

A new index to measure tooth wear – methodology and practical advice

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A new tooth wear index, designed to measure stages of tooth wear in enamel and dentine is presented. The index measures the lateral spread of wear in enamel and the depth of tooth wear in dentine. The index scores enamel loss at 5 levels and 6 levels in dentine and provides a more sensitive index for monitoring the progression of wear than older indices. The protocols and methods of the index are described and incorporate refinements based on the combined experiences of two independent studies conducted on adults and children. The findings of both studies are summarised and recommendations are made for future studies which investigate the prevalence of tooth wear in adults or children.

Key words: The exact tooth wear index (ETI)

Introduction

Standardised, reproducible and valid measurement and recording of conditions affecting the dentition are essential to the study of their distribution, determinants, natural history, prevention and treatment. Given the increasing interest in exploring these aspects in relation to tooth wear a new index was developed to improve its measurement. The impact of tooth wear is recorded using an index, the function of which is to record the physical appearance of wear on the dentition using a standardised numerical coding system, which can then be used to describe and analyse the condition in groups and populations. The ideal index should be simple to understand and use, clear in its scoring criteria and be demonstrably reproducible. Its application should be useful for research into the prevention and monitoring of the condition (Fares *et al.*, 2009). The development of the Exact Tooth Wear Index (ETI) was based on these requirements.

Probably the most commonly used tooth wear index is that developed by Smith and Knight (TWI) (Smith and Knight, 1984b). This five level ordinal index codes wear on surfaces, cervical, buccal, occlusal/incisal and palatal/lingual, using zero to indicate no wear and four to indicate at or near pulpal exposure. It was the first tooth wear index to code wear irrespective of aetiology and treatment need. The emphasis of the TWI however tends towards recording the more severe forms of wear with grade three indicating wear over $\frac{2}{3}$ of a surface exposing dentine and grade four, secondary dentine or pulpal exposure. Smith and Knight (1984b) used the index in a series of investigations which reported on the prevalence of tooth wear firstly, in a patient population referred to a dental school and secondly, in a study

undertaken in general dental practice (Smith and Knight, 1984a; Smith and Knight, 1984b; Smith and Robb, 1996). The authors were the first to use the term pathological tooth wear to describe those subjects with severe levels of wear and tooth wear requiring restorative intervention. Since then a number of researchers have used the basic structure of the index to measure the prevalence of tooth wear in children, adolescents and adults (Bartlett *et al.*, 1997b; Bartlett *et al.*, 1998; Dugmore and Rock, 2004; Harding *et al.*, 2003; Lussi *et al.*, 1991; Millward *et al.*, 1994; O'Brien, 1993; Whelton *et al.*, 2008).

Historically the TWI evolved partly from Eccles index (Eccles, 1979) which described the extent of 'erosive' tooth wear on teeth and initiated the division of the surface involved into thirds. The Eccles index (1979) recorded erosion on the buccal/facial, occlusal and palatal tooth surfaces in a referred population using the terms Class I, II, IIIa, IIIb, IIIc and IIId. However, this index was overly complicated particularly for measuring severe forms of wear. The TWI similarly recorded wear on the buccal/facial, occlusal and palatal tooth surfaces but without the class divisions of Eccles (1979) and, rather than being aetiological is descriptive.

The original aim of the TWI was to record the restorative treatment needs of a given population. Therefore the focus of the index and its sensitivity was biased towards severe forms of dentine exposure. One of the limitations of using the TWI to measure and monitor wear is that it records tooth wear in enamel as a single grade; loss of enamel characteristics on the buccal/labial, lingual/palatal, occlusal or incisal surface and minimal loss of contour in the cervical area (Smith and Knight, 1994b). Given the single score for enamel the TWI in its original form could not be used to monitor early forms of wear and

would be insufficiently sensitive to use in intervention studies investigating the effect of preventive treatments. An example of a TWI coding one is illustrated on the facial surfaces of the upper incisor teeth in Figure 1a, b and c. A TWI code 1 indicates that there is loss of surface characteristics, indicating enamel wear but gives no indication of the amount of tooth surface involved, whether it is confined to the cervical area or affects the entire facial surface. Recording enamel wear at different grades and measuring lateral spread would facilitate the estimation of the rate of wear and would be a useful tool in population studies identifying groups at risk of developing tooth wear into dentine. Incorporating a classification for different stages of wear in enamel would also assist with the targeting for prevention rather than classifying wear at a stage where restorative intervention is more probable. Prospective and longitudinal studies support the identification of tooth wear, and tooth wear, attributed to erosion at an early stage (Dugmore and Rock, 2003).

