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COMMENTARY

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International consensus on the assessment of bruxism: Report of a work in progress

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Summary

In 2013, consensus was obtained on a definition of bruxism as repetitive masticatory muscle activity characterised by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible and specified as either sleep bruxism or awake bruxism. In addition, a grading system was proposed to determine the likelihood that a certain assessment of bruxism actually yields a valid outcome. This study discusses the need for an updated consensus and has the following aims: (i) to further clarify the 2013 definition and to develop separate definitions for sleep and awake bruxism; (ii) to determine whether bruxism is a disorder rather than a behaviour that can be a risk factor for certain clinical conditions; (iii) to re-examine the 2013 grading system; and (iv) to develop a research agenda. It was concluded that: (i) sleep and awake bruxism are masticatory muscle activities that occur during sleep (characterised as rhythmic or non-rhythmic) and wakefulness (characterised by repetitive or sustained tooth contact and/or by bracing or thrusting of the mandible), respectively; (ii) in otherwise

healthy individuals, bruxism should not be considered as a disorder, but rather as a behaviour that can be a risk (and/or protective) factor for certain clinical consequences; (iii) both non-instrumental approaches (notably self-report) and instrumental approaches (notably electromyography) can be employed to assess bruxism; and (iv) standard cut-off points for establishing the presence or absence of bruxism should not be used in otherwise healthy individuals; rather, bruxism-related masticatory muscle activities should be assessed in the behaviour's continuum.

KEYWORDS

assessment, awake bruxism, bruxism, clinical inspection, cut-off points, definition, electromyography, polysomnography, self-report, sleep bruxism

1 | INTRODUCTION

Classifications and definitions of bruxism are numerous and have varied widely for decades. In 2013, international consensus was obtained on a simple and pragmatic definition of bruxism as a repetitive masticatory muscle activity that is characterised by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible, and that is specified as either sleep bruxism or awake bruxism, depending on its circadian phenotype.[1] The average citation rate—almost 40 per annum—of the article in which the new definition appeared, and its inclusion in both the fourth edition of the Guidelines for Assessment, Diagnosis, and Management of Orofacial Pain of the American Academy of Orofacial Pain,[2] and the third edition of the International Classification of Sleep Disorders,[3] serve to confirm its rapid and broad adoption by the field. Nevertheless, several issues related to the new definition remain to be clarified, specifically the exact meaning of bracing and thrusting, and the common suggestion that as sleep bruxism and awake bruxism are different entities they require separate definitions.

Along with the new definition, Lobbezoo et al[1] proposed a system for grading assessments of bruxism that is for determining the likelihood that a certain assessment of bruxism actually yields a valid outcome. Accordingly, possible sleep/awake bruxism is based on self-report only; probable sleep/awake bruxism on self-report *plus* clinical inspection; definite sleep bruxism on self-report, clinical inspection *plus* polysomnography (preferably combined with audio/video recordings); and definite awake bruxism on self-report, clinical inspection *plus* electromyography (preferably combined with ecological momentary assessment/experience sampling methodology [EMA/ESM]). Unlike the rapid acceptance of the new definition for bruxism, the grading system ignited a series of exchanges focused on the practical utility of the system, on the status of bruxism as disorder, behaviour, or risk factor and on the consequences thereof in terms of diagnosis and management.[4-6]

In March 2017, an international consensus meeting, Assessment of Bruxism Status, with bruxism experts from around the globe (see Table 1) took place in San Francisco, CA, USA, prior to the 95th General Session & Exhibition of the International Association for Dental Research (IADR). The full-day meeting was organised by the first author of this article on behalf of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Consortium Network (now named International Network for Orofacial Pain and

TABLE 1 Participants and contributors to the RDC/TMD Consortium Network Bruxism Consensus Meeting ("Assessment of Bruxism Status") on March 20th, 2017

