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Validation of the Basic Erosive Wear Examination

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Clinical index · Diagnosis · Reliability · Tooth wear

Abstract
The Basic Erosive Wear Examination (BEWE) is a practical index for screening tooth wear, using a 4-point ordinal scale (0–3). The highest score is recorded in each sextant and a total score (or BEWE sextant cumulative) is calculated per subject. This study aims to investigate if the BEWE sextant cumulative score compares to one comprising a percentage score from all tooth surfaces and as a highest BEWE per subject. The aim is to assess the validity of this score. A total of 350 subjects were recruited from hospital and general practice in southeast England. Buccal, occlusal and lingual/palatal BEWE scores were collected and percentages calculated based on scores 1, 1 and above, 2 and above and 3. BEWE sextant cumulative scores and highest BEWE scores were also recorded per subject. Spearman's correlation coefficients (p values) assessed the relationship between BEWE sextant cumulative scores, BEWE percentages and BEWE highest score per subject. The BEWE sextant cumulative score correlates significantly to a BEWE score taken as a percentage score from all tooth surfaces (Spearman's $r > 0.5$, $p < 0.001$) and especially to BEWE surface scores of 1 and above and 2 and above ($r > 0.8$, $p < 0.001$) and as a highest surface score per subject ($r > 0.8$, $p < 0.001$). BEWE sextant score provides a representation of tooth wear on all tooth surfaces. This study validates a tooth wear index, which provides clinicians with risk indicators of a patient's level of tooth wear and may help to guide clinical management.

Tooth wear, particularly erosive wear [Addy and Hunter, 2003; Dugmore and Rock, 2003; Nunn et al., 2003], is a growing problem in adults [Van't Spijker et al., 2009] and children [Nunn et al., 2000]. It can impact on quality of life, causing pain, discomfort, less satisfaction in appearance and reduced eating capacity [Al-Omiri et al., 2006]. Erosion is the loss of tooth surface by chemical dissolution due to an acid which is not produced by the oral flora but originates from intrinsic or extrinsic sources [ten Cate et al., 2008]. Intrinsic erosion is caused by stomach acid and arises due to vomiting or gastro-oesophageal reflux disease, whereas extrinsic erosion is caused by factors such as diet, lifestyle, environmental factors and some medicaments. Tooth wear indices have been developed primarily to calculate the prevalence within communities, but they have also been used to diagnose, grade and monitor tooth wear caused by attrition, abrasion and/or erosion [Smith and Knight, 1984; Bardsley, 2008]. Some indices record lesions on an aetiological basis (e.g. erosion indices), whereas others record lesions irrespective of aetiology (tooth wear indices). However, none have universal acceptance, perhaps due to a lack of standardisation in terminology

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and vague definitions of criteria, which mean that interpretation of severity scores is not clear cut [Bardsley, 2008].

The Basic Erosive Wear Examination (BEWE) is a relatively new, practical screen for scoring erosive wear. It was first described by Bartlett et al. [2008] as a simple way to screen tooth wear for use in general dental practice using a sextant cumulative score. The index was based on the Basic Periodontal Examination (BPE), which is widely used in general practice in many countries and is also sextant based [Smales et al., 1987]. The BEWE sextant score provides a guide to risk and so aims to increase awareness amongst clinicians of a patient's level of tooth wear and may also help to guide clinical management. Only two studies have assessed the reliability of the BEWE scoring system to date [Mulic et al., 2010; Dixon et al., 2012]. In the first study, the BEWE and the Visual Erosion Dental Examination (VEDE, another clinical ordinal scale used to measure erosive dental wear) were investigated. Inter- and intra-examiner agreement of the BEWE and VEDE indices were obtained and found to be similar. However, this study only reported erosive wear (not attrition/abrasion) and the VEDE measured erosive wear at the tooth surface level and not as a score per patient, as is the aim of the BEWE index. Moreover, no direct statistical comparison was made between both systems. In the second study [Dixon et al., 2012], the BEWE was compared to the Smith and Knight tooth wear index [Smith and Knight, 1984] on 164 adult patients. This demonstrated that the BEWE scores had a similar distribution to the tooth wear index scores.

