Variability in the Quantification of Abrasion on the Bruxcore Device

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The rate of abrasion of dental surfaces during short periods of time is difficult to measure clinically, but one quantifiable method is the use of the Bruxcore bruxism monitoring device. The aim of this study was to estimate the interobserver and intraobserver variation in the Bruxcore system using different reading methods. Fifteen volunteers used individually fabricated Bruxcore devices during 4 consecutive nights, and this procedure was repeated after 6 weeks. The abraded areas of the 30 Bruxcore devices were measured by two observers on two occasions and with three methods: microscope without a reference scale; microscope with a reference scale; and a computer-aided system. Intraobserver variation was small (5%), but interobserver variation was statistically significant for all three methods. The computer-aided system was superior to the other two methods. The interaction between Bruxcore values and observers was statistically significant for the microscope methods but not for the computer method. This was a desired property, indicating stability of the computer-aided method over the range of Bruxcore values observed. Small measurement errors, independent of the size of the measurements, can be expected using a trained observer and a computer-aided method for reading the Bruxcore bruxism monitoring device.
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Oromandibular parafunction is defined as "nonfunctional activity including clenching and grinding (bruxism) or rhythmic chewing-like empty mouth movements."[1] Abnormal wear of the teeth is a frequent consequence of sleep bruxism. In clinical practice, current parafunctional habits during sleep are diagnosed by a combination of ocular inspection of facets, typical defects on teeth, the patient's symptoms, or information from relatives on grinding sounds during sleep. Bruxism fluctuates over time and can be related to stress.[2] The majority of bruxing subjects are not aware of the phenomenon.[3]

For the clinician, the rate of dental abrasion is difficult to measure during short periods of time, but there are techniques available. One elegant but complicated procedure for measuring microwear is to examine epoxy replicas of dental impressions in a scanning electron microscope.[4] A more practical method for measuring the rate of abrasion in a short period of time and for a large number of patients is the Bruxcore bruxism monitoring device

(Bruxcore, Boston, MA) presented by Forgione[5] and Heller and Forgione.[6] This device is composed of laminated plastic sheets of different colors with a surface covered with microdots. The volumetric magnitude of abrasion is measured by counting the number of missing dots on the different layers. Referring to the counting of worn dots on the Bruxcore device, Pierce and Gale[7] found the interscorer reliability to be high among three scorers (range: $r = .97$ to $.99$, $P < .001$). However, in the experience of the authors of the present study, it is difficult to count a large number of missing dots with good precision. The aim of the present study was therefore to evaluate the interobserver and intraobserver variation in the Bruxcore system in relation to different measurement methods.

Materials and Methods

Fifteen women aged 22 to 53 years volunteered to participate in the study. They were all members of the staff of the Postgraduate Dental Education Center, Örebro, Sweden. The inclusion criteria were 14 teeth in each jaw, natural occluding contacts, a normal frontal vertical overbite, and no major occlusal interferences.

Outline of Study

Starting on a Sunday, the participants used a Bruxcore device during 4 consecutive nights. After 6 weeks, this procedure was repeated, yielding a total of 30 Bruxcore devices for analysis. The compliance was checked by identification of plaque using basic fuchsin stain painted on the Bruxcore device. The abrasion of each Bruxcore device was calculated by two observers using three different methods, and after 2 weeks these observations were repeated. For both observers, the time interval between the readings employing the different calculating techniques was 24 hours. The three methods were *(1)* microscope without a reference scale, *(2)* microscope with a reference scale, and *(3)* a computer-based system. The observers were calibrated for the various techniques prior to the study.

The Bruxcore

The Bruxcore is a plate, 0.6 mm thick, composed of four laminated poly(vinyl chloride) sheets of different colors. The topmost surface is printed with a halftone dot screen. To the naked eye, the surface of the Bruxcore looks grey, but the dots appear in a dissection microscope. In a prestudy evaluation of the density of dots on the Bruxcore sheet surface, 19.36 dots/mm^2 were observed.

Individual Bruxcore devices were fabricated in a vacuum press in which the Bruxcore sheet was heated and sucked over a maxillary plaster cast. The device was trimmed along the gingival margin. The degree of abrasion of the Bruxcore device was calculated by counting the number of missing dots (microscope-aided measurements) or the abraded area (computer-aided measurement) for each of the four layers. If the second, third, or fourth layer was exposed, the number of dots or the abraded area was multiplied by two, three, or four, respectively, and added to the first layer (Figs 1a and b).

