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REVIEW PAPER

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Research routes on improved sleep bruxism metrics: Toward a standardised approach

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Summary

A recent report from the *European Sleep Research Society's* task force "*Beyond AHI*" discussed an issue that has been a long-term subject of debate – what are the best metrics for obstructive sleep apnoea (OSA) diagnosis and treatment outcome assessments? In a similar way, sleep bruxism (SB) metrics have also been a recurrent issue for >30 years and there is still uncertainty in dentistry regarding their optimisation and clinical relevance. SB can occur alone or with comorbidities such as OSA, gastroesophageal reflux disorder, insomnia, headache, orofacial pain, periodic limb movement, rapid eye movement behaviour disorder, and sleep epilepsy. Classically, the diagnosis of SB is based on the patient's dental and medical history and clinical manifestations; electromyography is used in research and for complex cases. The

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emergence of new technologies, such as sensors and artificial intelligence, has opened new opportunities. The main objective of the present review is to stimulate the creation of a collaborative taskforce on SB metrics. Several examples are available in sleep medicine. The development of more homogenised metrics could improve the accuracy and refinement of SB assessment, while moving forward toward a personalised approach. It is time to develop SB metrics that are relevant to clinical outcomes and benefit patients who suffer from one or more possible negative consequences of SB.

KEYWORDS

dental sleep medicine, electromyography, obstructive sleep apnoea, phenotype, sleep bruxism, tooth-grinding

1 | INTRODUCTION

A recent 2020 paper in the *Journal of Sleep Research* summarised an issue that has been the long-term subject of debate, viz., the best metrics for obstructive sleep apnoea (OSA) diagnosis and treatment outcome assessments (Pevernagie et al., 2020). In this paper, members of the *European Sleep Research Society's* task force "*Beyond AHI*" critically appraised the current "gold standard" used to diagnose sleep apnoea, namely the apnea–hypopnea index (AHI). After summarising the evolution of this index and rigorously analysing the assumptions behind its use, the authors concluded that the use of the AHI as the prime diagnostic metric for clinically relevant OSA should be reconsidered. This paper, entitled, "*On the rise and fall of the apnea-hypopnea index: A historical review and critical appraisal*" inspired us to re-evaluate the current metrics for assessing sleep bruxism (SB).

Based on a proposed international consensus by a group of SB scientists, published in 2018, bruxism is currently defined 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 (Lobbezoo, Ahlberg, Raphael, et al., 2018). The dominant clinical manifestations of SB, based on self-reports and clinical examination, include awareness of a tooth grinding sound, jaw clenching, tooth wear, and morning jaw muscle pain or fatigue (Sateia, 2014; Stuginski-Barbosa et al., 2017). Opinion differs on whether SB should be considered as a behavioural and/or a motor condition, but in some cases it may be associated with detrimental consequences such as tooth damage, premature wear and tear of tooth restorations, headache, orofacial pain, and temporomandibular disorders (Mayer et al., 2016; Raphael, Santiago, & Lobbezoo, 2016a, 2016b). SB can occur alone or with comorbidities such as OSA and snoring, gastroesophageal reflux disorder (GERD), insomnia, headache, orofacial pain, periodic limb movement (PLM), rapid eye movement (REM) behaviour disorder (RBD), sleep epilepsy, and sexsomnia (Martynowicz et al., 2018; Mayer et al., 2016; Michalek-Zrabkowska, Wieckiewicz, Macek, et al., 2020).

Dental sleep medicine is complementary to medical sleep medicine, as dentists can screen for the presence of various sleep disorders or disorders that can also persist during sleep (e.g. OSA, insomnia, GERD, bruxism), of all ages, who consult them at least once a year. Although OSA diagnosis and management decisions are clearly in the domain of medical sleep physicians, dentists can contribute to screen individuals at risk of OSA and refer then to a physician, and in its management with oral appliances, and orthodontic and maxillofacial surgeries. Nevertheless, dentists can diagnose and manage SB in otherwise healthy individuals, i.e. in absence of medical comorbidities (Lavigne et al., 1999; Lobbezoo et al., 2016, 2020). The main issues, the why we should have metrics for SB diagnosis and how to use these, remain to be improved.

