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Vertical tooth surface loss – a narrative review

Part I: Epidemiology and diagnosis

Introduction: Tooth surface loss (TSL) is etiologically the sum of cumulative, multifactorial events, which ultimately lead to irreversible loss of tooth structure. Tooth surface loss can be pathological depending on its extent and progression and it can necessitate that the dentist initiates individualized preventive or therapeutic measures in cooperation with the affected patient.

Methods: A literature search for various studies published on PubMed and in the S3 guideline Bruxism up to February 2020 was conducted as part of this narrative review. The studies were evaluated based on topic-related search terms and also a manual search through their respective reference lists was performed. Standard values for TSL were defined and different methods for recording findings were compared.

Results: A sound diagnosis and regular monitoring are mandatory treatment steps for the dentist when treating patients with TSL. Clinical examinations including the "Tooth Wear Index" or the "Tooth Wear Evaluation System" are available for this purpose; these help convey, depending on the index applied, the qualitative and/or quantitative loss of tooth substance. Based on the severity and extent of TSL, thorough consideration is needed for determining if a conservative or an interventional treatment is indicated. Conservative measures include protective splints, fluoridation, and regular monitoring; interventional measures constitute definitive restorations after an initial pre-restorative phase.

Conclusion: A systematic decision tree for the diagnosis and therapy of patients with non-cariogenic, vertical TSL was developed based on the current recommendations found in literature. It is intended to provide dental practitioners with a guideline for the diagnosis and treatment of patients with TSL in their everyday practice.

Keywords: tooth surface loss (TSL); "Tooth Wear Evaluation System"; "Tooth Wear Index"; prosthetic rehabilitation

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Introduction

The causes of pathological tooth surface loss (TSL) are multifaceted and range from carious lesions, trauma, idiopathic and genetic factors (e.g. molar incisor hypomineralization [MIH] or amelogenesis imperfecta) to bruxism. The first published studies on the topic of non-cariogenic tooth substance loss appeared as early as the 1970s [30, 40]. The terms abrasion, attrition, erosion, bruxism and demastication have been introduced in literature to define and better describe tooth surface loss.

Mechanical wear of the tooth substance is described using the terms abrasion and attrition. Attrition is caused by the physiological wear of the tooth substance as a direct result of tooth-to-tooth contact [14, 23]. The wear facets associated with attrition are particularly evident in patients with bruxism. Bruxism is defined as a repetitive masticatory muscle activity, which is characterized by the grinding or pressing of the teeth and/or tensing or pressing of the jaws against each other. The two different types are sleep and awake bruxism, which can occur solitarily or in combination [31, 32]. Whereas attrition describes intrinsic mechanical wear, which is caused by direct functional or parafunctional tooth-to-antagonist contact, abrasion refers to extrinsic mechanical wear, which is not related to the function or parafunctions of the masticatory system, but rather to oral hygiene measures, such as excessive contact pressure during tooth brushing or to habitats such as fingernail or pin chewing [53]. Furthermore, it is worth noting that abrasion primarily refers to a physiological process; in contrast, pathological abrasion refers to mechanical wear, which includes abnormal wear of the hard tooth substance due to causes other than chewing processes. Enamel defects caused by toothbrushes and interdental space brushes, or so-called toothbrush abrasions, are often described in literature [54] and they are linked to improper brushing techniques. Other frequently listed examples that cause tooth abrasions are the retaining elements of dentures [22] or by foreign bodies such as the wearing of piercings in the oral cavity or habits like chewing on pins [49].