Name	City, State, Country
Jari Ahlberg[a,b]	Helsinki, Finland
Antoon De Laat[c]	Leuven, Belgium
Reny De Leeuw[a,c]	Lexington, KY, USA
Alan Glaros[a,b]	Kansas City, MO, USA
Takafumi Kato[a,b]	Osaka, Japan
Kiyoshi Koyano[a,c]	Fukuoka, Japan
Gilles Lavigne[a,c]	Montreal, PQ, Canada
Frank Lobbezoo[a,b]	Amsterdam, the Netherlands
Daniele Manfredini[a,b]	Padova, Italy
Karen Raphael[b]	New York, NY, USA
Vivian Santiago[b]	New York, NY, USA
Peter Svensson[a,c]	Aarhus, Denmark
Peter Wetselaar[b]	Amsterdam, the Netherlands
Efraim Winocur[a,b]	Tel Aviv, Israel

[a]Contributed to Lobbezoo et al.[1]
[b]Participated to the 2017 Consensus Meeting.
[c]Invited for the 2017 Consensus Meeting but unable to attend.

Related Disorders Methodology; INfORM) of the IADR. Invited experts unable to attend contributed to the consensus process via e-mail exchanges. All invited experts were included as co-authors of this article. The aims for the consensus meeting were as follows: (i) to further clarify the 2013 definition of bruxism, including the development of separate definitions for sleep bruxism and awake bruxism (ie, bruxism definition); (ii) to determine whether bruxism should be considered a disorder or merely a behaviour that can be a risk factor for certain clinical conditions (ie, bruxism status); (iii) to re-examine the 2013 grading system based on data for reliability, sensitivity and specificity of each source of information/ approach (ie, bruxism assessment) and (iv) to develop a research agenda for necessary studies on various bruxism topics (ie, research agenda). Following the consensus meeting, the first and last author of this article drafted the manuscript, which was then circulated by e-mail amongst the co-authors until consensus was reached.

2 | BRUXISM DEFINITION

Bruxism's international consensus definition[1] gave rise to several questions. First, whilst clenching and grinding of the teeth are well-known phenomena amongst dental researchers and clinicians, bracing and thrusting of the mandible appeared to need further clarification. According to Dorland's Medical Dictionary,[7] bracing means "holding parts together or in place" or "making something rigid or steady," whilst thrusting is described as "a sudden forceful movement." Translated to the masticatory system, bracing could be interpreted as forcefully maintaining a certain mandibular position and thrusting as forcefully moving the mandible in a forward or lateral direction—both activities without the necessary presence of tooth contact. This addition to "classical" bruxism activities (viz., clenching and grinding) accords with the current view that bruxism is mainly regulated centrally, not peripherally (ie, not caused by anatomical factors like certain characteristics of dental occlusion and articulation), and with the emerging consensus that bruxism may involve more than tooth contact.[8] However, it should be noted that current examination techniques may not differentiate between the associated masticatory muscle activities of clenching vs grinding, nor of bracing vs thrusting, and that novel approaches may be needed to better clarify the physiology and pathophysiology of such jaw activities.

Second, as sleep and awake bruxism are generally considered as different behaviours observed during sleep and wakefulness, respectively, the single definition for bruxism is recommended to be "retired" in favour of 2 separate definitions:

1. Sleep bruxism is a masticatory muscle activity during sleep that is characterised as rhythmic (phasic) or non-rhythmic (tonic) and is not a movement disorder or a sleep disorder in otherwise healthy individuals.
2. Awake bruxism is a masticatory muscle activity during wakefulness that is characterised by repetitive or sustained tooth contact and/or by bracing or thrusting of the mandible and is not a movement disorder in otherwise healthy individuals.

Note that both definitions begin with "masticatory muscle activity," a phrase intended to emphasise the role of the masticatory muscles during sleep and wakefulness as the source of potential clinical consequences. The emphasis on masticatory muscle activity is not intended to be limiting: studies of sleep bruxism or awake bruxism can include other measures (eg, heart rate variability, respiratory parameters, audio-video recordings).[9-11] However, it is imperative that at a minimum, studies on sleep and awake bruxism focus on masticatory muscle activity (or empirically validated proxies for it).

