A New Analyzing Method for Quantification of Abrasion on the Bruxcore Device for Sleep Bruxism Diagnosis

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Aims: *To evaluate a newly developed semi-automatic computer-based method to analyze the objectivity of the Bruxcore Bruxism-Monitoring Device (BBMD) by assessing the interrater reliability. The capability of the BBMD to differentiate between sleep bruxers (SB) and healthy controls was also verified by estimating the sensitivity, specificity, and predictive values.* ***Methods:*** *Forty-eight SB and 21 controls took part in this investigation. After a detailed clinical dental examination, each participant received a BBMD to be worn for 5 consecutive nights. The BBMDs were then scanned and rated by 2 independent examiners using the new method, which counted the abraded area in pixels. Interrater reliability was assessed by intraclass correlation coefficient (ICC) analyses.* ***Results:*** *The analyses showed a very high interrater reliability of ICC = 0.99, and comparison of the mean pixel scores revealed values that were approximately 8 times higher for the SB than for the controls. With a selected pixel score cutoff point of 2900, a sensitivity of 79.2% and a specificity of 95.2% were found. The clinical diagnosis was correctly predicted in 97.4% of the SB and 66.7% of the controls.* ***Conclusion:*** *The results support the assumption that the newly developed analyzing method for the assessment of the BBMD is a clinically suitable, objective, and applicable method that seems to be able to differentiate between SB and a healthy control sample. These data, however, need to be confirmed in further investigations using polysomnographic recordings.* J OROFAC PAIN 2005;19:232–238

Key words: abrasion, clinical assessment, reliability, sleep bruxism

Sleep bruxism is defined as a "stereotyped movement disorder characterized by grinding or clenching of the teeth during sleep".[1] At present, the etiology of sleep bruxism is still debatable. Several different theories—occlusal interferences,[2] sleep microarousals,[3–5] a side imbalance in striatal D2 receptor binding,[6,7] personality traits,[8–10] and stress[11–13]—have all been suggested as possible causes of the development of sleep bruxism, but its multifactorial nature is generally accepted.[14–16] Numerous methods for the assessment of sleep bruxism activity can be found in the literature: laboratory polysomnographic recordings,[3–7,17] portable electromyographic (EMG) recordings,[18–20] a force-based bruxism detection system,[21] questionnaires for self-evaluation of bruxism,[8,12,13] dental examinations,[22,23] examination of stone casts,[24] and measurement of abrasion on a diagnostic plate.[25–28]

It has been proven that polysomnographic recordings, ie, estimating comprehensive psychophysiological parameters in a sleep laboratory, provide the most suitable research diagnostic criteria for sleep bruxism when distinguishing between sleep bruxers (SB) and an appropriate control group.[17] This method is, however, of limited applicability because of its extensive technical complexity. Thus, such studies have had comparatively small samples, often fewer than 20 patients. In contrast to this, in a primary clinically orientated attempt to measure the degree of bruxism, 20 dentists inspected 29 stone casts and gold-plated models of individual teeth.[24] The results of these measurements demonstrated a rather low interrater correlation, ranging between 0.32 and 0.48.

Thus, a more workable and user-friendly assessment tool is needed that allows the examination of a larger sample and the observation of changes in sleep bruxism activity over shorter periods as a quantification and monitoring instrument. This need led the authors to consider new modes of analyses of the Bruxcore Bruxism-Monitoring Device (BBMD). Created in 1974, the BBMD is a polyvinyl chloride plate that consists of 4 layers with 2 alternating colors and a halftone dot screen on the topmost surface. To assess the abraded area, the creators recommended counting the number of missing microdots. The number of the layers uncovered represented the depth parameter. Both parameters were then combined in order to obtain an index number for the amount of bruxing.[25]

The BBMD was investigated using 3 different methods of measurement to assess the abraded area parameter. Two raters determined the uncovered areas on the BBMD by calculating the number of missing microdots viewed with a microscope with a reference scale, a microscope without a reference scale, and a computer-aided method.[28] The depth parameter was rated by following the recommendations of the manufacturer (Bruxcore).[25,26] The results showed a small intraobserver variation of 5%, whereas the interobserver variation was statistically significant for each of the 3 methods.