The Exact Tooth Wear Index (ETI) was developed to address the need to record tooth wear for both enamel and dentine at a more detailed level. The index has been used in two studies, a study on 1,010 university college students' aged 18-30 years in London, UK (Fares *et al.*, 2009) and another smaller study on 123 children aged 12 (± 0.32) years in Cork, Ireland (Harding *et al.*, 2009). This paper describes the index, the examination criteria and conventions, which should be adopted when using the index as developed during these early studies.

Description of the Exact Tooth Wear Index (ETI)

With the ETI enamel and dentine are scored separately, the enamel score indicates the lateral spread of the wear on a particular surface, four categories of wear are described ranging from confined to a small area ($< 1/10^{\text{th}}$) to more than 2/3rds of the surface ($\geq 2/3^{\text{rds}}$). There are 5 grades of dentine wear which indicate that dentine is exposed and the extent to which it is exposed, the categories range from loss of enamel exposing less than 1/10th of dentine surface to exposure of secondary dentine or pulp. In addition to an enamel and dentine score the buccal-cervical area is also scored for the depth of the lesion using a standard periodontal probe (Table 1).

It is recommended that standardised examination criteria be adopted when using the index, these criteria are described in Table 2. Examination of the teeth when dry under good lighting conditions is important when recording wear at the level of detail described. Use of a good quality dental mirror is also important. Reporting the location of the dental examination; clinic, school or other setting, is essential to allow appropriate interpretation of the results. Examination of the adults in London with the ETI was undertaken in a dental chair but not a dental clinic. In Cork the children were examined in the child's school using a portable dental chair¹ and Daray lamp² with illumination similar to a dental operatory light (12volt halogen light).

A number of conventions must be followed with the index, when difficulty arises in scoring a tooth surface the lower score should be applied; underestimating rather than overestimating the severity of wear. A surface with a restoration covering more than 25% is excluded and



Figure 1a. Tooth wear on the two central incisors is widespread but does not involve dentine. Most indices, including the TWI, would grade this as a single grade for enamel wear (loss of enamel surface characteristics) and may under-record the severity of damage to the tooth: Score with TWI = 1, Score with ETI = 4 for enamel and 0 for dentine.



Figure 1b. Tooth wear on the two central incisors in this sixteen-year-old teenager would score 1 with the TWI and with the ETI Score = 3 for enamel and 0 for dentine.



Figure 1c. Tooth wear in the incisal area of the two central incisors in this eight-year-old score 1 with the TWI and with the ETI Score = 1 for enamel on the left central and 2 for the right central and 0 for dentine on both.

scored 'R', similarly orthodontically banded surfaces are scored R. When tooth wear results in a reduction in clinical crown height (Figure 2) the wear not only affects the incisal surface but also results in half the buccal and palatal surfaces being worn away. To score wear only on the incisal surface would ignore its impact on the facial and palatal surfaces, and since the coronal

Table 1. Exact Tooth Wear Index (ETI)

<i>(A) ENAMEL</i>	
0	No tooth wear: no loss of enamel characteristics or change in contour
1	Loss of enamel affecting $< \frac{1}{10}^{\text{th}}$ of the scored surface
2	Loss of enamel affecting $< \frac{1}{3}^{\text{rd}}$ of the scored surface
3	Loss of enamel affecting at least $\frac{1}{3}^{\text{rd}}$ but $< \frac{2}{3}^{\text{rds}}$ of the scored surface
4	Loss of enamel affecting $\geq \frac{2}{3}^{\text{rds}}$ of the scored surface
<i>(B) DENTINE</i>	
0	No dentinal tooth wear: no dentine
1	Loss of dentine affecting $< \frac{1}{10}^{\text{th}}$ of the scored surface
2	Loss of dentine affecting $< \frac{1}{3}^{\text{rd}}$ of the scored surface
3	Loss of dentine affecting at least $\frac{1}{3}^{\text{rd}}$ but $< \frac{2}{3}^{\text{rds}}$ of the scored surface
4	Loss of dentine affecting $\geq \frac{2}{3}^{\text{rds}}$ of the scored surface, but no pulpal exposure
5	Secondary dentine formation or pulpal exposure
<i>(C) DEPTH ON CERVICAL BUCCAL SURFACES</i> <i>(measured with a standard W&H periodontal probe)</i>	
0	No tooth wear: no loss of tooth contour
1	$< 1\text{mm}$ loss of tooth surface depth
2	Tooth surface loss in depth measuring $\geq 1\text{mm}$ but $< 2\text{mm}$
3	Tooth surface loss in depth measuring $\geq 2\text{mm}$