Also note that both definitions end with "in otherwise healthy individuals," a phrase added to underline that whilst in most persons bruxism is not a disorder, it is a sign of a disorder in some (eg, individuals with REM behaviour disorder, obstructive sleep apnoea, epilepsy, etc., where the condition requires full attention by the responsible clinician; see the third edition of the International Classification of Sleep Disorders[3]). From a nosological point of view, the adoption of different names for bruxism being, or not being, a sign of a disorder may be considered.

3 | BRUXISM STATUS

Amongst the series of exchanges over whether bruxism should be considered a disorder,[4-6] Raphael et al[4] pointed out that if higher levels of masticatory muscle activity increase the risk of negative oral health consequences (eg, severe masticatory muscle pain or temporomandibular joint pain, extreme mechanical tooth wear, prosthodontic complications),[12-14] bruxism should be considered a risk factor rather than a disorder in otherwise healthy individuals. Whilst a risk factor is an attribute that increases the probability of a disorder but does not "guarantee" it, a disorder is a condition that is a harmful dysfunction per se, that is inherently causing harm to the person and representing a dysfunction in normal biopsychosocial processes.[15] Thereby, bruxism would not be a disorder in otherwise healthy individuals but might be a risk factor for negative oral health consequences. If not a risk factor for another disorder, bruxism may "just" be a motor behaviour with a multifactorial aetiology. Note that the term "behaviour" is defined in Dorland's Medical Dictionary[7] as "deportment or conduct; any or all of a person's total activity, especially that which can be externally observed." This implies that behaviour does not necessarily mean 1 is aware of the activity, or that—in contrast—the activity is involuntary, which is neatly captured by the 2 circadian phenotypes of bruxism (viz., sleep bruxism and awake bruxism).

Notably, although supporting evidence is still inconclusive, in some individuals the behaviour may even have positive consequences for the bruxer (eg, being the ending episode of respiratory arousals, so as to prevent the collapse or restore the patency of the upper airway whilst asleep[16,17]; or reducing the risk of detrimental chemical tooth wear by increasing salivation in case of gastro-oesophageal

reflux[18]), which would classify bruxism as a potential protective factor that is an attribute that decreases the chance of a negative health outcome. In addition, it can be associated with other clinical conditions (eg, sleep apnoea or other sleep disorders) or symptoms (eg, xerostomia) without a cause-and-effect relationship.[19-21]

In short, in terms of clinical consequences, bruxism may thus be classified as any of the following:

1. Not a risk or protective factor: bruxism is a harmless behaviour.
2. A risk factor: bruxism is associated with 1 or more negative health outcomes.
3. A protective factor: bruxism is associated with 1 or more positive health outcomes.

It should be noted that the latter 2 possibilities are not mutually exclusive (eg, OSA patients may have severe tooth wear due to protective sleep bruxism). In addition, for clinical application of the above, a dichotomous system (viz., the risk factor "bruxism" being present or absent) may be desirable. However, a complicating issue is the fact that the cut-off point for defining bruxism as a risk factor may vary depending on the health outcome for which it increases (or decreases) the risk. In addition, the criteria for bruxism to qualify as a risk factor may depend on co-risk factors with which it may interact to increase the probability of a specific health outcome. Thus, it seems premature to consider implementing a simple dichotomous classification system for either sleep bruxism or awake bruxism. Moreover, whenever we recognise that the underlying behaviour and degree of risk is continuous that is more masticatory muscle activity has the potential to progressively increase the risk of a certain health outcome, dichotomisation becomes only a clinical convenience. It may be preferable to acknowledge that classification may need to specify multiple degrees of behaviour characterised by increasing levels of risk.

4 | BRUXISM ASSESSMENT

This all leads to the question of "how to assess an individual's bruxism in a reliable, valid, and relevant way?", where "relevant" means that, apart from the presence or absence of masticatory muscle activity, it serves a clinical purpose to determine the point at which bruxism is likely to become a risk (or protective) factor for a disorder.

