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A narrative overview

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REVIEW

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Associations between tooth wear and dental sleep disorders: A narrative overview

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Abstract

Objectives: Tooth wear is a common finding in adult patients with dental sleep disorders. The aim of this paper was to review the literature on the possible associations between tooth wear and the following dental sleep disorders: sleep-related oro-facial pain, oral moistening disorders, gastroesophageal reflux disease (GERD), obstructive sleep apnoea syndrome (OSAS) and sleep bruxism.

Methods: A PubMed search was performed on 1 June 2018 using MeSH terms in the following query: Tooth Wear AND (Facial Pain OR Temporomandibular Joint Disorders OR Xerostomia OR Sialorrhea OR Gastroesophageal Reflux OR Sleep Apnea Syndrome OR Sleep Bruxism).

Results: The query yielded 706 reports on tooth wear and the mentioned dental sleep disorders. Several associations between tooth wear and the dental sleep disorders were suggested in the literature. It could be concluded that: (a) tooth wear is associated with dental pain and/or hypersensitivity; (b) oral dryness is associated with tooth wear, oro-facial pain and sleep bruxism; (c) GERD is associated with tooth wear, oro-facial pain, oral dryness, OSAS and sleep bruxism; (d) OSAS is associated with oral dryness, GERD and sleep bruxism; and (e) sleep bruxism is associated with tooth wear.

Conclusions: Tooth wear is associated with the dental sleep disorders oro-facial pain, oral dryness, GERD and sleep bruxism. The dental sleep disorders are interlinked with each other, which leads to indirect associations as well, and makes the consequences of each single condition difficult to disentangle. Knowledge of these associations is clinically relevant, but more research is needed to confirm their validity.

KEYWORDS

adult, gastroesophageal reflux disease, hypersalivation, hyposalivation, oral moistening disorders, oro-facial pain, ptyalism, sialorrhea, sleep apnoea, sleep bruxism, tooth wear, xerostomia

1 | INTRODUCTION

Tooth wear is a multifactorial condition, leading to the loss of dental hard tissues, viz., enamel, dentine and cementum.[1] Based on the purported aetiology, tooth wear can be mechanical or chemical (both intrinsic and extrinsic). Intrinsic mechanical wear (known as attrition) is a result of chewing and/or bruxism (eg, grinding), due to tooth-to-tooth contact, whilst extrinsic mechanical wear (known as abrasion) is a result of other factors than chewing and/or bruxism, for example, oral hygiene procedures and habits like nail- or pen-biting. Intrinsic and extrinsic chemical wear, both known as dental erosion, are the result of gastric acid and an acidic diet or environments containing airborne acid, respectively.[2] Intrinsic mechanical tooth wear is a physiological process, as the dentition is "designed" for function (chewing). Additionally, when the other wear mechanisms are involved, it can become pathological. It should be noted that single wear mechanisms rarely act alone, but interact with each other.[1] There is evidence that an acidic diet plays an increasingly important role in the multifactorial condition tooth wear.[3] This is also a common believe amongst dental clinicians, nevertheless, having knowledge of the whole etiological spectrum is of utmost importance.

Regarding the diagnosis of tooth wear, a comprehensive approach is necessary due to its multifactorial origin and manifestation. Recently, the Tooth Wear Evaluation System was described to implement a systematic approach to the diagnosis (qualification and quantification) and management of the condition [2]. The diagnosis tooth wear is not difficult, being simply the loss of dental hard tissues that is easy to differentiate from dental caries or trauma. However, to distinguish between the different sub-forms (ie, qualification) is very difficult. Regarding the qualification of tooth wear, there is no consensus at this time, although several proposals exist.[2,4,5] No difference in reliability between setting the diagnosis of chemical or mechanical tooth wear can be hypothesised. In all the studies mentioned in this overview, it was not always clear how the diagnosis was set. Regarding the quantification of tooth wear, the existing situation is even worse: more than one hundred different evaluation systems exist [6]. Comparison of the most commonly used systems nevertheless reveals that a universally accepted modular evaluation system is a possibility and a necessity.[6] Taking these considerations into account, it is clear that comparison of tooth wear research findings is difficult. It will take time before the dental community will reach consensus on this topic (see also Table 2).