The deformation process during the vacuum-press manufacture of the BBMD causes a change of the reference scale which could account for imprecise values of the abraded area parameter. Furthermore, the recommended calculations do not seem to conform to the real abrasion depth. It is necessary to abrade half of the cross-sectional dimension of a layer to assign the uncovered area to the respective layer. There is, however, no information provided about the point in time in which a layer changes its color.

The aim of this study was to evaluate a newly developed semiautomatic computer-based analyzing method to determine the objectivity of the BBMD by assessing the interrater reliability. The study also assessed any measurable differences between the pixel scores obtained for a sample of SB and healthy controls, as well as the sensitivity, specificity, and predictive values as a measure of quality of the diagnostic method.

Materials and Methods

Sample

A total of 69 subjects, 48 SB und 21 controls, participated in this study. The participants were recruited following a thorough dental examination. The diagnosis of sleep bruxism was based on the criteria of the American Sleep Disorders Association.[1] Individuals who met the following criteria were included in the SB group: healthy adults, between 20 and 40 years of age, sleeping partner reports of grinding sounds during the night in the last 6 months, and at least one of the following symptoms: self-report of muscle fatigue or pain on awakening, abnormal tooth wear or shiny spots on dental restorations, masseter hypertrophy upon digital palpation. Exclusion criteria were current dental treatment, cognition of sleep bruxism for more than 10 years, severe psychological disorders and/or the use of antipsychotic psychotropic drugs, central nervous system and/or peripheral nervous system disorders, more than 2 missing molars (excluding third molars), the presence of a prosthesis or extensive prosthetic restorations, and the presence of gross malocclusion. Healthy adults, recruited through announcements in local newspapers and placards on campus from whom sleep bruxism could be excluded represented the control group. They were matched with the SB group with respect to age, gender, and education. In addition, the 2 groups corresponded in terms of occlusal guidance. Exclusion criteria were the same as for the SB group as well as any signs or symptoms of sleep bruxism. All subjects gave informed consent to the procedures, which were approved by the Institutional Human Subjects Ethics Committee (Heinrich-Heine-University of Duesseldorf).

The Bruxcore Bruxism-Monitoring Device

The BBMD is a 0.51-mm-thick plate consisting of 4 laminated polyvinyl chloride layers of different

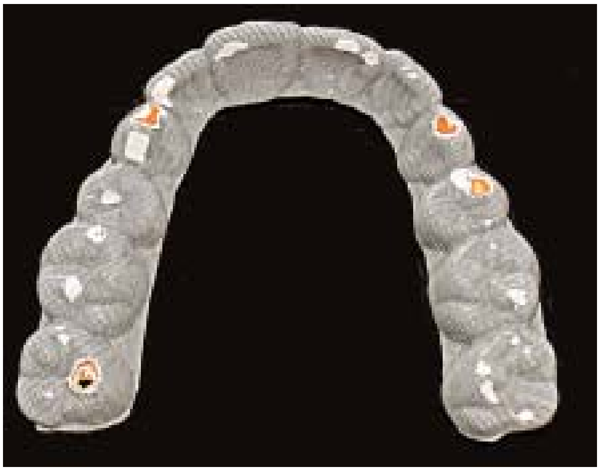

Fig 1a Photograph of a BBMD worn by a sleep bruxer for 5 consecutive nights. All the abraded layers can be seen.

Fig 1b Photograph of a BBMD worn by a control subject for 5 consecutive nights.

colors. The topmost surface is coated with a halftone dot screen.

In order to prepare an individual BBMD for each participant, maxillary impressions were taken. After a stone cast had been fabricated, the BBMD was made using a process similar to that used to make a hard or soft plate. The manufacturer recommends that the appliance be worn for 4 consecutive nights, but results of a university pilot study of the extent of abrasion on the BBMD favored its use for 5 consecutive nights. The participants in this study were therefore instructed to use the BBMD for a period of 5 consecutive nights.

Analysis of the Plate

After use, the plate was digitally photographed at a 90-degree angle and scanned. The photography conditions were standardized, ie, the distance between the BBMD and the camera aperture and the adjustment of the camera focus were constant for each photograph. This ensured a uniform benchmark for the test series. The photography took place in a daylight-isolated room with artificial scattered light in order to eliminate light reflexes. During photography, the plates were arranged on a dark background to obtain a definite background contrast. Figs 1a and 1b demonstrate 2 standardized photographs.