Approaches for assessing bruxism can be distinguished as non-instrumental or instrumental.[22] The outcome of the international consensus discussion is summarised under the following 4 headings: (i) Non-instrumental approaches; (ii) Instrumental approaches; (iii) Cut-off points and (iv) Grading.

4.1 | Non-instrumental approaches

Non-instrumental approaches for assessing bruxism include self-report (questionnaires, oral history) and clinical inspection, both for sleep and awake bruxism.[11]

Self-reported assessment of sleep or awake bruxism continues to be the primary tool in bruxism research and clinical practice. Despite the poor concordance with instrumental approaches,[23] partly due to the criteria used for instrumental assessment of sleep bruxism, self-report may be quite useful for certain applications. For example, the fact that it has been significantly associated with some psychological conditions, such as stress and anxiety (both measured with validated methods)[24] as well as muscle and joint pain,[25-27] makes self-reported bruxism worthy of further exploration for the study of bruxism pathophysiology. The noteworthy limitation here is that the complex bruxism-psyche relationship could actually drive self-reporting of the condition and so self-report might reflect distress rather than actual masticatory muscle activity. Therefore, improvement of self-reporting to enhance reliability and validity compared to instrumental measures should be a priority.

Specifically, 2 domains can be examined based on self-report, viz., the possible presence of sleep bruxism or awake bruxism, and their timeframe, referring to how often the behaviour is reported during, for example, a 1- or 2-week period. However, intensity and duration of specific masticatory muscle activity cannot be quantified easily via self-report.[28]

Current approaches for assessing awake bruxism start by making the patient aware of what is meant by clenching and bracing/thrusting, most easily defined as the teeth touching not for swallowing purposes, and as increased levels of masticatory muscle activity without tooth contacts, respectively. The patient is then asked to monitor their behaviour over a 1- or 2-week period, so that on returning to the clinic they may more confidently answer the question of whether or not they hold their teeth together. They may be requested to note in a diary at the end of each day if they recall having clenched their teeth that day. This is preferable to just asking for a summary estimate at the end of the 1-2 week period. Data collection can be enhanced by so-called EMA, or ESM, which provides multiple time-point reports over an observation period[29] and has allowed data gathering on the association between tooth contact habits and masticatory muscle pain.[30]

Approaches for assessing sleep bruxism based on self-report, although theoretically more difficult than for awake bruxism as the patient is asleep whilst performing the activity, do allow for more options. Specifically, multiple informants can be interrogated, viz., not only the patients themselves but also their bed partner or—in the case of children—their parents. The patient is again asked to monitor their own behaviour, and to record if they have somehow noticed (or have been told) that they grind their teeth, keep their teeth together or brace their jaw whilst sleeping, preferably using a diary. The bed partner can also be asked to keep a diary to record if they hear the patient grind their teeth at night. Together, multiple assessment reports of patients and bed partners over a 1-2 week period can provide a range across patients that can be useful in research and clinical practice to rate the likelihood that a patient does engage in sleep bruxism.

Clinical features of both awake and sleep bruxism include the presence of masticatory muscle hypertrophy as well as indentations on the tongue or lip and/or a *linea alba* on the inner cheek. However, these signs can also be consequences of functional oromotor activity, such as swallowing.[31] Damage to the dental hard tissues (eg, cracked teeth), repetitive failures of restorative work/prosthodontic constructions, or mechanical wear of the teeth (ie, attrition) may also be indicators of awake bruxism and sleep bruxism. However, although attrition may be indicative of (especially) sleep bruxism, it does not rule out past sleep bruxism without current activity. For a comprehensive clinical protocol for the qualification and quantification of tooth wear, see Wetselaar & Lobbezoo.[32]

4.2 | Instrumental approaches

Instrumental approaches for assessment are currently available for both forms of bruxism. The recommendations below flow logically from the proposed definitions.

Electromyographic (EMG) recordings during wakefulness may provide key evidence of awake bruxism. Ecological momentary assessment/Experience sampling methodology app-based assessments for real-time subjective information about masticatory muscle activities at certain time points during the awake phase can also provide evidence of awake bruxism.

