have not been satisfactorily validated, and the other quality criteria are often not sufficiently developed.

The validity of an instrument (tool) indicates to what extent it measures what it is supposed to measure, and ideally, a newly introduced index should be validated against a "gold standard". As no such a standard is currently available to measure erosion and tooth wear, a possible option for improving the current approach would be testing the construct validity of existing systems by comparing the results of different indices applied on the same group of subjects. This was the aim of a recent study that compared the BEWE index with the Visual Erosion Dental Examination (VEDE) (Mulic *et al.*, 2010). The

assessment of sensitivity and specificity also depends on a “gold standard”. For the diagnostic criteria of exposed dentin, the histological assessment of teeth may represent such a tool and the sensitivity and specificity of this quantitative variable has been investigated (Al-Malik *et al.*, 2001; Ganss *et al.*, 2006). For the clinical criteria regarding the differential diagnosis of subforms of wear, no such information on validity has been published.

To date, the prevalence of erosion has mostly been expressed as a simple yes-no decision in the form of “x% of the subjects having at least one tooth with grade x or grade y erosion/tooth wear”, which may significantly overestimate the problem. Only very few approaches include information about the number of teeth individually affected (e.g. Larsen *et al.*, 2000). Further, some indices represent full mouth recordings while others refer only to a part of the dentition presuming that marker teeth exist allowing for the identification of a subject having the condition as a form of screening procedure. It appears that first permanent molars and upper incisors could be relevant for this approach (Ganss *et al.*, 2001; Nunn *et al.*, 2003), but there are only few systematic comparisons of full mouth and partial recordings (Steele and Walls, 2000).

Further, an individual-based index should fulfil other criteria than one designed for population-based studies. Basically, an individual index should allow for a full assessment of the dentition, whereas the latter should take less time and ideally should be a short version of an extended individual-based index. Regarding both partial and full mouth recordings of tooth wear and erosion, there is no index with both a validated short and long version.

Future work needed– the research agenda

A main perspective for future work is the initiation of a consensus process in the scientific community, aimed at avoiding the further proliferation of indices. This process should lead to the development of an internationally accepted, standardised and validated index. A reasonable appraisal of the various forms of tooth wear as oral disease is needed to avoid overestimating its importance for oral health.

Such a process was initiated at the Consensus Workshop on current epidemiological approaches in the field of dental erosion held in 2007 and published in a special issue (Clin Oral Invest Suppl. 1, 2008). Participants were leading researchers in the field. The result was the development of the Basic Erosive Wear Index (BEWE) designed to fulfil most of the formal requirements generally considered important for indices (Bartlett *et al.*, 2008). The BEWE aims to provide a simple scoring system that allows re-analysis and integration of results from existing studies that have used other indices. It was proposed as an erosion index, but it is also suitable for other subforms of wear when used with the respective clinical criteria. Carrying forward the consensus initiative and the BEWE approach, which is still amenable for further development, is a source for improving the scientific knowledge about the role of tooth wear and its subforms for oral health. In this context, a next step will be to validate the BEWE and reconsider the threshold values classifying the severity levels.

A further topic for the research agenda is the initiation of data collection on the prevalence of (erosive) tooth wear on a population-based level, preferably integrated in caries prevalence surveys when applicable. For improving the validity of diagnostic criteria and to facilitate the differential diagnosis of subforms of tooth wear, a database providing clinical photos may help with training sessions and calibration. Considering analytical epidemiological studies, for instance identifying risk factors from life style and diet, or general health conditions, the development of a validated questionnaire needs to be initiated.

Last but not least, there should also be an emphasis on promoting communication between the basic and clinical sciences, and between the sciences and the area of Public Health Dentistry, in order to transfer research findings into practice, into policy and into public and private health systems.

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