Microscope-Aided Measurement

An Olympus SZ 40 dissection stereomicroscope (Olympus, Japan) with a range of magnification 7× to 40× was used for calculating the number of worn dots on the Bruxcore device (method 1). With the same microscope, the calculation was repeated using a step-shaped reference scale made from an unused Bruxcore plate and placed along the abraded areas (method 2).

Computer-Aided Measurement

A computer-aided measurement technique was achieved with a Macintosh IICi computer (Apple Computer, Cupertino, CA) equipped with a Neotech IG-ISV image grabber still video interface (Neotech, United Kingdom), which was connected to a Hitachi KP-C551 CCD camera (Hitachi Denshi, Japan) with a 55-mm Micro-Nikkor lens (Nikon, Japan). The grabbed picture of the Bruxcore was analyzed at magnification of 10× by using the software Optilab (Graftek, France). A perpendicular view of the abraded surface was measured (method 3). Before and several times during the study, a ruler was used to check the calibration of the equipment.

Statistical Analysis

The number of abraded dots, calculated from the microscope-aided assessments (methods 1 and 2), was divided by the density of dots per millimeter squared on the Bruxcore surface. Subsequently, all statistics were based on the abraded area expressed in millimeter squared. Analyses of variance in the computer package BMDP[8] were performed. Three major questions concerning the measurement processes were analyzed:

Fig 1a Bruxcore device with white abraded areas on the molars, the canines, and the left first premolar.

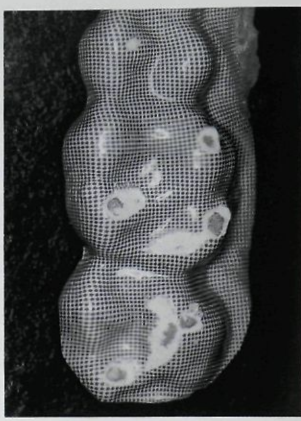


Fig 1b Same Bruxcore as in Fig 1a. The two molars exhibit extensive abrasion, and the second and third layers of the laminated Bruxcore device are visible.

1. Is it possible when simultaneously using different measurement methods and different observers to obtain measurement errors of constant (and small) variability?
2. If there are significant interactions between methods and observers, is it still possible to obtain measurement errors of constant (and small) variability with different observers simultaneously using one and the same method?
3. Is constant (and small) variability of the measurement errors most likely if only one observer uses the same measurement method throughout the whole observation series, and if so, which of the proposed methods has the desired properties?

Following the examination of these questions, the size of the measurement errors, and possibly the different components were to be estimated.

The statistical models allowed for both repeated measurements as well as the nesting of replications within methods and observers. In the first analysis, three major sources of variation—intraobserver, interobserver, and method—and their interactions were separated and expressed with their standard deviations (SD). Because the first analysis indicated interactions between methods, observers, and the size of the measurements, the second set of analyses were aimed at analyzing, conditional on method and observer, whether the measurement variability was approximately constant over the studied range, ie, the differences between the measurements should not increase or decrease with the size of the measured area. To examine this property, the approach outlined by Altman and Bland[9] was adopted. The absolute differences between the repeated readings were regressed on the mean values of the replications. Ideally, the regression line should have a slope equal to 0, and the deviations from the line should have a similar size over the whole range of measurements. In addition, the regression of the differences on the mean values of the replications will show if the differences tend to deviate systematically from 0 for higher measurements. The measurement error was expressed both as the coefficient of variation (SD/mean), and as a percentage of the total variation of the measured Bruxcore values.