Validation of tooth wear indices and particularly the BEWE is important to avoid diagnostic uncertainties [Mulic et al., 2010]. The BEWE, although examining all teeth, could be considered a partial mouth (as opposed to full mouth) scoring instrument because the multiplicity of sites is not considered when a single score is applied per sextant. No attempt has been made to validate the BEWE sextant cumulative score (giving the overall risk) with a BEWE score taken from all tooth surfaces. This is necessary for diagnostic, management and research purposes. This study, therefore, aims to investigate if the BEWE sextant cumulative score provides an accurate representation of the BEWE recorded on all tooth surfaces.

Subjects and Methods

One examiner was trained and calibrated by recording a BEWE score for each of 90 tooth surfaces, which was used for training and displayed electronically in a power point presentation (Microsoft Office PowerPoint 2007). An expert gold standard examiner also completed the same exercise separately. In order to assess the agreement of BEWE scores between the examiner and the gold standard, the scores were cross tabulated. Then, an inter-examiner Cohen kappa value (weighted) of >0.7 was obtained using Stata 11 software (StataCorp, USA). Operator retraining and calibration took place throughout the study.

The study received ethical approval (11/H0801/3). A convenience sample of 350 subjects was used. The selection of sites aimed to balance urban, suburban and rural populations based upon agreement of the site and relevant local health authorities. This sample consisted of subjects who consented and who fulfilled the necessary criteria. Inclusion criteria included dentate individuals aged 18–35 years old in good general health and attending for routine care only. Exclusion criteria included subjects exhibiting oral pathology or who wore orthodontic appliances. All subjects were provided with patient information sheets, had an opportunity to ask questions and were required to provide written consent prior to enrolling in the study. Those patients who, after reading the information sheet, consented to the study criteria were then examined.

Teeth were dried using compressed air and examined without magnification under normal dental surgery conditions. Buccal/bucco-cervical, occlusal/incisal and lingual/palatal BEWE scores were collected for each tooth surface. In the original scoring system of BEWE, incisal surfaces were not included [Bartlett et al., 2008], but they were included in this study to provide a reflection of tooth wear on all tooth surfaces. Missing teeth, traumatised or carious teeth and third molars were excluded in each subject. At the tooth surface level, surfaces were excluded if they were restored. The BEWE was designed to grade the extent/severity of erosive lesions, but in this study BEWE was used to record all forms of tooth wear including erosion, attrition and abrasion. In addition, tooth wear was recorded using BEWE from the whole of the buccal or lingual/palatal aspect including tooth structure affected by gingival recession. Therefore, wedge-shaped defects were also included. Gingival recession was recorded using a William's periodontal probe. Based on the guidelines for recording BEWE [Bartlett et al., 2008], tooth surfaces with no wear scored 0, surfaces with initial loss of surface texture scored 1, surfaces with a distinct defect and hard tissue loss <50% of the surface area scored 2 and surfaces with hard tissue loss ≥50% scored 3. BEWE scores of 2 or 3 often involved dentine. In order to calculate the BEWE sextant cumulative score or risk score, the sum of the highest score from each oral sextant was calculated. The risk categories are none (≤2), low (3–8), medium (9–13) or high (≥14). The medium and high categories may involve operative management [Bartlett et al., 2008]. Then, the percentage of tooth surfaces with BEWE grades of 1, 1 and above, 2 and above and 3 were calculated per subject. It should be noted that surfaces recorded as 'BEWE grade 1 and above' had BEWE grades of 1 and/or 2 and/or 3. In other words, tooth wear was present in these surfaces. A 'BEWE grade 2 and above' had BEWE score 2 and/or score 3. Finally, for each subject, the highest BEWE score recorded on a tooth surface was also obtained.

In order to assess intra-examiner reproducibility, examinations were repeated a second time on every 10th patient who was recruited. This second examination occurred immediately after the first for convenience and the BEWE scores were recorded again for every tooth surface in order to calculate the BEWE sextant cumulative score per subject, BEWE percentage score per tooth surface and BEWE highest score per tooth surface and subject a second time. The agreement between the quantitative data sets from the first and second clinical examinations were assessed using intra-class corre-

lation coefficients in Microsoft Office Excel 2007. The overall data were then analysed descriptively using Microsoft Office Excel 2007. Then, Spearman's correlation coefficients (and p values) were used to assess if there was a relationship between BEWE sextant cumulative scores and the BEWE percentages per tooth surface or BEWE highest score per subject, using Stata 11 software (StataCorp).