According to literature, the prevalence of severe tooth wear in adults increases from 3% at the age of 20 years to 17% at the age of 70 years.[7] The prevalence of tooth wear is increasing, although data are scarce and contradictory.[8,9] Physiological tooth wear is a slow process that does normally not lead to any subjective symptoms, but when it becomes pathological, dental hypersensitivity and/or dental pain (being a form of oro-facial pain) may occur.[10] Additionally, pathological tooth wear can result in difficulties with chewing/eating; impaired orofacial aesthetics because of loss of dental hard tissue; crumbling off dental hard tissue; and deterioration of dental restorations.[2,10]

Tooth wear is irreversible, which may require repeated and increasingly complex and expensive restorations.[10] Therefore, it is important that the diagnosis of tooth wear is made early, and adequate preventive measures are undertaken in order to prevent as much as possible the loss of dental hard tissue.[10,11]

Not only tooth wear is becoming increasingly significant in the management of the long-term health of the dentition,[11] but dentists are also becoming more involved with patients requesting information or needing management of oral and dental conditions in relation to dental sleep disorders.[12] At this moment, dental sleep medicine is yet not recognised in the general medical literature nor recognised in the dental literature, although these terms were introduced already two decades ago.[12] We do think, however, that we are at a turning point, as was mentioned in a recent review, in which a new definition of dental sleep medicine was proposed [13]: "dental sleep medicine is the discipline concerned with the study of the oral and maxillofacial causes and consequences of sleep-related problems." In our opinion, the term dental sleep medicine is an appropriate one, although debate continues. We do realise that other choices regarding definitions and terminology are possible. Importantly, however, the dental profession ultimately must make a definitive choice, in order to enable speaking the same language, using identically definitions and terms. The sleep-related problems, to which the proposed definition of dental sleep medicine refers, are as follows: oro-facial pain; oral moistening disorders (both oral dryness and oral wetness; in this narrative overview, we focus on oral dryness); gastroesophageal reflux disorder (GERD); sleep-related breathing disorders (including snoring and obstructive sleep apnoea, OSAS; in this narrative overview, we focus on OSAS); and mandibular movement disorders (including dyskinesia, dystonia, and sleep bruxism; in this narrative overview, we focus on sleep bruxism). Some peer-reviewed journals in the field allowed us to introduce the above concepts.[14,15] For descriptions/definitions of these conditions, see Table 1.

As in the case of the evaluation of tooth wear, also regarding the assessment of the dental sleep disorders, a wide variety of tools are used (see Table 2). For these reasons, it is hard to organise the available material into a qualitative systematic literature review. A narrative overview was instead performed in the attempt to summarise the available knowledge.

The aim of this paper was to review the literature on the possible associations between tooth wear (both mechanical and chemical) and dental sleep disorders (viz., oro-facial pain, oral dryness, GERD, OSAS and sleep bruxism), as well as the mutual associations between these disorders themselves. There is evidence that the mentioned dental sleep disorders do have an association with tooth wear, whilst at the same time it is clear that tooth wear is not the only sign or symptom of these disorders. By searching the available literature thoroughly, we will update the existing knowledge and can probably set future research questions. The results can support dental clinicians to have a better comprehension of the possible aetiological factors of tooth wear in their patients, and thus improve the provided dental care.

2 | METHODS

On 1 June 2018, the biomedical literature was searched in PubMed (US National Library of Medicine), using Mesh-Terms in the following query: Tooth Wear AND (Facial Pain OR Temporomandibular Joint Disorders OR Xerostomia OR Sialorrhea OR Gastroesophageal Reflux OR Sleep Apnea Syndrome OR Sleep Bruxism). The MeSH-term Tooth Wear includes Tooth Attrition, Tooth Abrasion and Tooth Erosion; The MeSH-term Facial Pain includes Toothache (dental pain and/or hypersensitivity); the MeSH-term Temporomandibular Joint Disorders includes Temporomandibular Joint Dysfunction Syndrome; the MeSH-term Sleep Apnea Syndrome includes OSAS. We have chosen to use MeSH-terms in order to select only those articles that focus on our research aim. The titles and (when available) the abstracts of the publications were screened to establish whether the publications could shed light on the research aim. In addition, it was examined if a direct association and/or an indirect association (meaning through another dental sleep disorder) was present between tooth wear and a sleep disorder. For all studies, the main inclusion criterion for retrieval of the full text was that the study related to the research question about associations between tooth wear, oro-facial pain, oral dryness, GERD, OSAS and/or sleep bruxism. To be included, the study had to describe the results of an original research in adults, had an appropriate study design or included a review of one of the subtopics of this study. In order to avoid missing relevant literature, as a search expansion strategy, the reference lists of the full-text articles were hand-searched for additional studies. Publications were excluded for reasons like describing single cases, rare disorders, syndromes, subgroups of patients, restorative treatment procedures or articles written in languages other than English or Dutch. The search resulted in 706 publications, of which 101 were included in this narrative review. Because of the heterogeneity in the design and quality of the studies, only a narrative approach was possible (see also Table 2).

2.1 | Associations between tooth wear and dental sleep disorders

The possible associations (both direct and indirect) between tooth wear and oro-facial pain, oral dryness, GERD, OSAS and sleep bruxism are presented in Table 3.