Results

The mean values and standard deviations for the abraded area, aggregated over method, observer, and replication, are shown in Table 1. Inspection of the size of the standard deviations relative to the mean values indicated that the distribution of the

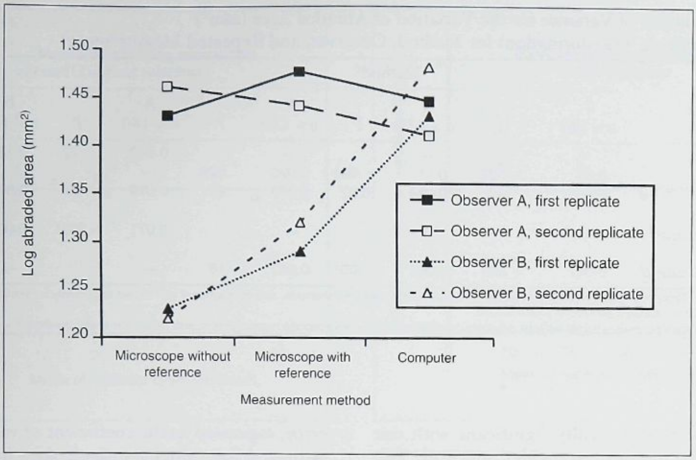


Fig 2 Mean Bruxcore abraded area for the methods, observers, and repeated measurements after logarithmic transformation (n = 30).

abraded area was positively skewed, ie, it was not a normal (gaussian) distribution. Accordingly, the data were logarithmically transformed, yielding a more gaussianlike distribution. The logarithmic transformation also improved the distributional properties of the measurement errors toward an approximately constant variability.

Figure 2 illustrates the mean values for the data separated for method, observer, and replication. Observer A showed the smallest intermethod variation. There was also an indication of an interaction between method and observer where observer A showed similar values for all three methods; observer B produced results that were not similar for all three methods. The interobserver variation was smallest for method 3. The intraobserver variation was small for both readers.

The interaction between method and observer indicated by the data in Fig 2 and confirmed by a first analysis of variance model with $P < .001$ for this interaction required a second formal statistical analysis separate for method and observer (Table 2). The interobserver variation was statistically significant for all three methods, although this was less evident ($P = .028$) for method 3 than for the other two methods. Observer A did not have a statistically significant intermethod variation ($P = .22$); observer B showed a statistically significant difference between the three methods ($P < .001$). The intraobserver variation never reached statistical significance.

Table 1 Means (and SD) for the Abraded Area (mm^2) Aggregated Over Method, Observer, and Repeated Measurement Before and After Logarithmic Transformation*

Source of variation	Untransformed data	Logarithmic data
Method†		
1	7.68 (11.35)	1.34 (1.29)
2	8.46 (12.60)	1.38 (1.34)
3	8.88 (13.17)	1.44 (1.34)
Observer		
A	9.14 (13.53)	1.44 (1.36)
B	7.54 (11.19)	1.33 (1.28)
Replication		
1	8.25 (12.02)	1.39 (1.32)
2	8.43 (12.68)	1.39 (1.32)

*Means and SD are based on 120 measurements for each method and on 180 measurements for each observer and replication.
†Method 1 = microscope measurement without reference scale; method 2 = microscope measurement with reference scale; method 3 = computer-aided measurement.

The most important results of Table 2 concern the interaction factors. The interactions between the Bruxcore values and the different methods and

Table 2 Analysis of Variance for the Variation of Abraded Area (mm²) (After Logarithmic Transformation) for Method, Observer, and Repeated Measurement*

Source of variation	Method† 1 n = 120	P	Method† 2 n = 120	P	Method† 3 n = 120	P	Observer A n = 180	P	Observer B n = 180	P
Method	—		—		—		0.012	.22	0.12	< .001
Interobserver	0.15	< .001	0.11	< .001	0.023	.028	—		—	
Intraobserver	0.069	.99	0.084	0.82	0.075	.81	0.076	.17	0.076	.12
Interaction Method × Bruxcore	—		—		—		0.071	< .001	0.099	< .001
Interaction Observer × Bruxcore	0.047	< .001	0.087	< .001	0.032	.16	—		—	

*Estimates of the different sources of variation (method, interobserver, and intraobserver, and interactions) are shown separately for method and observer and are expressed as standard deviations with P values.

†Method 1 = microscope measurement without reference scale; method 2 = microscope measurement with reference scale; method 3 = computer-aided measurement.

observers were statistically significant with one exception—the computer-aided method. The absence of a statistically significant difference is a desirable property because it indicates stability in the measurement method over the range of Bruxcore scores observed. The results thus far indicate that one observer and one measurement method is the most optimal way of measuring the Bruxcore scores.