Further examination was carried out using the image processing software KS 300 (Carl Zeiss). On the basis of binary pictures, the software was able to calculate the uncovered abraded areas on the splint. As a result of the pronounced difference between the halftone dot screen and the uncovered colored layers beneath, clearly circumscribed areas appeared on the surface.

Initially, the software counted the number of pixels in the abraded area of each layer separately. Because the BBMD is composed of 4 layers, each of identical thickness, the depth parameter could be easily calculated. Both parameters, abraded area and depth, were combined for the assessment of a predominantly abrasive sleep bruxism activity in order to obtain a score, viz, the pixel score. By using an algorithm especially conceived and balanced for this purpose, the software automatically detected and counted the uncovered areas for the first 2 layers (white 1 and red 1). The assessment of the abraded areas in layers 3 and 4 proved to be more complex, because the BBMD consists of 4 layers with only 2 alternating colors. Therefore, the algorithm was not able to differentiate whether the uncovered area was, for example, located in layer 1 or 3. Figure 2 illustrates the layering of the BBMD. Layers 3 and 4 were uncovered in only 10.1% of the plates. In these, the abraded areas on layer 3 and/or 4 (white 2 and red 2) were assigned

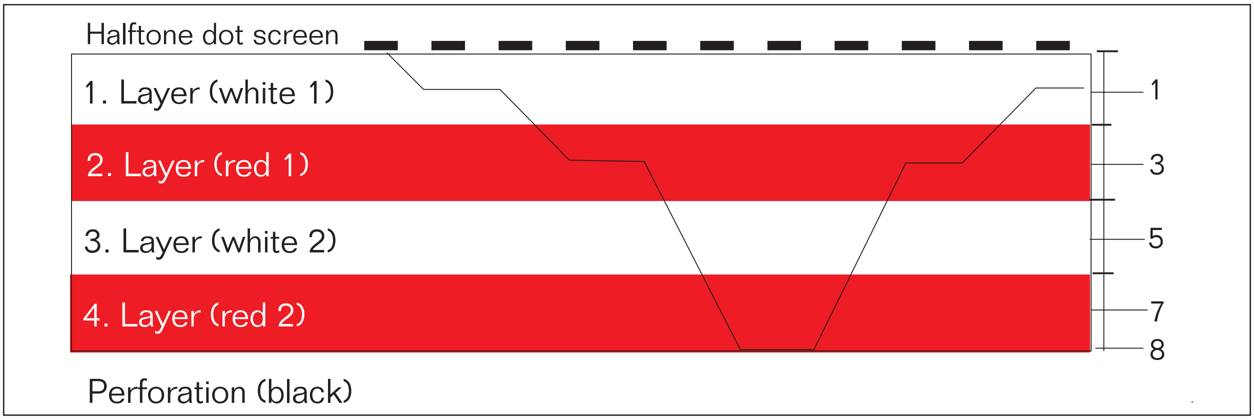

Fig 2 Schematic illustration of the cross-sectional profile of the BBMD. The halftone dot screen represents the uppermost surface, and the solid line a typical abraded area that included all areas of the BBMD. The numbers on the right refer to the factors used in the analysis of the layers.

manually by both raters, and the histogram function of the image processing software Photoshop version 6.0 (Adobe) was used subsequently to count the number of pixels.

Since it is necessary to abrade half of the cross-sectional dimension of a layer to assign the uncovered area to the respective layer, each layer was divided on a theoretical basis into 2 parts for further analyses. This resulted in a total of 8 parts for the 4 layers and, after theoretical consideration for the loading of the cross-sectional profile, the number of pixels in the abraded area of the first layer (white 1) was multiplied by a factor of 1, and that of the second (red 1), third (white 2), fourth (red 2), and last layer (black = perforation) by factors of 3, 5, 7, and 8, respectively.

Two raters carried out this semiautomatic analysis independently in order to verify the objectivity of this method.