TABLE 1 Definitions of dental sleep disorders as distinguished by Lobbezoo et al[13]

Condition	Definition
Oro-facial pain (OFP)	Oro-facial pain refers to pain associated with the hard and soft tissues of the head, face and neck. These tissues, whether skin, blood vessels, teeth, glands or muscles, send impulses through the trigeminal nerve to be interpreted as pain by the brain circuits that are primarily responsible for the processing that controls complex behaviour. The complaint of OFP encompasses a diagnostic range from neurogenic, musculoskeletal, and psychophysiological pathology to headaches, cancer, autoimmune phenomenon, and tissue trauma (de Leeuw & Klasser[16])
Oral moistening disorders	Oral moistening disorders can be divided in having too little or too much saliva, respectively, yielding oral dryness and oral wetness • Hyposalivation is an objective reduction of the salivary flow; salivary gland hypofunction has been defined as any objectively demonstrable reduction in whole and/or individual gland flow rates • Xerostomia is defined as the subjective sensation of oral dryness; although it is most commonly associated with salivary gland dysfunction, it may also occur with normal gland activity. The terms hyposalivation and xerostomia are often incorrectly used interchangeably • Hypersalivation (or sialorrhea or ptyalism) is the condition of increased salivary flow (Lobbezoo et al[13]; Wolff et al[25]; Löfgren et al[27]; Moore & Guggenheimer[78]; Hopcraft & Tan[26]; Boyce & Bakheet[79])
Gastroesophageal reflux disease (GERD)	Gastroesophageal reflux disease is defined, in the so-called Montreal definition and classification, as a condition that develops when the reflux of stomach contents causes troublesome symptoms and/or complications The disease was subclassified into esophageal and extra-esophageal syndromes, and the recognition of laryngitis, cough, asthma, and chemical intrinsic tooth wear as possible GERD syndromes (Vakil et al[80])
Sleep-related breathing disorders	Sleep-related breathing disorders include snoring and obstructive sleep apnoea syndrome (OSAS) • Snoring is a familiar condition that is characterised by loud breathing sounds produced in the upper airway during sleep; loud snoring is considered as the most important alarm symptom for OSAS • OSAS is the most common type of sleep apnoea and is caused by obstruction of the upper airway. It is characterised by repetitive pauses in breathing during sleep, despite the effort to breathe, and is usually associated with a reduction in blood oxygen saturation (Deary et al[46]; American Academy of Sleep Medicine Task Force, Sleep[45])
Mandibular movement disorders	Mandibular movement disorders include oromandibular dystonias, oro-facial dyskinesias, sleep bruxism, and awake bruxism • 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 • 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 (Lobbezoo et al[56])

TABLE 2 Description of used tools to diagnose tooth wear and the various dental sleep disorders

Condition	Assessment tool
Tooth wear	To assess tooth wear, qualification and quantification are necessary. Qualification (recognise and distinguish between the different sub-forms of tooth wear) is difficult and in the majority of the studies not performed. Regarding the qualification of tooth wear, there is no consensus at this time, although several proposals exists (Wetselaar & Lobbezoo[2]; Gandara & Truelove[4]; Ganss & Lussi [5]). Quantification (grading the severity of tooth wear) is performed in more than a hundred different ways, with an equal number of different indices or evaluation systems, also here no consensus (Wetselaar & Lobbezoo[2]; Wetselaar et al[6]; Margaritis & Nunn[81]; Schlueter & Luka[82])
Oro-facial pain	In this narrative overview dental pain or hypersensitivity and TMD pain were eventually associated with tooth wear. Since pain is a subjective experience, dental pain or hypersensitivity were assessed by oral history taking, questionnaires, several dental tests and the use of an index, the Cumulative Hypersensitivity Index (CHI) (West et al[17]; Burnett et al[18]; Wazani et al[19]; Olley et al[20]; Macfarlane et al[21])
	TMD pain was assessed using the Research Diagnostic Criteria for Temporomandibular Disorders (Dworkin & LeResche [83]; Schierz et al[22]; Seligman & Pullinger [23])
Oral dryness	Hyposalivation can be determined by quantifying the unstimulated or stimulated whole saliva (sialometry). Since there is a great variability in individual salivary flow rates and a wide range of flow rate is accepted, the accurate assessment of dysfunction can be difficult; with this in mind it can be argued if measurement of salivary flow rates can be used as a discriminating tool (Löfgren et al[27]). In addition a wide variety of tests are available, like secretion tests (sialometry, sialochemistry, oral Schirmer's test, and so on), mucosal/surface test, functional tests, glandular morphology (scintigraphy or sialography), and questionnaires or interviews (Löfgren et al[27]; Thomson et al[84])
Gastroesophageal reflux disease (GERD)	Gastroesophageal reflux disease is a complex disease with a heterogenous symptom profile. Assessment is performed by clinical history taking, questionnaires, and response to antisecretory therapy, and different tools, like endoscopy, pH monitoring (wire or wireless 24, 48, and 96 h), and/or multichannel intraluminal impedance-pH (Gyawali et al[85]). All the assessment tools have their limitations because there are no universal cut-off criteria (Vakil et al[80]; Gyawali et al[85]). Additional signs and symptoms must be present, like heartburn, regurgitation, chest pain, chronic cough and hoarseness as mentioned in the Montreal definition (Vakil et al[80])
Obstructive sleep apnoea syndrome (OSAS)	The diagnosis of OSAS requires the combined assessment of the objective demonstration of abnormal breathing during sleep and relevant clinical features (signs and symptoms). The golden standard for diagnosing the objective abnormal sleep is a polysomnography (at home or in a sleep laboratory), after which the severity is determined by calculating the Apnoea-Hypopnea index. It is possible to distinguish between Positional (POSAS) and non-positional OSAS, some determine the amount of Respiratory Effort Related Arousals, some determine the Upper Airway Resistance Syndrome. Additional by a drug-induced sleep/sedation endoscopy, the obstruction sites can be determinate
	Relevant clinical features (signs and symptoms) during sleep are snoring, witnessed apnoea by the bedpartner, choking or gasping, recurrent awakenings and insomnia. During wakefulness these are daytime sleepiness, unrefreshing sleep, fatigue, memory/concentration impairment, personality changes, morning nausea, and morning headaches. Structured interviewing and/or questionnaires can reveal these clinical features (American Academy of Sleep Medicine Task Force, Sleep [45])
Sleepbruxism	Sleepbruxism can be assessed non-instrumental or instrumental. Non-instrumental means@Non-instrumental approaches includes self-report (questionnaires, oral history) and clinical inspection. No consensus is present regarding these approach. Instrumental approaches are electromyographic recordings (including other measures used in somnography or polysomnography; audio and/or video recordings can supplement EMG data)@No consensus is present regarding cut-off points of the findings@The grading system is as follows: (a) possible sleep bruxism is based on a positive self-report only; (b) probable sleep bruxism is based on a positive clinical inspection, with or without a positive self-report; (c) definite sleep bruxism is based on a positive instrumental assessment, with or without a positive self-report and/or a positive clinical inspection (Lobbezoo et al[56])