The scattergram of the differences between the repeated measurements as a function of the mean of the replications indicated no trend for either of the two observers for method 3. The slope of the regression line was not statistically significantly different from 0. Method 1 in particular, but also method 2, did show increasing variability for larger values of the abraded area as well as a systematic deviation from 0 for large abraded areas. Observer A tended to have the most consistent results in these comparisons (Figs 3a to 3c).

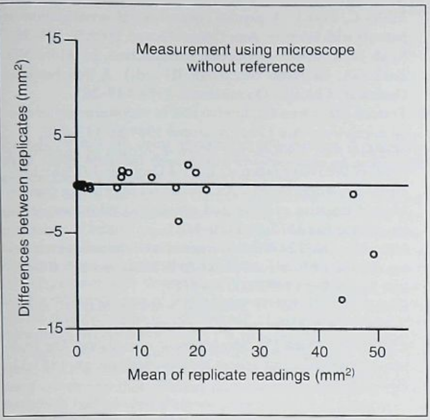
Estimates of the different sources of variation were expressed as standard deviations for the logarithm of the abraded area. The variation in the 30 Bruxcore values was estimated in the same units to be approximately 1.30. The intraobserver variation was approximately 0.07, thus about 5% of the standard deviation of the Bruxcore values, for all three methods and for both observers. Method 3, which had an interaction between observer and Bruxcore values that was not statistically significant, had an estimated interobserver variation of 0.023. The intermethod variation for observer A was 0.012, which was only one tenth of the corresponding value for observer B, although the presence of statistically significant interaction factors (method × Bruxcore) made these estimates less informative. The relative size of the measurement error, expressed as the coefficient of variation, was estimated from the logarithmic data for any given method and observer to be approximately 5%.

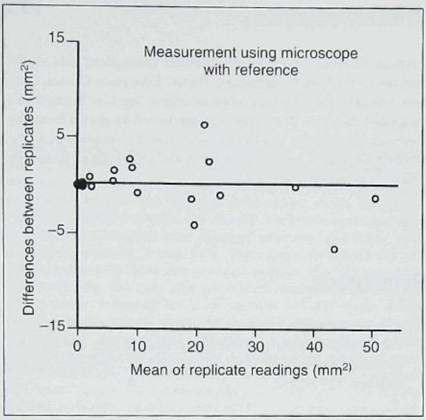
Discussion

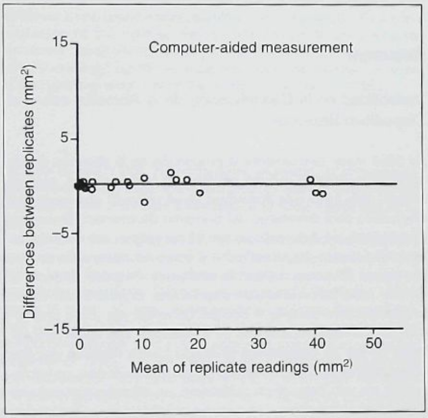
Originally measuring the degree of abrasion on the Bruxcore surface was done by calculating the number of abraded dots.[5] In the present study, we tried to improve the precision of the measurements by introducing two additional reading methods, in all yielding two microscope-aided methods and one computerized method. We found that the intraobserver variation between two duplicate readings was relatively small and of approximately the same size for the two observers and the three methods. In addition, we found that the intermethod variation differed with a magnitude of 10 between the two observers. The interobserver variation was at least five times higher for the microscope-aided methods than for the computerized one, although the presence of statistically significant interactions makes these estimates less informative than the estimates of the intraobserver variation.

In the statistical analysis, it was assumed that the variability for each method, observer, and repeated measurement was independent of the size of the abraded area. However, this was not always the case. The logarithmic transformation of the original data changed the distributional properties toward normality and improved the independence of the measurement variability. The relatively constant measurement variability for the computerized method was another advantage of this method.