The use, misuse and validity of SB metrics have been recurrent issues for >30 years, and two "work in progress" consensus papers, and several commentaries on SB definition, classification, and methods of data collection have been published (Casett et al., 2017; Lobbezoo et al., 2018; Lobbezoo, Ahlberg, Raphael, et al., 2018; Manfredini et al., 2019, 2020; Meira & Ettlin, 2018; Raphael et al., 2016b; Stuginski-Barbosa et al., 2017; Thymi et al., 2021) The latest international consensus suggested classifying metrics as either being non-instrumental (self-report, clinical examination) or instrumental (electromyography [EMG]) (Lobbezoo, Ahlberg, Raphael, et al., 2018). However, there is still uncertainty in respect of the optimisation, improvement, and clinical relevance of SB research metrics and scoring criteria; on how to perform data collection and scoring; and which tools/devices are the best to use. Due to the lack of standardisation in data collection methodology and analyses, and a consensus regarding the interpretation of the data, the translation of new evidence to clinical practices may be difficult. Clearly, diagnostic and treatment outcomes need to be supported by evidence-based data.

The objectives of the present review are to: (a) examine the use and misuse of SB metrics in a larger context based on the aforementioned work on the AHI and OSA; (b) critically review the history of masticatory muscle activity (MMA; also named RMMA, the "R" was for rhythmic) scoring criteria, initially used for research purposes or investigation of mechanisms; (c) examine the reasoning behind the common practice of performing sleep testing for a definitive SB diagnosis, which is probably not essential for all individuals with

SB clinical manifestations; and (d) stimulate the development of an evidence-based collaborative taskforce on SB metrics. The final aim should be the identification of the most predictive clinical manifestations and observations (muscle activity and/or other variables) with use of the most accurate scoring method for diagnosis and treatment decision-making to preserve the optimal health and quality of life of individuals with SB.

2 | FROM OSA METRICS TO SB METRICS

From the 1970s, presence and severity of sleep apnoea syndrome was quantified uniquely by apnoea. In the early 1990s, hypopnea was added, with specific characteristics to classify it as a sleep-disordered breathing condition, with regular updates from the *International Classification of Sleep Disorders*, of the *American Academy of Sleep Medicine (AASM)*, this from 1990 to 2014 (AASM, 2014; Guilleminault et al., 1973). In adult individuals, an AHI of <5 events/hr was considered normal, 5–14.9 events/hr mild, 15–29.9 events/hr moderate, and ≥30 events/hr severe OSA (Gottlieb & Punjabi, 2020; Pevernagie et al., 2020).

Identifying the best metrics for OSA is considered a "work in progress", and studies continue to seek to better explain the cause(s) of OSA, improve diagnostic sensitivity and specificity (predictive values), and identify the most significant factors that influence or contribute to predicting health outcomes and that can be used to help clinicians and patients to select the most effective treatments (Pevernagie et al., 2020). New technologies and analysis methods may be proven to be complementary or decisive metrics in respect to OSA screening, diagnosis, treatment choice, and disease outcome. These include blood and salivary biomarkers and the use of artificial intelligence (Dutta et al., 2020; Fleming et al., 2018; Kheirandish-Gozal & Gozal, 2017; Stretch et al., 2019; Yan et al., 2019).

In respect of SB, two consensus papers raised similar issues (Lobbezoo et al., 2013; Lobbezoo, Ahlberg, Raphael, et al., 2018), and an effort to standardise awake bruxism and SB multi-dimensional evaluation system is emerging (Manfredini et al., 2020). The notion will be to develop a system in two axes: Axis A, which will be subject-clinically and -instrumentally based taking into consideration aetiological/risk factors; and Axis B assessing groups of factors and conditions such as psychosocial, sleep, drug and substance use or abuse ones. In a similar way to OSA and the use of AHI, it is probably also time to move beyond the use of a single instrument, which in the case of SB is the EMG MMA index. The development of new technologies and analysis methods offer a unique opportunity to identify the best SB metrics with a global assessment of medical-social-psychological and clinical data of a given individual. Ideally, these should be personalised to the clinical manifestations and the expected outcome. Moving toward the use of the best metrics for diagnosis and for assessing treatment outcomes, which are based on research evidence collected with standardised methodologies and the most accurate technologies, is essential.