2.1.1 | Oro-facial pain and tooth wear

Oro-facial pain is a multifactorial condition, with a prevalence of around 5.3%-22%.[16] Amongst the 706 publications, only seven described the association between tooth wear and oro-facial pain.[17-23] The publications did not distinguish oro-facial pain during wakefulness or sleep. Concerning the association between tooth wear and dental pain/hypersensitivity, at first sight, contradictory findings were reported (see Table 4). When looking into detail, one can conclude that the conflicting reports can be explained by the fact that tooth wear is used as an umbrella term. When tooth wear is differentiated between chemical wear and mechanical wear, one can conclude that chemical wear can cause oro-facial pain (dental pain/hypersensitivity), whilst mechanical wear does not cause oro-facial pain (dental pain/hypersensitivity). Regarding tooth wear and TMD pain, Schierz et al[22] demonstrated an odds ratio of 1.11, concluding that there was no statistically significant or clinically relevant relationship between tooth wear and the risk of TMD pain. Although others [23] stated that multifactorial models using mechanical tooth wear severity and rates may differentiate masticatory muscle pain patients from asymptomatic controls, they commented that these models cannot determine causation or whether any of the

TABLE 3 Possible direct and indirect associations between tooth wear and dental sleep disorders

Direct		Indirect	
TW → OFP	Table 4		
OD → TW	Table 4	OD → TW → OFP	Table 4
OD → OFP	Table 4		
OD → SB	Table 4	OD → SB → TW	Table 4
		OD → SB → TW → OFP	Table 4
		OD → SB → OFP	Table 4
GERD → TW	Table 5	GERD → TW → OFP	Table 5
GERD → OFP	Table 5		
GERD → OD	Table 5	GERD → OD → TW	Table 5
		GERD → OD → TW → OFP	Table 5
GERD → OSAS	Table 5	GERD → OSAS	Table 5
		GERD → OSAS → OD	Table 5
		GERD → OSAS → OD → TW	Table 5
GERD → SB	Table 5	GERD → SB → TW	Table 5
		GERD → SB → TW → OFP	Table 5
OSAS → OD	Table 5	OSAS → OD → TW → OFP	Table 5
OSAS → GERD	Table 5	OSAS → GERD → TW	Table 5
OSAS → SB	Table 5	OSAS → SB → TW	Table 5
SB → TW	Table 6		
SB → OFP	Table 6		
		SB → GERD → TW	Table 6

Abbreviations: →, association; GERD, gastroesophageal reflux disease; OD, oral dryness; OFP, oro-facial pain; OSAS, obstructive sleep apnoea syndrome; SB, sleepbruxism; TW, tooth wear.

differentiating mechanical tooth wear is secondary to TMD pain.[23] Based on this available evidence, one may conclude that chemical tooth wear is directly associated with dental pain and/or hypersensitivity (most probably in young patients, when the tooth wear process develops fast) and not with TMD pain. No publications were found in relation to other oro-facial pains, like neuropathic pain or headache.