Electromyographic recordings during sleep provide key evidence of sleep bruxism. Electromyographic recordings may also include other measures used in somnography or polysomnography. Audio and/or video recordings can supplement EMG data. Issues of importance here include the threshold in the EMG channel(s) above which a masticatory muscle activity is considered a true activity burst or event. For example, the threshold can be determined as a percentage of the maximum voluntary contraction level, as n times the relaxed baseline level, or as the muscle activity level achieved during swallowing. Other issues concern the EMG outcome measures to be determined. Classically, the number of activities (as bursts, or clustered burst in episodes) are counted and expressed per hour of sleep (indices). Sometimes, the duration of these activities is summed up and expressed per hour of sleep.[33] Unfortunately, such data only give a partial representation of the amount and pattern of muscle activity. Thus, for a more accurate assessment, EMG outcome measures like power (area), peak amplitude and interval duration between activities could be included,[34-36] although the practical and valid use of such outcomes needs to be confirmed. Measures that help distinguish clenching from grinding in a feasible way would also be helpful additions.

4.3 | Cut-off points

For various reasons, using standard cut-off points for everyone for the "gold-standard" assessment of sleep bruxism[37,38] or non-sleep bruxism should not be considered optimal for clinical use in otherwise healthy individuals. Apart from the facts that cut-off points were originally proposed for research purposes, that some circularity is present in the criteria used to establish these cut-off points, and that they were established for research purposes in a super-selected study sample,[4] there is growing awareness that a cut-off point should not be used to describe a potentially harmless behaviour. On the other hand, if bruxism is a risk factor for certain oral health outcomes, clinical consequences may well depend upon the presence and extent of other risk factors. This issue is best exemplified by the still inconclusive literature on the polysomnographic assessment of sleep bruxism and its clinical consequences.[39]

Determining a cut-off point for each clinical consequence might prove to be unrealistic. Indeed, a variety of conditions may interact with bruxism (and with each other) in the clinical setting, thus influencing the particular degree of bruxism that leads to a negative health outcome. For instance, whilst prolonged clenching can be a very plausible overload mechanism for the masticatory muscles and temporomandibular joints,[40] once masticatory muscle fatigue or pain sets in, adaptation may lead to a reduction of masticatory muscle activity,[41,42] thus making it impossible to establish a clear cut-off for the presence of fatigue or pain.

Based on that, it is suggested that bruxism-related masticatory muscle activity should be assessed in its continuum, thereby not only focusing on the raw number of bruxism events to correlate with clinical consequences. Available data suggest it is not the number of bruxism events per se that represents a risk factor but rather the general level of EMG activity, which was found to be higher in temporomandibular disorder cases than in controls.[35] This means that in the case of sleep bruxism the total amount and duration of activity over relaxed baseline level should be measured. Similarly, for awake bruxism indicators should be used of increased waking EMG masticatory activity (ie, awake tooth contact) associated with increased probability of having a temporomandibular disorder.

4.4 | Grading

As outlined in the Introduction, Lobbezoo et al[1] proposed a grading system for bruxism to determine the likelihood that a certain assessment of bruxism actually yields a valid outcome. One of the main criticisms on this grading system, by Raphael et al,[4] was that the system is "stackable" (ie, self-report *plus* clinical inspection [*plus* instrumental assessment]), thus assuming that both self-report and clinical assessment yield fully sensitive but insufficiently specific outcomes compared to the gold-standard instrumental assessment. However, it is not unlikely for the presence of bruxism to be established instrumentally, whilst self-report and/or clinical inspection are negative. Therefore, it is suggested that the grading system proposed in 2013 is transformed as follows:

1. Possible sleep/awake bruxism is based on a positive self-report only.
2. Probable sleep/awake bruxism is based on a positive clinical inspection, with or without a positive self-report.

3. Definite sleep/awake bruxism is based on a positive instrumental assessment, with or without a positive self-report and/or a positive clinical inspection.