Table 2. Examination Criteria and Conventions

<i>Criteria</i>
Illuminate the teeth using a halogen light source
Teeth dried prior to examination
Mirrors front reflecting and un-scratched
State the location of the examination
Score all permanent teeth except third permanent molars
The surfaces scored are: Buccal/Facial, Occlusal/Incisal, Lingual/ Palatal. and Buccal-Cervical in that order.
Once some part of the tooth is present in the mouth it is scored, all unerupted surfaces are scored 0
Enamel is scored first and then dentine
<i>Conventions</i>
When in doubt with regard to a score the lower score should be applied
A tooth surface with a restoration covering more than 25% of a surface is scored R (excluded).
Orthodontically banded surfaces are scored R
When tooth wear has occurred so that clinical crown height is lost, the buccal / facial and palatal / lingual surfaces are scored for loss of tooth wear as well as the incisal/occlusal surface, otherwise no indication of future wear can be incorporated.



Figure 2. Tooth wear along the incisal surface of incisor teeth. Grading the wear should involve the impact on the facial and the palatal surfaces where dentine and enamel have clearly been lost.

cross-sectional area would remain reasonably constant, so progression could not be detected. Theoretically, if the incisal score reached grade 4 (near pulpal exposure) with more than half the crown height lost then the index would not differentiate further progression. In these situations a convention needs to be established. The authors recommend when wear impacts upon other tooth surfaces these should also be graded. In this case, the wear on the occlusal/incisal surface and the impact on the height of the buccal and palatal surfaces are recorded as well. Therefore in the case of the worn incisal surface the impact of the wear on the palatal and buccal/facial surfaces should also be registered.

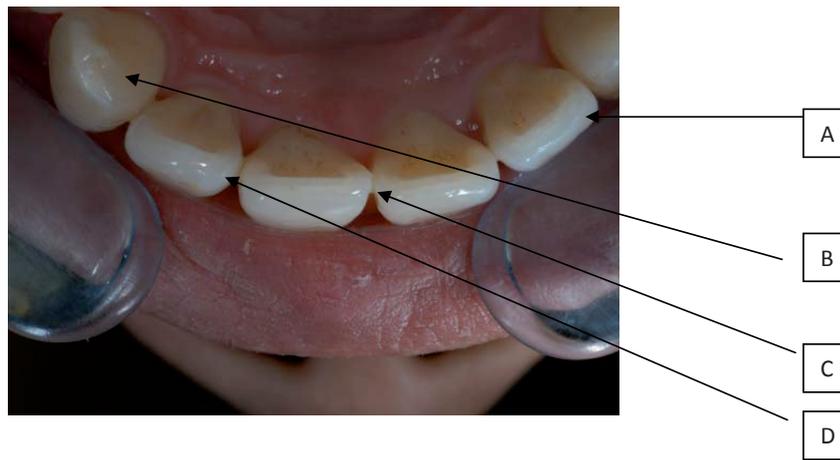
Training and calibration are critical to applying the ETI. For the success of the index examiners should be trained initially on photographs and study models to il-

illustrate the cut-off between the different grades and to establish an understanding of the classification system. Once examiners are familiar with the index, training on individual subjects can proceed. The selection of cases is important and should represent the spectrum of wear which is to be expected in the population studied.

Examiners need to discuss a wide range of scores with the trainer before proceeding to a series of full examinations on their own which are also discussed with the trainer. Finally to ensure consistency and reliability, a proportion of subjects (10%) are randomly selected for intra-examiner reliability. Figures 3-5 show typical examples of wear from grade 0 to 4 for enamel and 0 to 5 for dentine.