2.1.2 | Oral Moistening Disorders and tooth wear

With the umbrella term oral moistening disorders, we cover all the disorders that have to do with an abnormal quantity or composition of the saliva, so both oral dryness (with the already longer existing terms hyposalivation and xerostomia) and oral wetness (with the already longer existing terms hypersalivation, sialorrhea and ptyalism). It should be stressed that is not our intention to replace these terms with the umbrella term. Nevertheless, the umbrella term is in our opinion a useful one and will only exist in addition to the well-established familiar terms. Saliva is of paramount importance for the maintenance of oral health, and therefore, in-depth knowledge amongst healthcare professionals is of great importance. Oral dryness is a multifactorial condition, with a prevalence that varies from 10% to 80%.[24] Oral dryness can be physiological and is related to age, gender, body weight and the time of the day.[24] Oral dryness can be caused by salivary gland hypofunction, thus an objectively measured decrease in salivation, hyposalivation.[24-27] Oral dryness can also be the subjective "feeling" of a dry mouth, xerostomia [26] or the subjective "sensation" of dry mouth, which is often (but not always) associated with hypofunction of the salivary glands".[25] In general, the pathological condition that most frequently causes oral dryness is the use of certain medications: more than a thousand drugs are denoted as xerogenic in the medical literature.[25] Other pathological factors resulting in oral dryness are radiotherapy to the head and neck, and systematic disorders, like autoimmune diseases (eg, Sjögren's syndrome), diabetes, depression, anxiety, stress or malnutrition.[24,26] Oral dryness upon awakening is considered a possible symptom of OSAS,[28] a lower salivary secretion is seen in patients with GERD.[29] Oral wetness is also a multifactorial condition, for which prevalence rates at the general population level are not available. It can be physiological during tooth eruption, during the first half of pregnancy, during menstruation, as well as in association with smell and mechanical stimuli (such as mastication) and taste stimuli.[24] The pathological causes of hypersalivation include those of: oral origin, such as the first stages of wearing dentures, dental pain or any irritation or inflammatory process in the oral-pharyngeal or digestive regions (eg, GERD); neurological disorders, such as Parkinson's disease, epilepsy, encephalitis or certain tumours; exogenous poisoning; several medications; and several serious infectious diseases.[24] Amongst the included papers, none of them reported an association between oral wetness and tooth

TABLE 4 Possible direct associations between tooth wear and OFP; possible direct and indirect associations between OD and tooth wear, OFP and SB

Direct			Indirect		
Tooth wear					
	Reference	**Association**			
cTW → DP/HY	17,20	Yes			
TW → HY	18,19	Yes			
mTW → DP/HY	21	No			
mTW → TMDP	22,23	No			
Conclusions: Chemical tooth wear can directly be associated with dental pain and/or hypersensitivity; there is no association between tooth wear and TMD pain					
Oral dryness					
	Reference	**Association**		**Reference**	**Association**
OD → mTW + cTW	30,31	Yes	OD → TW → DP/HY	17-20	Yes
OD → OFP	32	Yes			
OD → SB	32	Yes	OD → SB → TW → DP/HY	17-20	Yes
			OD → SB → TW	34	No
			OD → SB → TW	35	Yes
			OD → SB → TMDP	34	No
			OD → SB → TMDP	35	Yes
Conclusions: Oral dryness can directly be associated with mechanical tooth wear (when less saliva causes less lubrication), chemical tooth wear (when less saliva results in less buffer capacity), oro-facial pain (irritation of the soft tissues of the oral cavity), and sleep bruxism (compensating the oral dryness)			*Conclusions*: Oral dryness can indirectly be associated with oro-facial pain (dental pain/hypersensitivity due to tooth wear, with or without sleep bruxism); oral dryness might be indirectly associated with tooth wear (due to sleep bruxism) or TMD pain (due to sleep bruxism); opposite findings are revealed		

Abbreviations: →, association; cTW, chemical tooth wear; DP, dental pain; HY, hypersensitivity; mTW, mechanical tooth wear; OD, oral dryness; OFP, oro-facial pain; SB, sleep bruxism; TMDP, TMD pain; TW, tooth wear.

wear. Two reviews revealed a possible direct association between oral dryness and tooth wear, namely with mechanical tooth wear (when less saliva causes less lubrication) and chemical tooth wear (when less saliva results in less buffer capacity) [30,31] (Table 4). Other direct associations were oral dryness with oro-facial pain (causing irritation of the soft tissues of the oral cavity[32,33];) and sleep bruxism (compensating the oral dryness; [32]). Oral dryness is indirectly associated with oro-facial pain (dental pain/hypersensitivity through tooth wear, see above; regarding the indirect association between oral dryness and temporomandibular pain (through sleep bruxism), and tooth wear (through sleep bruxism), opposite findings revealed.[34,35]

2.1.3 | Gastroesophageal reflux disease (GERD) and tooth wear

The prevalence of GERD is high in the Western world, ranging from 10% to 40%.[36] The prevalence increases with age and BMI, and men are more frequently affected than women.[36] GERD can be considered physiological when occurring after a meal without further complaints and during pregnancy. It becomes pathological when a mechanical impairment of the esophagogastric junction is present and complaints develop.[36] GERD is considered as a multifactorial disease; instigating factors are obesity, age and trauma.