3 | SLEEP BRUXISM AND COMORBIDITIES

Although SB is not a life-threatening condition, it can be concomitant to other conditions and sleep disorders, such as, in alphabetic order and not ranked by importance: GERD, insomnia, OSA/snoring, periodic limb movements of sleep (PLMS) up to sexsomnia, RBD and sleep epilepsy; the last three being less frequent (Martynowicz et al., 2018; Mayer et al., 2016). Each condition needs to be evaluated independently, because comorbidities may coexist (be coincidental) without interacting or may be a risk factor and/or contribute to explaining the onset or exacerbation of MMA-SB (Ahlberg et al., 2020). The cause-and-effect links, as for example between OSA and SB, GERD and SB, or PLM and SB, remains to be demonstrated and is most likely occurring in sub-groups of individuals with some yet to define phenotype. For most individuals, MMA activities are not a risk for general or oral health. Indeed, it has been suggested that MMA during sleep may contribute to lubricating the oropharyngeal tissues and, as such play a putative positive role in maintaining airway patency (Khoury et al., 2008; Lavigne et al., 2003; Manfredini et al., 2015). Furthermore, SB can also be relieved, exacerbated, or be secondary to different medications, e.g. clonidine and selective serotonin reuptake inhibitors (de Baat et al., 2020; Mayer et al., 2016; Melo et al., 2018). However, due to the low level of evidence, caution is required before generalising the associations between SB to comorbidities and/or use of medications to observed clinical manifestations that may be more prone to occur in more vulnerable individuals.

4 | SCREENING AND DIAGNOSIS TOOLS OR DEVICES USED FOR OSA AND SB

Examining the evolution of the tools used for OSA screening and diagnosis is illustrative of what we need to develop for SB. For OSA, several screening questionnaires are available (e.g. STOP-Bang [snoring, tiredness, observed apnoea, high blood pressure, body mass index, age, neck circumference, and male gender], Berlin, NoSAS [Neck circumference, Obesity, Snoring, Age, Sex]) (Chiu et al., 2017; Marti-Soler et al., 2016). For SB, several screening questionnaires are also available, but their validity for clinical use and for health outcomes still needs to be fully established (e.g., BRUX scale, Oral Behaviours Checklist) (Markiewicz et al., 2006; van der Meulen et al., 2006).

For diagnosis, home sleep apnoea testing (HSAT) with only one channel for oximetry (Type 4) can contribute to the possible recognition of a sleep breathing disorder, while the use of Type 2 (unattended home polysomnography [PSG]) and Type 3 multi-channels (cardiorespiratory polygraphy) HSAT, or especially sleep laboratory PSG (labelled as Type 1) are better tools to establish a definitive/confirmatory diagnosis. Importantly, the initial diagnosis of OSA also includes data from the patient's medical and lifestyle history, as well as considering clinical indicators (i.e., body mass index, fat distribution, the anatomy of the upper airway). Although

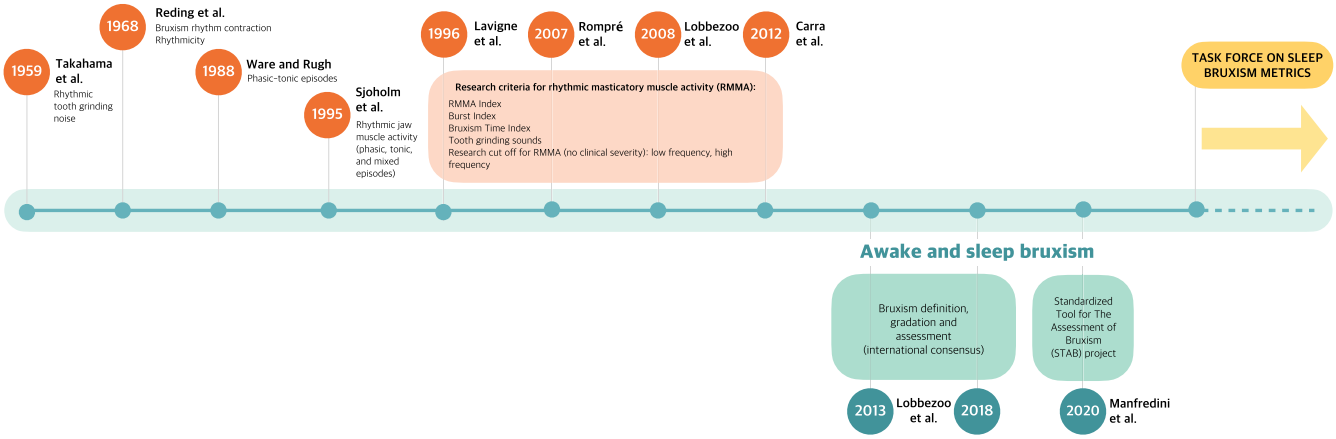

FIGURE 1 Historical timeline describing the evolution of sleep bruxism scoring and cut-off metrics over time. References from depicted studies: (Carra et al., 2012; Lavigne et al., 1996; Lobbezoo et al., 2008, 2013; Lobbezoo, Ahlberg, Raphael, et al., 2018; Manfredini et al., 2020; Reding et al., 1968; Rompre et al., 2007; Sjoholm et al., 1995; Takahama, 1959; Ware & Rugh, 1988)