It should be stressed that this modified grading system is only a proposal, and may even be at odds with the difficulties associated with the application of cut-off points for assessing sleep bruxism and awake bruxism discussed above. Research is obviously needed to establish the reliability, validity and responsiveness to change of this new grading system.

5 | RESEARCH AGENDA

Clearly, we are still far from the ideal assessment of sleep bruxism and awake bruxism. Whilst research over the past 2 decades has shed light on the neurovegetative correlates of bruxism episodes,[43,44] future studies should be directed to a better comprehension of the possible clinical correlates, both negative and positive ones, within the paradigm of bruxism as a behaviour in otherwise healthy individuals. The challenge will be to establish the most reliable and valid approach (either a single 1 or 2 or more combined) that is also the most feasible. To that end, the A4 principle is suggested: accurate (reliable, valid), applicable (feasible), affordable (cost-effective) and accessible (suitable for everyday clinical use). In that context, several suggestions for research on the assessment of bruxism were put forward during the international consensus meeting in San Francisco.

The need for self-reported measures of sleep bruxism and awake bruxism requires research to become more precise on the specifics of the methods used. As a result, the intuition of the clinician when examining persons suspected of bruxing needs to become formalised in specific questions conducted over a period of time. In addition to determining which of the currently available questions and methods may be the most reliable, as well as the utility of employing EMA/ESM for self-report, research should also assess the potential bias that some self-reported methods are suspected of introducing. For instance, the clinician's preconceived ideas and the patient's hyperawareness of clenching via public media sources or following counselling from the dentist may tend to overestimate the true extent of bruxism activities. Regarding timeframes for self-report, here, we recommend 1-2 weeks, but is there an ideal time period based on research? For this purpose, longitudinal studies on the natural course of bruxism are needed. More generally, research should also adopt a multifactorial approach (ie, self-report *plus* different combinations of clinical signs/symptoms) that might be useful to create a model for predicting consequences. This could lead to discovering algorithms of specific clinical presentations in combination with self-report over a certain time period that would hopefully yield greater concordance with other (instrumental) measurements of bruxism and would be associated with clinical signs and symptoms. These are all verifiable questions that would improve the use of self-report.

There is a need for high-quality research on the instrumental assessment of both forms of bruxism. For example, we need to know how long to collect masticatory muscle activity for both circadian manifestations of bruxism to feel confident that we have a representative sample of an individual's "real life" bruxism. Similarly, we need to know how masticatory muscle activities associated with sleep and awake bruxism change over prolonged periods, including the life-span.

We have emphasised the need to collect masticatory muscle activity as an essential component for assessing both sleep and awake bruxism. For awake bruxism, studies on the concordance between EMG data and data collected via EMA/ESM are needed. Such research, even if technically difficult and with limitations (eg, the risk that wearing EMG electrodes on the face during wakefulness actually influences the behaviour under study), could be useful to delve deeper into the correlation between self-perception of muscle tension and actual activity of the masticatory muscles. We also need to collect concurrent data on possible aetiological factors, comorbidities and other risk factors that may contribute to negative (or positive) health outcomes associated with sleep bruxism or awake bruxism.

6 | CONCLUSIONS

1. Sleep and awake bruxism are masticatory muscle activities that occur during sleep (characterised as rhythmic or non-rhythmic) and wakefulness (characterised by repetitive or sustained tooth contact and/or by bracing or thrusting of the mandible), respectively.
2. In otherwise healthy individuals, bruxism should not be considered as a disorder, but rather as a behaviour that can be a risk (and/or protective) factor for certain clinical consequences.
3. Both non-instrumental approaches (notably self-report) and instrumental approaches (notably electromyography) can be employed to assess bruxism, but further research is needed to assess their use in the clinic, using the A4 principle described above: accurate (reliable, valid), applicable (feasible), affordable (cost-effective) and accessible (suitable for everyday clinical use).
4. Cut-off points for establishing the presence or absence of bruxism should not be used in otherwise healthy individuals; rather, bruxism-related masticatory muscle activities should be assessed in the behaviour's continuum.

DISCLOSURES

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