Amongst the included papers, 65 publications described the direct association between GERD and tooth wear and oro-facial pain (irritation of the soft tissues), including five recent reviews (Table 5). In a systematic review from the gastroenterological community,[37] it was concluded that there is a strong association between GERD and intrinsic chemical tooth wear, and that the severity of the tooth wear seems to be correlated with the severity of GERD symptoms. Recently, this was concluded again by four reviews from the dental community [38-41] (Table 5). It is suggested that inspection of the oral cavity in search for intrinsic chemical tooth wear should become a routine manoeuvre in patients with GERD, and cooperation between physicians and dentists is strongly advocated to prevent or ameliorate possible oral effects of GERD.[41]

Three other studies described the possible indirect association between GERD and tooth wear through oral dryness.[42-44] On the one hand, it was revealed that patients with GERD had an impaired salivary flow rate as compared to controls [42,43] and additionally a poorer salivary buffering capacity.[43] However, on the other hand, Saksena et al[44] reported no difference in salivary flow or buffer capacity between patients with GERD and controls (see Table 5). Based on the available evidence, one may conclude that GERD is

TABLE 5 Possible direct associations between GERD and tooth wear, OFP, OD, OSAS and SB; possible indirect associations between GERD and tooth wear, OFP, OD and SB; possible direct associations between OSAS and OD, GERD and SB; possible indirect associations between OSAS and tooth wear, and OFP

Direct			Indirect		
	Reference	Association		Reference	Association
GERD					
GERD → cTW	[37-41]	Yes			
GERD → OFP	[37-40]	Yes	GERD → TW → OFP	[37-41]	Yes
GERD → OD	[29]	Yes	GERD → OD → TW	[42,43]	Yes
			GERD → OD → TW	[44]	No
			GERD → OD → OFP	[29]	Yes
GERD → OSAS	[51-53]	Yes			
GERD → SB	[65-68]	Yes	GERD → SB → TW	[34]	No
			GERD → SB → TW	[35]	Yes
			GERD → SB → OFP	[34]	No
			GERD → SB → OFP	[35]	Yes
Conclusions: GERD can be directly associated with chemical tooth wear, oro-facial pain (irritation of the soft tissues of the oral cavity), oral dryness, OSAS, and sleep bruxism			*Conclusions*: GERD can be indirectly associated with tooth wear (through oral dryness and sleep bruxism) and oro-facial pain (due to tooth wear, oral dryness, and sleep bruxism); opposite findings are revealed		
OSAS					
OSAS → OD	[28]	Yes	OSAS → OD → TW	[30,31]	Yes
			OSAS → OD → TW → DP/HY	[17-20]	yes
OSAS → GERD	[51,52,54,55]	Yes	OSAS → GERD → cTW	[51,52,54,55]	yes
OSAS → SB	[69-75,86]	Yes	OSAS → SB → mTW	[49]	yes
OSAS → SB	[76]	No			
Conclusions: OSAS can be directly associated with oral dryness, GERD, and sleepbruxism			*Conclusions*: OSAS can be indirectly associated with tooth wear (through oral dryness), with chemical tooth wear (through GERD) with mechanical tooth wear (through sleep bruxism), and with oro-facial pain (dental pain/hypersensitivity, through tooth wear)		

Abbreviations: →, association; cTW, chemical tooth wear; DP, dental pain; HY, hypersensitivity; mTW, mechanical tooth wear; OD, oral dryness; OFP, oro-facial pain; SB, sleepbruxism; TW, tooth wear.

directly associated with intrinsic chemical tooth wear, oro-facial pain (irritation of the soft tissues), OMD (see above), OSAS (see below) and sleep bruxism (see below). GERD is indirectly associated with chemical and mechanical tooth wear (due to OMD and sleep bruxism; see above, and below) and oro-facial pain (due to tooth wear, oral dryness, and sleep bruxism; see above, and below; see Table 5).

TABLE 6 Possible direct and indirect associations between SB and tooth wear, OFP and GERD

Direct			Indirect		
Sleep bruxism					
	Reference	Association			
SB → mTW	[34]	No			
SB → mTW	[35]	Yes			
SB → OFP (TMDP)	[34]	No			
SB → OFP (TMDP)	[35]	Yes			
			SB [→] GERD [→] cTW	[65-68]	Yes
Conclusions: Sleep bruxism might be directly associated with mechanical tooth wear and oro-facial pain (TMD pain); opposite findings are revealed			*Conclusions:* Sleep bruxism can be indirectly associated with intrinsic chemical tooth wear (through GERD)		

Abbreviations: →, association; cTW, chemical tooth wear; DP, dental pain; HY, hypersensitivity; mTW, mechanical tooth wear; OD, oral dryness; OFP, oro-facial pain; SB, sleepbruxism; TW, tooth wear.