Results

Demographics

A total of 350 adult subjects were recruited from eight sites in primary (63%) or secondary care (37%) in the south east of England between June 2011 and February 2012. A convenience sample of 43–44 consecutive subjects was obtained at each site. Subjects originated from small/mid-sized towns (53%), metropolitan areas (36%) or rural regions (11%) and were aged between 19 and 35 years (mean 27, SD 3.6, SE 0.2). Within this sample, there were 24,093 tooth surfaces. Of these, there were 8,053 buccal, 8,014 occlusal and 8,026 lingual tooth surfaces. The total number of tooth surfaces affected by gingival recession was 2,164 (13.1%).

Summary of BEWE Sextant Cumulative, BEWE per Tooth Surfaces and BEWE Highest per Subject

Intra-examiner reproducibility of repeated clinical outcomes taken from 10% of subjects showed intra-class correlation coefficients ≥0.96.

The BEWE sextant cumulative or risk score per subject ranged from 0 to 16 (median 7, inter-quartile range, IQR, 5–9, mean 6.5, SD 3.77). At the subject level, the highest BEWE score recorded on at least 1 tooth surface of 1 was 44% (n = 153), of 2 was 37% (n = 129), of 3 was 10% (n = 36) and of 0 was 9% (n = 32).

Figure 1 shows the percentage distribution of BEWE scores per tooth surface. Tooth surfaces had a BEWE 0 (40%, n = 9,716), BEWE 1 (36%, n = 8,673), BEWE 2 (20%, n = 4,741) or BEWE 3 (4%, n = 883). The median and IQR of percentage scores of 1, 1 and above, 2 and above and 3 for buccal, occlusal and lingual surfaces per subject is shown in table 1. This table shows that a median 43% (IQR 21–57) of occlusal surfaces, 17% (IQR 0–27) of buccal surfaces and 0% (IQR 0–8) of lingual surfaces had a BEWE score of 1 and above per subject.

For those subjects with a highest BEWE score of 1 on at least 1 tooth surface, the BEWE sextant cumulative score, by definition, was always ≤8. The risk category for these subjects (from Bartlett et al., 2008) was 'low' risk. Amongst those subjects with a highest BEWE score of 3 on at least 1 tooth surface (10%, n = 35), the BEWE sextant cumulative score ranged from 9 to 16 ('medium' to 'high' risk categories), except on 1 subject who had a sextant score of 4 (low risk).

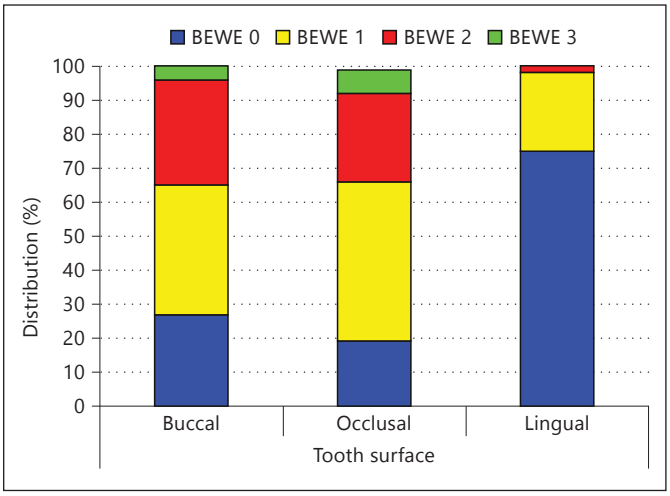

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Fig. 1. Percentage distribution of BEWE scores per tooth surface.

Table 1. Median (IQR) of percentage BEWE scores for buccal, occlusal and lingual surfaces per subject

	Buccal	Occlusal	Lingual	Total
BEWE 1	9 (0–19)	29 (19–42)	0 (0–8)	15 (9–21)
BEWE 1 and above	17 (0–27)	43 (21–57)	0 (0–8)	19 (12–29)
BEWE 2 and above	0 (0–8)	8 (0–17)	0 (0–0)	3 (0–9)
BEWE 3	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)

Correlation of BEWE Sextant Cumulative, BEWE Percentage Scores per Tooth Surfaces and BEWE Highest Score per Subject

Table 2 shows the Spearman correlation coefficients, 95% confidence intervals (CI) and p values for the relationship between the BEWE sextant cumulative score and the BEWE percentage score on tooth surfaces per subject. Correlations for tooth surfaces with a BEWE 1 and above and a BEWE 2 and above were >0.8 ($p < 0.001$), BEWE 1 only were 0.528 ($p < 0.001$) and BEWE 3 only were 0.513 ($p < 0.001$). There was no recorded BEWE 3 on lingual tooth surfaces and hence this could not be correlated to the BEWE sextant cumulative score.