HSAT is the current standard for assessing a definitive diagnosis of at-risk individuals (Kapur et al., 2017), the diagnosis may also include the following clinical manifestations: sleepiness and fatigue, unrefreshing sleep, unexplained nocturia, gastroesophageal reflux, morning headache, frequent awakenings, awareness of cessation of breathing, and/or intermittent snoring. There are some specific phenotypes, observable genetic or environmental characteristics that do not directly explain the disorder, but can contribute to predicting OSA and its consequences. These include gender (not only being a male; women have their own characteristics such as dominant breathing events in REM sleep and higher mortality), older age, anatomical factors (e.g. retrognathia), physiological breathing activity and responsiveness (e.g. low to high loop gain, arousal threshold, oropharyngeal muscle tone) (Basoglu & Tasbakan, 2018; Carberry et al., 2018; Eckert & Malhotra, 2008; Lavigne et al., 2020; Won et al., 2020). The clustering of phenotypes can contribute to define endotypes, a subtype of a condition implying distinct pathophysiological mechanisms. The importance of investigating phenotypes and endotypes is largely related to achieving a high level of precision medicine in the management of sleep disorders (Light et al., 2019; Malhotra et al., 2020; Pepin et al., 2018). An example of the latter can be observed in OSA, where individuals presenting certain endotypes may obtain more benefits from specific management strategies (Lavigne et al., 2020). For instance, individuals with OSA that present a lower loop gain, higher arousal threshold, moderate pharyngeal collapsibility, and weaker muscle compensation showed a better response (in respect of the AHI OSA metric) to oral appliance therapy, which was independent of body mass index and neck circumference (Bamagoos et al., 2019). Regarding SB, we still need to clarify the presence of distinct phenotypes, e.g. using different characteristics based on autonomic heart rate variability and sleep arousals, age, gender, and comorbidities, which could contribute to MMA genesis and, therefore, could help us to make a more appropriate SB diagnosis, based on risk and patient characteristics, and deliver targeted treatment in accordance to precision medicine (Castroflorio et al., 2017; da Costa Lopes et al., 2020; Mayer et al., 2016; Wieczorek et al., 2020).

According to the *AASM*, HSAT for sleep apnoea is indicated only for suspected cases, and not as a screening procedure in the general population: in "*uncomplicated adults presenting with signs and symptoms that indicate an increased risk of moderate to severe OSA*", based "*on the patient's medical history and a face-to-face examination by a physician, either in person or via telemedicine*", HSAT "*should not be used for general screening of asymptomatic populations*" (Rosen et al., ,2017, 2018). Hence, due to the apparent absence of treatment benefits for otherwise OSA asymptomatic cases, screening is not recommended for all individuals without a risk and probability assessment (Jonas et al., 2017). The recommendations in respect of SB suspected cases remain to be delineated, as described below.

For decades, the MMA-SB EMG biomarker was predominantly used in research and in clinical settings without a clear assessment of its predictive value on oral health outcomes (Manfredini et al., 2019). It remains to be demonstrated, as discussed below, whether other instrumental metrics such as salivary, blood or microbiota biomarkers; tooth contact or jaw movement may be more accurate in assessing the effects of SB on health and quality of life. Furthermore, home SB testing may not be needed for all individuals with SB; we need to set criteria for such a decision based on the personal and social impact of SB, and the presence of comorbidities.

5 | MASTICATORY MUSCLE ACTIVITY-SB SCORING: A HISTORICAL PERSPECTIVE – FROM PRAGMATIC RESEARCH CRITERIA TO CLINICALLY SUITABLE CRITERIA

Clinical science is always a work in progress, in close relation with technological developments and social trends. The history of how "pragmatic" scoring and MMA cut-off criteria emerged needs to

be reiterated; see Figure 1 for a timeline. These empirical and non-evidence-based criteria were derived from the literature for research purposes, such as for scoring PSG data on characteristics or mechanisms studies of SB.

In this respect, in 1968, Reding et al., suggested criteria for a SB sleep laboratory EMG study undertaken at the University of Chicago (Reding et al., 1968). These were defined as rhythmic EMG incidents when Type 1 sleep laboratory PSG was used. A rather acceptable scoring reliability was reported between scorers, with an inter-scorer agreement of 92%. It appears that the authors recognised that tooth-grinding, a typical clinical sign of SB, was characterised by rhythmic EMG incidents, as previously reported by Takahama (1959).