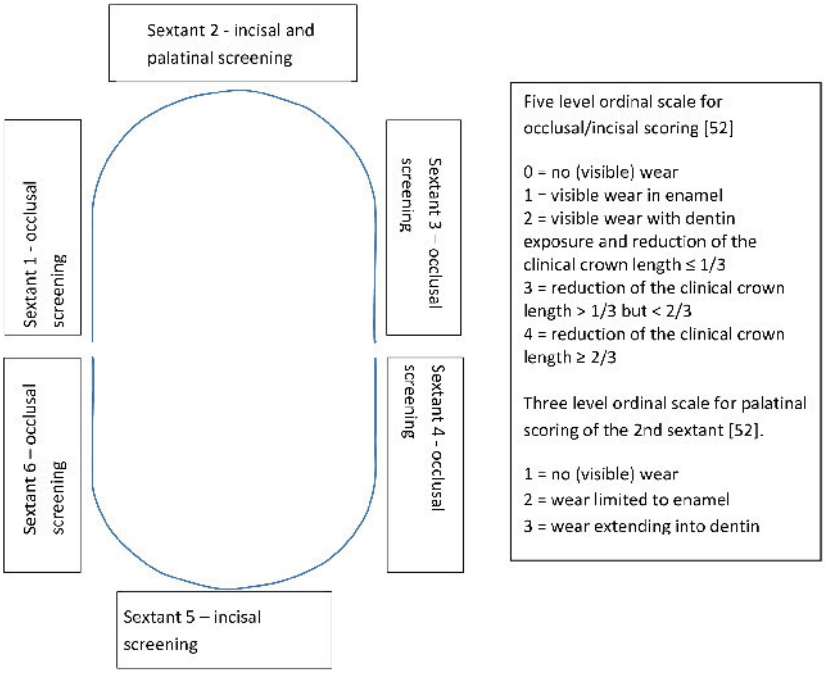

Figure 1 Quantitative screening using the TWES; in addition to the five level scale for each sextant [52], the palatinal surfaces in the 2nd sextant are graded using a three level scale. For each sextant, the highest value is recorded.

Demastication represents a special form of abrasion. In this case, wear is produced by abrasive substances contained in food. Even though demastication plays a less important role in modern times, the examination of 7000 – 8000-year-old human skulls has proved that the main cause of severe tooth wear in the past was coarse food containing sand and gravel [51].

Erosion is defined as a pathological, non-cariogenic destruction process of tooth surface that is caused by the action of acids on teeth without obligatory bacterial involvement [49]. Etiologically, exogenous (extrinsic) and endogenous (intrinsic) factors can be differentiated. Extrinsic factors include erosions resulting from dietary habits, environmental influences or particular lifestyles (combination of frequent acidic substance consumption and excessive oral hygiene). In Addition drugs with a low pH value can either directly cause erosions, or indirectly, by reducing saliva secretion. Diseases, which provoke reflux or chronic vomiting, are summarized as intrinsic factors, which can lead to erosions. In this case, lesions originating on the oral and occlusal tooth surfaces are predominantly observed [26].

With respect to a patient's particular case, it is unrealistic to consider the various causes of non-cariogenic TSL in isolation from one another; thus, it must be assumed that the loss is multifactorial and the different subtypes must be cumulated. For example, to some degree, the presence of erosions promotes the development of abrasions [49].

With regard to the long-term preservation of the natural dentition in the context of an aging population, the problem of non-cariogenic TSL is becoming increasingly important [41]. Given these circumstances, the diagnosis and regular clinical monitoring of TSL is substantial. Yet, to date, there are few evidence-based guidelines, which describe a systematic treatment approach for helping to guide the diagnosis and treatment of patients with TSL in everyday practice. As part of the literature search conducted in this narrative re-

Author	Sample size	Prevalence
Abrasion		
Kitchin 1941 [27]	n = 200	20–29 yrs: 58,0 % 30–39 yrs: 84,0 % 40–49 yrs: 96,0 % 50–59 yrs: 94,0 %
Radentz et al. 1976 [42]	n = 80	17–45 yrs: 50,0 %
Bergström and Lavstedt 1979 [9]	n = 818	18–25 yrs: 15,9 % 26–35 yrs: 37,6 % 36–45 yrs: 41,1 % 46–55 yrs: 40,3 % 55–65 yrs: 40,8 %
Hand et al. 1986 [21]	n = 520	≥ 65 yrs: 56,0 %
Bergström and Eliasson 1988 [8]	n = 250	21–60 yrs: 85,0 % at least 1 surface lesion 22,0 % at least 1 deep lesion
Akgül et al. 2003 [1]	n = 428	20–30 yrs: 2,0 % 31–40 yrs: 5,7 % 41–50 yrs: 12,9 % ≥ 51 yrs: 29,6 % Total: 9,1 %
Erosion		
Nautsch and Klimm 1989 [38]	n = 300 (16–35 yrs)	4,0 %
Klimm et al. 1991 [28]	n = 2499 (16–35 yrs)	3,4 %
Jaeggi et al. 1999 [25]	n = 417 (19–25 yrs)	82,0 % (erosion degree I occlusally)
Williams et al. (1999) [56]	n = 525 (14 yrs)	labial: 17,0 % palatinal: 12,0 %
Deery et al. 2000[12]	n = 129 (11–13 yrs) (UK) n = 125 (11–13 yrs) (US)	UK: 41,0 % US: 37,0 %
Ganss et al. 2001 [19]	n = 1000 (∅ 11,4 yrs)	Decidious teeth: 71,0 % Permanent teeth: 12,0 %
Al–Ma Jed et al. 2002 [2]	n = 354 (5–6 yrs) n = 862 (12–14 yrs)	5–6 yrs: 34,0 % 12–14 yrs: 26,0 %
Al–Malik et al. 2002 [3]	n = 987 (2–5 yrs)	31,0 %
Schiffner et al. 2002 [47]	n = 655 (35–44 yrs) n = 1027 (65–74 yrs)	35–44 yrs: 10,7 % 65–74 yrs: 7,9 %
Arnadóttir et al. 2003 [4]	n = 278 (15 yrs)	21,6 %
Dugmore and Rock 2004 [13]	n = 1753 (12 yrs)	59,7 %
Caglar et al. 2005 [10]	n = 153 (11 yrs)	28,0 %
Peres et al. 2005 [39]	n = 499 (12 yrs)	13,0 %
Salas et al. 2017 [46]	n = 1210 (8–12 yrs)	25,1 %
Truin et al. 2005 [50]	n = 832 (12 yrs)	24,0 %
Wiegand et al 2006 [55]	n = 463 (2–7 yrs)	Up to 32,0 %