Table 3 shows the Spearman correlation coefficients (p values) for the relationship between BEWE sextant cu-

Table 2. Spearman's correlation coefficients, 95% CIs and p values for relationship between BEWE sextant cumulative scores and BEWE percentages per tooth surface

BEWE percentages	Tooth surface			Total
	Buccal	Occlusal	Lingual	
BEWE 1	0.457* (0.370–0.536)	0.356* (0.260–0.444)	0.293* (0.194–0.386)	0.528* (0.448–0.600)
BEWE 1 and above	0.696* (0.638–0.746)	0.788* (0.744–0.825)	0.157** (0.057–0.257)	0.853* (0.821–0.879)
BEWE 2 and above	0.674* (0.613–0.728)	0.676* (0.615–0.730)	0.333* (0.237–0.423)	0.805* (0.762–0.837)
BEWE 3	0.307* (0.209–0.399)	0.455* (0.367–0.534)	–	0.513* (0.431–0.586)

All scores zero. * $p < 0.001$, ** $p = 0.003$.

Table 3. Spearman's correlation coefficients, 95% CIs and p values for relationship between BEWE sextant cumulative score and BEWE highest score per subject

Tooth surface			Total
Buccal	Occlusal	Lingual	
0.750* (0.700–0.793)	0.699* (0.642–0.749)	0.406* (0.315–0.490)	0.785* (0.741–0.822)

* $p < 0.001$.

mulative score and the BEWE highest score per subject. The correlation for the highest BEWE scores recorded on all tooth surfaces is >0.7 ($p < 0.001$), for buccal and occlusal tooth surfaces is >0.7 ($p < 0.001$) and for lingual tooth surfaces is 0.4 ($p < 0.001$).

Discussion

This study demonstrates that the BEWE sextant cumulative score provides a representation of a BEWE score recorded as a percentage of tooth surfaces per patient or as a highest score per patient (95% CI 0.7–0.8, $p < 0.001$). This means that the sextant score is a useful screening tool for assessing tooth wear, which avoids the need for recording tooth wear on every tooth surface.

The results show how well the BEWE sextant cumulative score reflects the wear process occurring on each tooth surface and for different amounts of tooth wear. The data show that it relates more to tooth surfaces with a BEWE score of 1 and above and 2 and above (≥0.8, $p < 0.001$) and to a slightly lesser extent BEWE scores of 1 and 3 (≤0.5, $p < 0.001$). This shows that the BEWE sextant cumulative score relates well to tooth surfaces with early wear and distinct tissue loss involving dentine, but less to those with minimal wear affecting enamel (BEWE score 1 only) or extensive wear affecting at least 50% of a tooth surface (BEWE score 3 only). Although this might suggest that subjects who have minimal or advanced wear may not be placed into the appropriate BEWE risk categories for tooth wear, the risk categories for BEWE sextant cumulative as described by Bartlett et al. [2008] include a variation in the BEWE sextant cumulative score, which avoids over- or underestimating the amount of tooth wear. For example, subjects who had a highest BEWE score on any tooth surface of 1 had a sextant cumulative score ≤8 and hence, the risk score for these subjects would still be low. In addition, among subjects who had a BEWE 3 on a tooth surface (4%, n = 14), the risk score was medium or high in all but 1 subject. Hence, there could be potential for reduction in the accuracy of BEWE in rare cases of advanced localised wear. Overall, however, correlation of the BEWE sextant cumulative score to the highest BEWE score recorded on a tooth surface per subject was >0.7 ($p < 0.001$).