In 1988, a significant case series from Ware and Rugh from San Antonio, Texas, USA, proposed criteria to assess the duration and amplitude of rhythmic events (Ware & Rugh, 1988). In this paper, for the first time to the best of our knowledge, a distinction between types of EMG patterns was made, and phasic and tonic events were born (Ware & Rugh, 1988). Subsequently, in 1995, the differential scoring of masseter EMG events into phasic (tooth grinding episode), tonic (clenching), and mixed events (combination of both) was adopted by a Scandinavian group that proposed "rhythmic jaw movement" was characteristic of "heavy bruxists" (Sjoholm et al., 1995).

In 1996, a Canadian group proposed the use of RMMA to characterise EMG recordings of the masseter, temporalis, and digastric jaw muscles. The proposal was made by Jacques Montplaisir, a sleep scientist in PLMs, who had used EMG recordings of the anterior tibialis muscle as an index of events/hr of sleep, in his mechanistic and clinical researches on that sleep disorders. The "R" for rhythmic in RMMA was proposed in analogy to the "P" for periodic of PLMs, as these muscle events tend to recur over the course of sleep. To reach the objectives of SB research, i.e. to test mechanistic hypotheses that could help to better understand the genesis of MMA (formerly named RMMA), the Montreal group used receiver operating characteristic curve analysis. Research cut-off points of >4 events/hr were identified for Type 1 recording. These preliminary cut-off points were derived from a small sample size of young and otherwise healthy individuals, with and without tooth grinding complaints (Lavigne et al., 1996). Rompré, with colleagues from the same research group, identified in a larger population a subgroup of SB individuals with a low MMA frequency with no or a limited history of tooth grinding sounds. The individuals with 2–4 events/hr of sleep were different in respect of clinical manifestation (greater self-awareness of awake bruxism/clenching and report of morning jaw muscle pain/fatigue) compared to those with moderate to high (≥4 events/hr) MAA indexes (Rompre et al., 2007).

Moving from the traditional PSG to ambulatory EMG recording, a Dutch group found an MMA index of 2.1 events/hr of sleep, clinically identified SB individuals. Furthermore, they proposed another scoring variable, a bruxism time index that was three-times higher in SB compared to non-SB individuals (Van Der Zaag et al., 2008). The estimation of this interesting outcome, the duration of the bruxism, may have relevance when assessing MMA in relation to the presence of conditions such as pain, headache, tooth damage and, as has recently been suggested, comorbid OSA (Smardz, Martynowicz, et al., 2020).

6 | SLEEP BRUXISM EMG CUT-OFF MIGRATION FROM SLEEP LABORATORY TO HOME TESTING

In the absence of other alternatives, the EMG cut-off points established in the research described above were later used in general and clinical population studies, although they were not initially produced for such purposes (Maluly et al., 2013; Martynowicz et al., 2019; Sateia, 2014). Clinical cut-offs were also proposed for home ambulatory recording studies assessing SB; with some studies using cut-offs similar to those observed in sleep laboratories, while others adopted much higher values (Castroflorio et al., 2014; Maeda et al., 2020; Stuginski-Barbosa et al., 2017; Van Der Zaag et al., 2008; Yamaguchi et al., 2020). The fact that ambulatory MMA scoring demonstrated such large differences highlights the lack of methodological standardisation and the need for more effort to standardise SB metrics (Manfredini et al., 2020). These discrepancies may be influenced by challenges related to discriminating MMA from other orofacial activities in the absence or in the presence of comorbidities, and furthermore, to identify when EMG events during sleep occur in short wake stages.

Indeed, use of EMG alone may limit the accuracy and specificity of MMA scoring. The use of audio-video can contribute to avoiding over-scoring MMA, and newer developments using Type 3 sleep recording devices have also contributed to better accuracy of MMA results (Carra et al., 2015; Castroflorio et al., 2014; Miettinen et al., 2020; Saczuk et al., 2019). In the absence of audio-video, it may be wise to recognise that over-scoring of EMG events is possible, this may be partly due to the occurrence on non-MMA-specific oral activities such as snoring or swallowing, vocalisation, sucking and grunting, tooth tapping; diagnostic accuracy is then a challenge (Carra et al., 2015; Dauvilliers et al., 2018; Dutra et al., 2009; Kato et al., 2013). The recognition of MMA from other orofacial activities may also represent sleep instability or some sleep disorders that may not be captured using MMA scoring algorithms that are too restrictive (Carra et al., 2011; Kato, Katase, et al., 2013). Although one-channel Type 4 recording tools may have some value, users should keep in mind they cannot confirm the absence or presence of concomitant conditions, e.g. OSA, or rare conditions such as sleep epilepsy or the presence of RBD that may represent neurodegenerative risk. EMG activities of the masseter and/or temporalis muscle can be briefer than the contraction associated with SB, such as is the case in epileptic spikes, or idiopathic or RBD-related myoclonic contraction (Abe et al., 2013; Kato, Katase, et al., 2013; Kato et al., 1999). Alternatively, they may be long tonic contractions characteristic of OSA (Smardz,