Statistical Analysis

The statistical analysis was performed with the statistical software SPSS version 12. Intraclass correlation coefficient (ICC) was employed to estimate the interrater reliability. The pixel scores of SB and controls are presented as means with standard deviations (SDs). The significance was tested by the *t* test. The sensitivity (percentage of SB with sleep bruxism) and specificity (percentage of controls without sleep bruxism) of the new computer-based analyzing method, given as a pixel score of the BBMD, were also calculated. For this purpose, an appropriate cutoff point was derived after plotting the receiver-operator characteristic (ROC) curve of the mean pixel score of both raters.[29,30] As a measure for the diagnostic account of the method, positive and negative predictive values (PPV and NPV) of the selected cutoff point were evaluated.[31] The PPV reflects the percentage of participants reclassified as SB who were originally assigned to the SB group following the clinical examination. The NPV corresponds to the participants classified as controls originally assigned to the control group following the clinical examination. For all statistical analyses, an α-error probability of $P < .05$ was adopted as the level of statistical significance.

Results

Comparison of the 2 study groups showed no significant differences with respect to age, gender, or occlusal guidance (Table 1). For the entire sample, rater 1 calculated a mean of 6446.70 (SD = 6602.08) and rater 2 a mean of 6122.80 (SD = 6553.65) for the pixel score. The values, independently determined by the 2 raters, demonstrate an ICC of 0.99 with a statistical significance of $P < .01$. Figure 3 depicts the scatter plot diagram.

The measurements of rater 1 provided mean pixel scores of 8731.54 (SD = 6709.62) for the SB group and 1224.19 (SD = 1111.40) for the control group. Rater 2 obtained mean pixel scores of 8403.75 (SD = 6658.26) for the SB group and 909.19 (SD = 906.97) for the control group. The pixel scores collected for the SB ranged from a minimum of 187.50 to a maximum of 25,721.00 and for the control group from a minimum of 0 to a maximum of 3032.50. When the results of raters 1 and 2 were averaged together, the mean pixel

Table 1 Sociodemographic Data and Data Related to Occlusal Guidance

	SB	Control	P
Age* (y)	29.38 ± 4.41	28.10 ± 5.75	< .317
Gender	33 F; 15 M	13 F; 8 M	< .579
Canine guidance (%)	2.1	9.5	< .163
Incisal guidance (%)	25	28.6	< .756
Group guidance (%)	72.9	61.9	< .360

* Values are presented as means ± SDs.

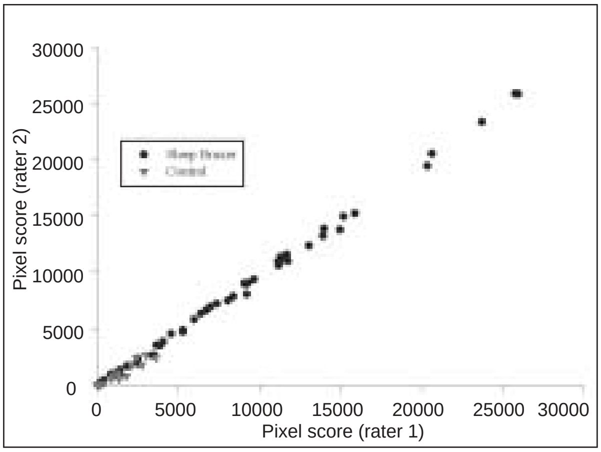

Fig 3 The pixel scores of the SB and controls are graphically presented as a scatter plot.

scores were 8567.65 (SD = 6682.10) for the SB group and 1066.69 (SD = 997.43) for the control group. All mean comparisons between the 2 groups were statistically significant ($P < .01$).

After the ROC curve was calculated for the averaged scores of both raters, the cutoff point was determined at a pixel score of 2,900. At this cutoff point, based on the clinical examination, the sensitivity of the new analyzing method of the BBMD amounted to 79.2% and the specificity to 95.2%. The PPV and the NPV were evaluated in relation to the clinical classification. With this cutoff value, it can be predicted that 97.4% of participants with a pixel score above the cutoff will be SB and that 66.7% of participants with a pixel score below the cutoff will not be.

Discussion

Previous analyses of the measurement of sleep bruxism activity using the BBMD were based on counting the number of missing microdots on the surface of the plate.[25–28] These investigations relied on the knowledge of the number of microdots per square millimeter on the plate previous to the fabrication of the customized plate. The present study evaluated a computerized method of estimating the abraded area in pixels. In order to avoid inaccuracies resulting from the deformation process in the vacuum-press, the BBMD was calculated independent of the missing microdots on the surface. The objectivity of this method was confirmed by assessing the interrater reliability. Additionally, it was investigated whether the developed algorithm distinguished between SB and controls.