The BEWE scoring system, in contrast to other tooth wear scoring systems, does not distinguish between enamel loss and dentine exposed [Ganss et al., 2006; Bartlett et al., 2008]. Previous studies divulge that it can be particularly difficult to differentiate lesions localised to enamel or dentine especially in the cervical area of teeth and that this could lead to diagnostic uncertainties [Holbrook and Ganss, 2008]. Severe wear has also been shown to be masked by restorations in the cervical area [Donachie and Walls, 1995]. However, our study has shown that the BEWE sextant cumulative score relates to tooth wear

scores from all tooth surfaces. In particular, correlation of the BEWE sextant cumulative to the BEWE percentage scores for tooth surfaces and to the highest BEWE score per subject were greater for buccal and occlusal surfaces than for lingual tooth surfaces. Unlike the latter, buccal and occlusal tooth surfaces were shown to more likely have dentine exposure and these surfaces included buccal-cervical lesions (also known as non-carious cervical lesions). Despite this, the study also showed that percentage scores on lingual tooth surfaces did not correlate well with the BEWE sextant cumulative score. This may be explained by the median percentage BEWE for lingual surfaces, which was 0 (IQR 0–0). Lingual tooth wear, when present (25%, 87 subjects), was often localised to enamel. Other clinical studies have also recorded less wear on lingual [Radentz et al., 1976; Khan et al., 1999] compared to buccal tooth surfaces, but fortunately treatment would not be required in these cases. The BEWE sextant cumulative score identifies the most severe wear, which in our study was more likely buccal or occlusal.

The BEWE was adopted based on the BPE or Community Index of Periodontal Need (CPITN) [Ainamo et al., 1982]. CPITN is now commonly used in dental practice to screen periodontal disease by measuring the maximum pocket depth in each oral sextant using a probe and adding these together to create a sextant score. This provides an indication of the patient's risk of periodontal disease. Previous research has nonetheless shown that the CPITN may under- or overestimate the level of periodontal pocketing or fail to reflect the level of pocketing in all teeth. Similar to our study, one paper compared the CPITN to a measurement of periodontal probing taken from every tooth, but it found that the CPITN fails to measure periodontal disease in comparison to the full mouth assessment ($p < 0.001$) [Bassani et al., 2006]. Another study also reports that CPITN often underestimates the depth of periodontal pocketing in sextants that have deeper pockets [Diamanti-Kipioti et al., 1993] despite the CPITN formerly being reported as having better suitability for severe disease diagnosis [Ainamo and Ainamo, 1985]. The problems with overestimating the depth of periodontal pocketing using CPITN may be due to the use of a periodontal probe to measure pocket depth, but the CPITN itself is also a partial score, with one score recorded per sextant, and can also under-represent the disease. Similarly, the BEWE index might also be expected to underestimate the level of tooth wear due to its sextant design and this was the case in 1 subject in our study. However, the BEWE is unlike previous commonly used tooth wear indices such as the Smith and Knight index [Smith and Knight, 1984], which were more detailed and could overestimate the amount of tooth wear by asking the examiner to estimate the proportion of teeth affected by tooth wear [Ganss et al., 2006]. In addition, our study demonstrates that the BEWE sextant cumulative score can be a useful screening tool that reflects the total amount of wear occurring in the mouth.

The reproducibility of clinical assessment using the BEWE was extremely high in this study, but this may be explained in part because subjects were examined a second time within 30 min of the first exam. This was to avoid inconvenience to the subject and the practice of recalling the same patient at another appointment. However, there would ideally be a time lapse between the first and second clinical examination. A convenience sample was also used as this study took place at various sites and aimed to accommodate all subjects willing to complete the study and who fulfilled the necessary inclusion/exclusion criteria. A second method to ensure consistency using the BEWE scoring system in this study was to use a single examiner throughout the study who received ongoing training. Intra-examiner agreement to an expert examiner through calibration exercises remained at >0.7 throughout the study. Although a single examiner was used in this study, other studies have also demonstrated good agreement between various examiners when assessing tooth wear using alternative wear indices [Smith and Knight, 1984].

In conclusion, this study has validated the BEWE sextant cumulative score. This score appears to provide a simple method to alert clinicians to the tooth wear process. There is no gold standard in the evaluation of tooth wear but there is a need for such a standard given the importance of this disease process. The clinical implications are that the scoring system is particularly good for recording wear more consistently than previous commonly used indices and in selecting those patients who may require treatment management. Bearing in mind all the detailed analysis, the main aim of the BEWE is to assist general dental practitioners in screening for erosive tooth wear. The findings from this study lend support to its use and show that it is fit for purpose.

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Disclosure Statement

The authors confirm that there are no conflicts of interest.

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