Tooth abrasion during sleep depends on many factors such as the magnitude, direction, and dura-







Figs 3a to 3c Scattergrams for differences in repeated measurements of the Bruxcore device (n = 30) against mean values of the replications for the preferred examiner (observer A) and three methods.

tion of the force exerted; the number of occluding teeth; the antagonist abrasive capacity; and the basic characteristics of the saliva. The measurement of the abraded area of the Bruxcore device used in the present study meets several of the above requirements for a good estimation. However, no studies have previously been presented about the validity of the Bruxcore device, ie, the ability of the method to measure the desired property. Moreover, the Bruxcore device, which is not adjusted in occlusion, is reported to affect changes in bruxing activity.[7]

The cumulative electromyographic (EMG) signal from the masseter and the temporalis muscles may be used to measure oromandibular parafunction during sleep. The disadvantage with the EMG technique is, however, that it is difficult to separate tooth clenching from abrasive bruxism and other forms of parafunctional muscle activity. Pierce and Gale[7] also concluded that the Bruxcore device did not measure the same construct as did the EMG measure. Therefore, it is obvious that the gold standard must be divergent when measuring abrasive bruxism and bruxism, per se.

In conclusion, when using the Bruxcore device in scientific studies, we recommend that one trained observer measure the abraded area and that a computer-aided measurement method be used. This is likely to give small measurement errors that will be independent of the size of the abraded area. However, if the distribution of the actual measurements is not normal, a logarithmic transformation may be needed.

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Resumen

Variabilidad en la Cuantificación de la Abración sobre el Dispositivo Bruxcore

Es difícil medir clínicamente la proporción de la abración de las superficies dentales durante períodos de tiempo cortos, pero un método que se puede cuantificar es el utilizado por medio del dispositivo para monitoreo del bruxismo denominado Bruxcore. El propósito de este estudio fue el de estimar las variaciones ocurridas dentro del observador y entre los observadores con el sistema Bruxcore, utilizando diferentes métodos de lectura. Quince voluntarios utilizaron dispositivos Bruxcore fabricados individualmente durante 4 noches consecutivas. Este procedimiento fue repetido después de 6 semanas. Las áreas desgastadas de los 30 dispositivos Bruxcore fueron medidas por dos observadores en dos ocasiones y con tres métodos: un microscopio sin una balanza de referencia; un microscopio con una balanza de referencia; y un sistema asistido por un ordenador. La variación ocurrida dentro del observador fue pequeña (5%), pero la variación entre los observadores fue estadísticamente significativa en todos los tres métodos. El sistema asistido por un ordenador fue superior en comparación a los otros dos métodos. La interacción entre los valores Bruxcore y los observadores fue estadísticamente significativa en los métodos microscópicos pero no en el método que utilizó el ordenador. Esta fue una propiedad deseada, que indicaba la estabilidad del método asistido por el ordenador sobre la serie de valores Bruxcore observados. Se pueden esperar errores de medición pequeños, independientes del tamaño de las medidas, al utilizar un observador entrenado y un método asistido por ordenador para la lectura del dispositivo de monitoreo de bruxismo denominado Bruxcore.

Zusammenfassung

Unterschiede in der Messung der Abrasionen durch das Bruxcore-Gerät

In kurzen Zeitabständen ist klinisch die Quantität der Zahnabrasion schwierig zu messen. Es besteht aber die Möglichkeit, diese Abrasion durch eine spezielle Vorrichtung (Bruxcore-Gerät) zu quantifizieren. Ziel dieser Studie war es, die Verläßlichkeit dieser Methode zu testen.15 freiwillige Probanden trugen eine individuell hergestellte, spezielle Schiene während 4 aufeinanderfolgenden Nächte, dieser Versuch wurde nach 6 Wochen wiederholt. Die abradierten Stellen dieser Schienen wurden von 2 Untersuchern im Abstand von 6 Wochen und jeweils mit 3 unterschiedlichen Methoden gemessen: mit einem Mikroskop ohne Referenzmaßstab, mit einem Mikroskop mit einem Referenzmaßstab und mit einem computergesteuertem System. Die Messungen unterschieden sich innerhalb des selben Untersuchers wenig (5%), aber zwischen den beiden Untersuchern waren die Unterschiede für alle drei Methoden statistisch signifikant. Das computergesteuerte System war den anderen 2 Methoden überlegen. Eine Wechselwirkung zwischen den gemessenen Werten und den Untersuchern war für die Mikroskopmethoden signifikant aber nicht für die Computermethode, dies weist auf die Verläßlichkeit der computergesteuerten Methode hin. Kleine Meßfehler, die unabhängig von der Größe der Messungen sind, können aber auch bei einem geübten Untersucher bei der computergesteuerten Methode erwartet werden.