Martynowicz, et al., 2020), or have a persistent EMG tone similar to awake levels, with no EMG dipping, in some individuals with jaw muscle pains (Santiago & Raphael, 2019). Furthermore, if MMA alone is to be used, it should be done for values estimated ideally when the individual under testing is definitely asleep, so as to exclude the wake stage during non-REM and REM sleep.

Single-channel home SB recording is easy and inexpensive to use and has high patient acceptability for multiple recordings, and has been a great technological improvement in dental sleep medicine, but it is limited due to the absence of audio-video, lack of EMG specificity, and wake/sleep recognition. Therefore, its diagnostic validity remains to be proven, as does its predictive value for health risk and treatment assessments.

Moreover, as in the case of AHI, whether to use grading with cut-off points or a continuum curve is another debate. In addition, MMA metrics used for adults needs to be accustomed for testing in children or adolescents with Type 2 and 3 or single-channel Type 4 recording systems. Furthermore, scoring with a Type 3 or 4 recording device has not yet been standardised, and is not fully in agreement with clinical manifestations and parental or sleep partner reports (Huynh et al., 2016; Manfredini et al., 2020; Restrepo et al., 2018).

Although these MMA-SB instrumental metrics have research potential, their clinical validity remains to be determined (Manfredini et al., 2019; Stuginski-Barbosa et al., 2017). The use of a single biomarker, hence the EMG-MMA, is probably pushing us to move beyond similarly to the ongoing trend in the use of AHI for OSA in sleep medicine.

7 | SLEEP BRUXISM DIAGNOSIS – FROM CLINICAL INTUITION TO EVIDENCE

Sleep bruxism is not a "one type and one treatment" condition for all individuals. It is a multifaceted condition, and it can have different age and sex/gender manifestations. Moreover, SB can be associated with various behaviours and/or health conditions that have some health hazard (Lobbezoo, Ahlberg, Raphael, et al., 2018; Mayer et al., 2016; Michalek-Zrabkowska, Wieckiewicz, Smardz, et al., 2020). Therefore, age, sex/gender, and the presence of comorbidities need to be considered when making a diagnosis (Mayer et al., 2016; Smardz, Wieckiewicz, et al., 2020).

Ultimately, not all patients with SB will need treatment, but whether they do or not is a decision that is currently made empirically. Similarly to OSA, the risks to health (including oral health) and the quality of life of individuals with SB (and probably sleep partners if a grinding noise is a major complaint) should form the basis for this decision, using a personalised approach focussed on the individual when it is time to select treatments (Edwards et al., 2019). Again, the use of artificial intelligence will probably help us to expand our capacity and the speed of reaching a differential diagnosis, hopefully improving the accuracy of a definitive diagnosis and leading toward a better selection of treatment plans.

8 | DETERMINING THE NEED FOR HOME TESTING IN INDIVIDUALS SUSPECTED OF HAVING SB

In respect of SB diagnosis and treatment decisions, the words "work in progress", which were used in the Lobbezoo and colleagues 2018 consensus paper, sum up the current situation, particularly when taking into account the presence of comorbid sleep conditions that can further complicate the situation (Cunha et al., 2020; Lobbezoo, Ahlberg, Raphael, et al., 2018; Mayer et al., 2016). For a SB diagnosis, based on non-instrumental (e.g. self-reports, visual tooth wear observation, medical and dental history) and instrumental (e.g. EMG) approaches, a gradation was proposed and recently revised by the International Bruxism Consensus Group (Lobbezoo et al., 2013; Lobbezoo, Ahlberg, Raphael, et al., 2018):

- Possible SB/awake bruxism is based on a positive self-report only.
- Probable SB/awake bruxism is based on a positive clinical inspection, with or without a positive self-report.
- Definitive SB/awake bruxism is based on a positive instrumental assessment, with or without a positive self-report and/or a positive clinical inspection.