2.1.4 | Tooth wear and obstructive sleep apnoea syndrome

Obstructive sleep apnoea syndrome (OSAS) is the most common type of a sleep-related breathing disorders that is caused by transient obstruction of the upper airway and is a multifactorial condition as well. It is characterised by repetitive interruptions in breathing during sleep, despite the effort to breathe, and is usually associated with a reduction in blood oxygen saturation.[45] Snoring is a familiar condition that is characterised by loud breathing sounds, produced in the upper airway during sleep. Although these sounds give rise to social embarrassment, it still can be considered as physiological, whilst OSAS is considered as a pathological condition.[46]

The prevalence of OSAS, according to general population-based studies, is approximately 3%-7% for adult men and 2%-5% for adult women [47] but higher figures have been reported. In this regard, a recent systematic review highlighted that the prevalence depends on the severity of the condition, with estimated ranges between 9% and 38% for mild OSAS, and 6% to 17% for moderate OSAS, men more affected than women.[48] Factors that increase vulnerability for the disorder include higher age, male sex, obesity, family history, menopause, craniofacial abnormalities and certain health behaviours like cigarette smoking and alcohol usage.[47]

A direct association between tooth wear and OSAS cannot be hypothesised. Amongst the included papers, only one publication described a possible indirect association between tooth wear and OSAS [49] (Table 5). These authors concluded that patients with tooth wear had a high frequency of OSAS, and they found a positive association between tooth wear severity and the severity of the OSAS. Although they did not differentiate between chemical and mechanical tooth wear, the authors suggest that tooth wear assessment can be a tool to identify patients at risk for having OSAS.[49] An explanation given by the authors is the possible association between OSAS and sleep bruxism. The patients in the study were treated with an oral appliance, and in that context, it is worth noting that evidence exists that the use of an occlusal splint can worsen the sleep apnoea.[50]

The possible association between GERD and tooth wear was already described, concluding a strong association between GERD and chemical intrinsic tooth wear. The possible associations between OSAS and GERD themselves are described as well. There is an association because of common risk factors, like gender and obesity.[51,52] GERD can proceed OSAS because an inflammation that results from reflux into the hypopharynx causes weakening and oedema in these tissues, thus resulting in worsening an upper airway obstruction.[53] The opposite namely that an apnoea event precedes an GERD event is also described; the reflux is then probably due to the generation of negative intrathoracic pressures during obstructive apnoeas and arousals [54,55] (Table 5). Independent of the temporal relationship, one can hypothesise that, because of the coexistence of GERD and OSA, patients with OSA show more (intrinsic chemical) tooth wear in comparison with healthy individuals, because the associated GERD activities cause more chemical tooth wear.

2.1.5 | Sleep bruxism and tooth wear

According to a recent consensus paper, sleep bruxism and awake bruxism are considered different behaviours observed during wakefulness and during sleep. Both are multifactorial conditions as well.[56] This means that a single definition for bruxism is no longer recommended, so that two separate definitions are proposed. Within this framework, 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, whilst 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.[56] In otherwise healthy individuals, bruxism should not be considered as a disorder, but rather as a behaviour, a physiological phenomenon, that can be a risk (and/or protective) factor for certain clinical consequences. Bruxism will be considered as pathological when a person experiences the possible negative consequences, like oro-facial pain (eg, meaning pain in the masticatory system).[56] The prevalence of bruxism varies from 8% to 31.4%, that of sleep bruxism from 9.7% to 15.9%, depending on the diagnostic methods used. Bruxism activities were found to be unrelated to gender, and a decrease with age was described in older people.[57] Considering the possible association between bruxism and tooth wear, three possible interactions are described in the literature: tooth wear causes bruxism; tooth wear is a valid clinical diagnostic tool for bruxism; and tooth wear is a consequence of bruxism, meaning directly or indirectly associated with bruxism.

Considering the first interaction, viz., that tooth wear causes bruxism, it was concluded that there is no evidence available that occlusal interferences (worn dentitions) are involved in the aetiology of bruxism.[35,58] Considering tooth wear possibly being a valid diagnostic tool for bruxism, five studies concluded that this is not the case,[59-63] whilst only one study concluded the opposite.[64] This can be explained by the fact that tooth wear is a multifactorial condition, and therefore always a combination of mechanical and chemical wear. Furthermore, tooth wear is irreversible; hence, assessing tooth wear does provide information regarding the actual amount of tooth surface loss, but does not provide information regarding the timing of the tooth surface loss, in other words: whether the process is ongoing or a result from earlier loss.