Generally, the variability between individuals (interrater) is assumed to be greater than that within each individual (intrarater). As the present results demonstrated a very high interrater reliability (ICC = 0.99), the need to evaluate the intrarater reliability was considered negligible. This finding supports the objectivity of the described method. The measured interrater reliability was identical to that of the recommended method of analysis first published in 1974.[25,26] Up to now, measurement has been based on counting a predefined unit, the microdot; however, the previous method of analysis is associated with the aforementioned inaccuracies. The correlation coefficients range between 0.33 and 0.99 for other procedures, such as the application of a portable EMG-based recording system or the analyses of stone casts for the clinical assessment of current sleep bruxism activity.[24,32,33]

It is interesting to note that the pixel score obtained for the SB was approximately 8 times higher than that for the control group. Another research study of polysomnographic recordings in a sleep laboratory reported 8 times more rhythmic masticatory muscle activity episodes per hour of sleep in SB than in normal subjects.[4]

The cutoff point determined for the pixel score indicated good sensitivity, specificity, and predictive values. However, these results have to be regarded with caution because the participants were not confirmed to be SB in a sleep laboratory.

In terms of validated and objective parameters for the assessment and monitoring of sleep bruxism, polysomnographic recordings documenting sleep bruxism in a sleep laboratory are considered "the gold standard." The classification of the participants in this study as SB on the basis of clinical selection criteria, including the detection of abnormal tooth wear, could have caused subjects with signs of past sleep bruxism but without current sleep bruxism activity to be classified as SB or subjects with incipient sleep bruxism activity to be classified as controls.[34]

In this context, attention should be drawn to the fact that the BBMD measures a predominantly grinding movement, thus a sort of abrasive sleep bruxism, in contrast to an EMG recording which demonstrates every type of muscle activity. Previous investigators[27] had already assumed this after comparing nocturnal EMG recordings with the BBMD They supposed that the BBMD could have a therapeutic effect and that it would moreover measure a construct other than that measured by nocturnal EMG recordings. However, due to the fact that their sample was composed solely of SB and that they also used the conventional method of counting the number of missing microdots on the surface for the analysis of the BBMD, the results of the present study data can hardly be compared with their study. Our research team was also aware of the possibility that the integration of an occlusal appliance could affect the original sleep bruxism behavior. The exact mechanism of its effectiveness is, however, not yet understood.[15] The literature reveals contradictory results, partially due to differences in the type of occlusal appliance. A few studies found no reduction of sleep bruxism–related motor activity,[35–37] whereas others demonstrated a significant decrease of muscle activity in participants wearing a stabilization splint or a hard splint.[38,39] Moreover, an increase in EMG activity has been observed in approximately 20% of participants using a soft splint.[40] It is a limitation of the study design that a statement cannot be made as to whether the BBMD induces an increase of bruxism activity or causes a treatment effect. Due to the properties of the material, which is similar to a hard splint, a treatment effect could be possible. This could explain the fact that a discrete number of SB exhibited comparatively low pixel scores, overlapping with the range of the controls. To assess possible influences on the original bruxism behavior, polysomnographic recordings and the new analyzing method of the BBMD need to be compared. A polysomnographically diagnosed sample, including an SB group wearing a BBMD every night over a predefined period, an SB control group, and a healthy control group should be investigated in a follow-up study with a repeated measurement design.

In conclusion, the present data support the assumption that the newly developed analyzing method is a reliable technique for the interpretation of the BBMD, independent of the number of microdots on the surface of the plates, and concurrently it takes the depth parameter more precisely into consideration. The described algorithm appears to be sufficiently well balanced, so that the rater does not have to undergo extensive training. Thus, the BBMD combined with the newly developed computer-based analyzing method seems to be a clinically feasible instrument that allows the practitioner to quantify abrasion over a short period. Moreover, the investigation of the validity parameters, sensitivity, and specificity indicate the ability to differentiate between SB and healthy controls. These findings, however, need to be confirmed using polysomnographic recordings for the validation of the test group.

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