Although this gradation system seems intuitive and logical to use for SB, it needs to be further tested for its concordance with clinical severity and sensitivity, and in respect of outcome assessments. The emergence of portable EMG (Type 4 recording devices) to monitor SB activity, as well as more recent innovations, have provided tools to better assess the agreement between clinical history and manifestations, and long-term changes in MMA behaviour, as well as assessment of treatment outcomes (Jadidi et al., 2013; Solberg et al., 1975).

It may be too early to conclude when and how we use home testing for SB in the absence of any manifestation of breathing disorders or neurological conditions. As listed in item 3 of Table 1, a critical question emerges: "Do all individuals with possible to probable SB need home EMG-MMA (or equivalent) sleep testing in the absence of an at-risk health comorbidity?" Furthermore, many issues (see Table 1) need to be clarified, such as what are the best tests to use (Type 3, or single-channel Type 4) before recommending home EMG-MMA (or equivalent) recording for SB in otherwise healthy individuals (Manfredini et al., 2020; Mayer et al., 2016).

It may be time to develop a SB metric taskforce as was done for AHI (Pevernagie et al., 2020); such a task force should include a consideration of self-reports, medical and dental history, clinical observation, and putative quantitative metrics such as MMA or others to be demarcated and validated. These may include salivary, blood or eventually microbiota sampling (Michalek-Zrabkowska, Wieckiewicz, Smardz, et al., 2020); methods estimating tooth contact (by smartphone technologies or *in situ* bio-sensing in the mouth or embedded in an oral splint) and assessing heart and hypoxia activities (Castroflorio et al., 2014; Colonna et al., 2020; Funato et al., 2014; McAuliffe et al., 2015; Mizumori et al., 2013; Saczuk et al., 2019;

TABLE 1 Path to explore and to improve sleep bruxism (SB) metric validity and clinical relevance

1. Clarify semantics and terminology
2. Clarify, as is the case for OSA, that SB can be symptomatic (e.g. a relevant clinical manifestation with the confirmed presence of an SB-related EMG event and comorbid health risks). but also asymptomatic (e.g. the presence of SB-related signs and symptoms, sometimes with an EMG event but no associated health risk)
3. Decide whether individuals with possible to probable SB need home sleep testing in the absence of at-risk health comorbidity
4. Define when and how Type 3, or Type 4 home sleep testing should be used
5. Clarify concordance or discordance when data from Type 1 sleep laboratory testing with audio-video are compared to Type 2 (unattended home PSG) or Type 3 multi-channels (cardiorespiratory polygraphy), or to Type 4 single-channel recording methods
6. Clarify that data collection should be done with tools that have the best currently available ecological validity (i.e. represent as much as possible the condition and risk we want to assess), that are non-invasive, secure (biologically and provide safety for personal data), and cost efficient
7. Validate the scoring criteria for masticatory muscle activity (MMA) subtype events and other emerging methods or biomarkers such as salivary mediators, heart and oxygen variables, jaw movement and/or sound for various ages and gender groups
8. Validate the relevance of scoring MMA subtype events (phasic, tonic, mixed event; non-specific orofacial activity, myoclonus, etc.) and/or an index of events/hr of sleep or per night
9. Validate if emerging biomarkers are complementary or decisive variables in screening, diagnosis, and treatment outcome assessments
10. Assess, in a bias-protected mode, if commercially automated scoring methods for MMA or another SB metric are valid
11. Identify criteria and/or outcome metric concordance that may differ when used for diagnosis and/or for treatment outcome assessments
12. Use analysis methodology with predictive power based on risk assessments. Research tools or methods may have different levels of ecological validity and may provide different answers, depending on how the question is phrased and on the population under test, e.g. general population versus clinical patient
13. Assess which are the essential and best co-variables (risk factors, signs and symptoms; phenotype to endotype and biomarkers) based on evidence from clustering, machine learning, or other analytical methods
14. Assess, short- and mid-term, phenotype + endotype + biomarkers, correspondence to health risk factors, quality of life, and treatment outcome(s)
15. Revise our standards when technological and knowledge advances occur in the diagnosis and/or treatment for SB

EMG, electromyography; OSA, obstructive sleep apnoea; PSG, polysomnography.

Suzuki et al., 2020; Zani et al., 2019); jaw movement sensors; and the assessment of grinding sounds to take into consideration clinical manifestations in wake and sleep behaviours (Akamatsu et al., 1996; Manfredini et al., 2020; Martinot et al., 2020; Mizumori et al., 2009; Okura et al., 2017; Yoshimi et al., 2009). A number of questions need to be clarified in respect of the use of these metrics, such as: should they be used as single measures or as complementary tools? Should they only be used when indicated in respect of a specific patient profile, in line with the precision medicine concept? And, do they have a predictive value?