Considering the third interaction, sleep bruxism is (directly) associated with tooth wear, amongst the included papers and the additional relevant literature, one review concluded that bruxism is not directly associated with tooth wear and with oro-facial pain [34] (Table 6), whilst another conclude that the direct association exist [35] (Table 6). The different conclusions are possible due to the fact that if sleep bruxism has been diagnosed more robustly, no consistent relationship has been found between sleep bruxism and tooth wear.[34]

Above, the association between GERD and tooth wear was outlined. Interestingly, also evidence exists that sleep bruxism and GERD are associated with each other [65-68] (Table 6). Hypothetically,

when the onset of a GERD event precedes the onset of a sleep bruxism event, more tooth wear can be caused by the fact that grinding on the acid stomach contents covering the teeth can accelerate the amount of hard tissue loss.

Another interesting finding is the existing evidence of the possible association between sleep bruxism and OSA, in order to find out the possible implications for tooth wear. Two studies showed this association based on self-report [69,70] (Table 6). Six studies showed the association based on polysomnography [71-76] (Table 6). One study opposed regarding the possible association between sleep bruxism and OSAS [76] (Table 6). A review discussed the possible theories regarding the associations between sleep bruxism and OSAS [77] (Table 6). Hypothetically, when sleep bruxism and OSA are related, it is possible that patients with OSA show more tooth wear in comparison with healthy individuals, because the associated sleep bruxism activities cause more mechanical tooth wear. The temporal relationship between sleep bruxism and OSA is not important regarding their influence on tooth wear, since only the SB activities cause mechanical tooth wear. The temporal relationship between sleep bruxism and GERD is important regarding their influence on tooth wear, because when GERD precedes sleep bruxism, the softening of the hard dental tissues by the stomach acid can accelerate the tooth surface loos by the sleep bruxism activities.

3 | CONCLUSIONS

Dental sleep disorders and tooth wear are associated with each other, and all are common multifactorial conditions. For some disorders, this association can be direct, whilst for others the association can be indirect or both. The multifactorial nature of these conditions leads to a variety of assessment tools, which makes comparison of the findings in the literature difficult. Therefore, the below-mentioned conclusions are drawn with caution and must be used in a restraint way. We would like to stress out that further research is a necessity to better substantiate the conclusions in the future. The results of this narrative overview, however, can nevertheless serve as a starting point for further research.

For chemical tooth wear, a direct association with dental pain and/or hypersensitivity can exist. OMD can directly be associated with mechanical tooth wear (when less saliva causes less lubrication), chemical tooth wear (when less saliva results in less buffer capacity), oro-facial pain (irritation of the soft tissues of the oral cavity and sleep bruxism (compensating the oral dryness). Oral dryness can indirectly be associated with tooth wear, oro-facial pain (dental pain/hypersensitivity due to tooth wear and TMD pain through sleep bruxism). GERD can directly be associated with chemical tooth wear, oro-facial pain (irritation of the soft tissues of the oral cavity), oral dryness, OSAS and sleep bruxism. GERD can indirectly be associated with tooth wear (through oral dryness and sleep bruxism) and oro-facial pain (due to tooth wear, oral dryness and sleep bruxism). OSAS can directly be associated with oral dryness, GERD and sleep bruxism, and can indirectly be associated with chemical tooth wear (through GERD) and mechanical tooth wear (through sleep bruxism), and oro-facial pain (dental pain/hypersensitivity through tooth wear). Sleep bruxism seems to be directly associated with mechanical tooth wear and oro-facial pain (TMD pain). Sleep bruxism is indirectly associated with chemical tooth wear (through GERD).

Since the dental sleep disorders are interlinked with each other, the consequences are difficult to disentangle. When several sleep disorders are present at the same time, several scenarios are possible. The sleep disorders can have a synergetic effect to accelerate the tooth wear process. For example when during sleep a reflux event is followed by a bruxing event (the stomach acid will soften the hard dental tissues, which will wear away more easily by the followed grinding), or counteract and slow down the tooth wear process (for example when a bruxing event is followed by an increase of salivary flow, the risk of mechanical tooth wear is neutralised by the improved lubrication). Although more research is needed to confirm the validity of the assumed associations between the dental sleep disorders, improving knowledge is clinically relevant, because avoiding damage to the hard dental tissues during a lifespan is key. The results can support dental clinicians in finding all the aetiological factors of the assessed tooth wear in their patients, and thus improve the provided dental care. Furthermore, there is a strong need for an interdisciplinary clinical team to manage oral health-related sleep disorders.[87] Such a team ideally should consist of dentists specialised in TMD/oro-facial pain, dentists specialised in dental sleep medicine, and dentist specialised in restorative/prosthetic dentistry, particularly in diagnosing and managing tooth wear. Only a comprehensive approach can result in a state of the art diagnostic process and thereby resulting in optimal care.

CONFLICT OF INTEREST

For this document, The authors declare no conflict of interest.

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