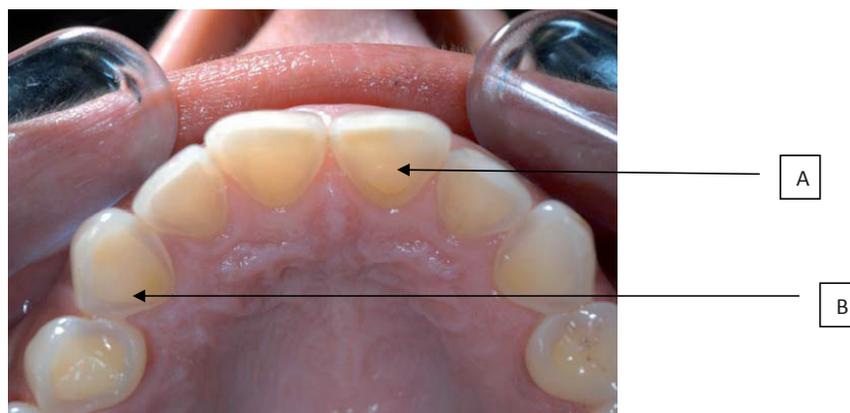
Analysis of the results.

Tooth wear data were analysed using SPSS / SAS (version 9.1). Various authors have presented the outcome of tooth wear differently, some have presented the results as the number of subjects with dentine exposed on at least one tooth (Bardsley *et al.*, 2004) whilst others have reported the percentage of surfaces involved (Dugmore and Rock, 2004). Both methods are appropriate but if there is an absence of consistency in reporting results it becomes difficult to compare studies. The authors advise that both outcomes are recorded for all prevalence data so that the results can be compared in the future. This would be similar to reporting the DMFS/dmfs and percentage with caries/caries free in a study on dental caries (1997).



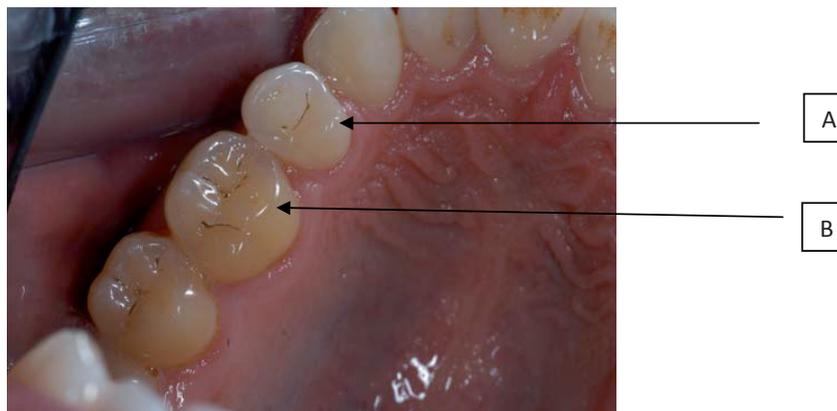
- A = Score 4 enamel and 0 dentine: Loss of enamel affecting $\geq \frac{2}{3}$ of the scored surface and no dentinal tooth wear: no loss of dentine
- B = Score 4 enamel and 1 dentine: Loss of enamel affecting $\geq \frac{2}{3}$ of the scored surface and Loss of dentine affecting $< \frac{1}{10}$ of the scored surface
- C = Score 3 enamel and 0 dentine: Loss of enamel affecting at least $\frac{1}{3}$ but $< \frac{2}{3}$ of the scored surface and No dentinal tooth wear: no loss of dentine
- D = Score 0 enamel and 0 dentine: no tooth wear: no loss of enamel characteristics or change in contour and no dentinal tooth wear: no loss of dentine

Figure 3. Scoring for tooth wear along the incisal surfaces of upper anterior teeth



- A = Score 4 enamel and 4 dentine: Loss of enamel affecting $\geq \frac{2}{3}$ of the scored surface and Loss of dentine affecting $\geq \frac{2}{3}$ of the scored surface, no pulpal exposure
- B = Score 3 enamel and 2 dentine: Loss of dentine affecting at least $\frac{1}{3}$ but $< \frac{2}{3}$ of the scored surface: Loss of dentine affecting $< \frac{1}{3}$ of the scored surface