9 | SUGGESTIONS TO EXPLORE AND IMPROVE SB METRIC VALIDITY AND CLINICAL RELEVANCE

Opinions, commentaries, and consensus papers are important, because they stimulate and advance discussion; we need more evidence-based findings to support our diagnosis and treatment decisions. The emergence of the STAB dental academic researchers' group, STAB stands for 'Standardised Tool for the Assessment of Bruxism', is an excellent start toward improved global measures; note STAB is targeting both awake bruxism and SB in the dental context (Manfredini et al., 2020). In Table 1, we have listed a few suggestions for a possible working agenda directed to improve the validity and clinical relevance of SB metrics.

As has been done in sleep medicine, and as no single or combined clear or definitive metrics, biomarkers, and methodologies (e.g. self-report, test result from HSAT or SB testing, PSG, genetics, salivary or microbiota) are yet considered as standards for diagnostic and treatment decisions, we probably need to build a collaborative taskforce working group. Such a taskforce should, among many other characteristics, (a) be representative of more than one group of researchers or clinicians, and include patient representatives, (b) be under the umbrella of one or preferably a consortium of a few scholarly and clinical societies, and (c) be in a regular updating mode and in alignment with social and technical developments.

It is clear based on the current literature that we need to:

- Define the type and number of diagnostic variables to be collected with a standardised methodology.
- Collect data in larger sample sizes through collaborative studies.
- Clarify screening or diagnostic tools and methodologies; standardisation is needed, but it should not prevent innovation.
- Assess separately whether it is better to use cut-off points or a continuum of outcomes for research and in clinical use and explore new analytical methods, such as the use of artificial intelligence.
- In the analysis of MMA and/or other SB metrics, consider the role or influence of age-sex/gender comorbidities and other factors.
- Explore the use and validity of other emerging metrics such as jaw movement and/or sound analyses, and heart rate variability as complementary measures.

Furthermore, we should be careful not to compare studies for general epidemiological purposes with mechanistic (including using medication as proof of concept), clinical diagnostic, and therapeutic efficacy studies. The study design and methodology

are not the same, and technologies also influence the accuracy of outcomes of interest. When it is time to test associated risk factors in relation to outcomes, we need to be careful, as was demonstrated in respect of OSA treatment and cardiovascular risk (Javaheri et al., 2019; Pack et al., 2020). A risk of methodological bias may generate more confusion that prevents patients receiving the best treatment option.

Two OSA-related taskforce exercises can be used as models. The AHI-OSA task force of the *European Sleep Society*, as described above, and of the *AASM*. The latter used the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) system, which is based on existing solid evidence for the development of guidelines, and the RAND (contraction of Research AND Development) Appropriateness Method for consensus (https://aasm.org/clinical-resources/practice-standards/). As a matter of fact, the AASM group recommended a regular revision every 5 years, with possible updates if new evidence becomes available. An eloquent and valuable note from that group that can be potentially translated to dental sleep medicine is:

> Choosing wisely recommendations should not be used to establish coverage decisions or exclusions. Rather, they are meant to spur conversation about what is appropriate and necessary treatment. As each patient situation is unique, providers and patients should use the recommendations as guidelines to determine an appropriate treatment plan together.

In the era where evidence-based meets personalised dental sleep medicine, the added value of such progress in SB metrics is essential.

10 | CONCLUSION

Reassessing and upgrading SB metrics (both qualitative and quantitative), with evidence-based data, will improve the accuracy and relevance of diagnosis and treatment decisions. Current advances in technologies and methodologies offer unique opportunities to estimate MMA (or other equipotent or better metric or metrics) accuracy and its predictive value. To achieve this aim, the establishment of a collaborative taskforce on SB metrics that includes dental and sleep researchers, technology developers, and the participation of clinicians and patients, would be required. Several models are available from OSA research, such as the work conducted by the *AASM* or the *European Sleep Research Society's* "*Beyond AHI*" task force.

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CONFLICT OF INTEREST

AHB, CDF, DAGG, DM, JA, JS-B, KB, MCC, NH, TCAC, TK, MW: none to declare in relation to this paper. GL hold a Canada Research Chair in pain, sleep and trauma. PS is a paid consultant for Sunstar Suisse who manufactures Grindcare. FL is a member of the academic advisory board of Sunstar Suisse who manufactures Grindcare. FL and GA are member of the scientific advisory board of Sunstar Suisse who manufactures Grindcare (Oral Function).

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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