Figure 4. Scoring for tooth wear on the palatal and occlusal surfaces of teeth



A = On the palatal surface Score 1 enamel 1 and 0 dentine: Loss of enamel affecting $< 1/10^{\text{th}}$ of the scored surface

B = On the occlusal surface Score 2 enamel and 1 dentine : Loss of enamel affecting $< 1/3^{\text{rd}}$ of the scored surface and Loss of dentine affecting $< 1/10^{\text{th}}$ of the scored surface

Figure 5. Scoring for tooth wear on the molar and premolars

Reproducibility

The reproducibility of the index in the adult study reported substantial agreement for enamel and dentine (Kappa 0.88) (LandisKoch, 1977). With the children, one examiner (MH) conducted the examinations. During training prior to fieldwork a Kappa score of 0.8 for both enamel and dentine was achieved, with one of the authors (SS) as the gold standard. During the study an intra-examiner kappa score of 0.85 and 0.91 for enamel and dentine respectively were achieved. Kappa is a compound measure of agreement that tests if agreement exceeds that predicted by chance.

There is little consensus about what statistical methods are best to analyze reproducibility. Two commonly used statistics are the Intraclass Correlation (ICC), which assesses rating reliability by comparing the variability of different ratings of the same subject to the total variation across all ratings and all subjects, and the Kappa coefficient. There are three cases of ICC, 1: Raters for each subject are selected at random, 2: The same raters rate each case (a random sample of all raters), 3: The same raters rate each case (these are the only raters of interest). There are two possible analyses for each of these cases, 1: to estimate the reliability of a single rating, or 2: To estimate the reliability of a mean of several ratings. This gives a total of six different ICCs. Kappa is often incorrectly described as a 'chance-corrected' measure of agreement whereas it really tests if agreement exceeds that predicted by chance. Kappa is a compound measure of agreement that does not distinguish between types and sources of disagreement. In essence, the ICC is better able to discriminate for situations which involve different assessors or multiple assessments.

Discussion

Measurement of progression presently includes subjective assessment of study casts (Bartlett *et al.*, 2005), silicone putty matrices or surface topographical measurement with profilometers (Bartlett *et al.*, 1997a; Sundaram *et al.*, 2007). Before the ETI the only way to measure enamel

wear would have been profilometers, but the challenge is the requirement of study models and the time needed to scan tooth surfaces, which is currently around 1 hour per tooth. The time commitment means that laser profilometry is unsuitable for epidemiological studies. The ETI can be used on large population-based studies and should permit the measurement of progression of wear on enamel and dentine surfaces. In child and adolescent populations a separate buccal-cervical score can be omitted due to the absence of this defect in this younger group.

Unlike some earlier indices the ETI scores early enamel wear. It is important to measure and monitor the early stages as these surfaces are thought to be more prone to progression over time and may in the future allow longitudinal studies to be conducted. Changes to the shape of teeth, as a result of wear into dentine, may not be initially obvious due to compensatory dento-alveolar growth (Crothers and Sandham, 1993; Dahl *et al.*, 1975) but in time tooth sensitivity can develop and dental appearance and aesthetics compromised. But these gross changes become clinically obvious; what is needed is a measure to allow progression to be monitored at a much earlier state and the ETI has this capability. Dugmore and Rock (2003) previously conducted a longitudinal study and measured progression at the dentine level but from a preventive approach measurement on enamel would be more appropriate. This group of researchers did not measure changes on individual surfaces of each tooth but measured progression as a total change in each subject. The modification of the TWI to the ETI allows enamel and early dentine changes to be measured improving the potential for long term studies. Ethical approval has been granted to re-examine the twelve-year-old children in Cork, with this new data for fourteen-year-olds and the data collected at age twelve progression or otherwise can be assessed.

An index that records early change, which is reproducible and permits early identification of tooth wear, has been described. Adoption of the ETI, which will record both loss of enamel and loss of dentine will permit the recording of tooth wear in a consistent manner and allows for comparison between studies. Using the ETI, early or

small changes in enamel and dentine can be recorded, but equally if that level of detail is not required or for some statistical analyses, grades can be merged, but the opportunity to compare like with like is retained.

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