Table 1 Study results of the prevalence of abrasion and erosion.

view, various studies published on PubMed as well as in the S3 guideline Bruxism up to February 2020 were evaluated on the basis of topic-related search terms; moreover, a manual search through the studies' respective reference lists was conducted. The search terms used were: tooth surface loss, (severe) tooth wear, (loss of) vertical dimension, tooth wear treatment options, prevalence of dental erosion, prevalence of dental abrasion, diagnosis and management of dental erosion, tooth wear index, tooth wear evaluation system. The first part of this narrative review describes the epidemiology, classification and diagnosis of non-cariogenic TSL; the second part outlines different treatment options while also presenting effective, evidence-based therapeutic approaches with a focus on restorative prosthetic measures.

Norm values for non-cariogenic TSL

The findings in literature vary with regard to the prevalence of non-cariogenic TSL due to the heterogeneity of the sample groups in terms of collective size, age and eating habits (Table 1).

For instance, a large-scale epidemiological study that examined over 3100 young European adults aged 18–35 years (3187 patients) reported a prevalence of non-cariogenic TSL in about 30 % of young adults [7]. A systematic review from 2015 analyzed the incidence of erosive TSL in children as well as younger adults aged 8–19 years and it reported a 30 % prevalence of non-cariogenic TSL [45]. Another large epidemiological study involving 1125 Dutch adults investigated the parameters age, gender, socioeconomic status and TSL of the affected teeth. The prevalence of mild, moderate, and severe TSL was reported to be 13 %, 80 %, and 6 %, respectively. Men and persons having a low socioeconomic status exhibited a higher severity of TSL than women or persons with a higher socioeconomic status. Additionally, it was found that mild to moderate tooth wear occurs frequently and that its prevalence increases with age [53].

Figures 2–4 Patient case; the patient was examined before the start of treatment using the TWES. For the maxilla, a value of 4 was recorded for all 3 sextants (2nd sextant, palatinal 3). In the mandible, a value of 3 in 4th and 6th sextants and a value of 2 for the 5th sextant was recorded.

Score	Surface	Criteria
0	B/L/O/I	No loss of enamel surface characteristics
	C	No change in contour
1	B/L/O/I	Loss of enamel surface characteristics
	C	Minimal loss of contour
2	B/L/O	Loss of enamel exposing dentine for < 1/3 of tooth surface
	I	Loss of enamel just exposing dentine
	C	Defect is less than 1 mm deep
3	B/L/O	Loss of enamel exposing dentine for > 1/3 of tooth surface
	I	Loss of enamel and substantial loss of dentine
	C	Defect is 1–2 mm deep
4	B/L/O	Complete enamel loss, pulp exposure, secondary dentine exposure
	I	Pulp exposure or exposure of secondary dentine
	C	Defect is more than 2 mm deep, pulp exposure, secondary dentine exposure

Table 2 Tooth Wear Index from Smith und Knight [48]; in the description of the tooth surfaces, "B" stands for "buccal", "L" for "labial", "O" for "occlusal", "I" for "incisal" and "C" for "cervical".

To a certain degree, TSL is an age-related physiological phenomenon [6]. In many studies, TSL is more pronounced in men than in women [24]; conversely, in other study groups, no gender-specific differences were found [43]. Scientific studies have described the shortening of the lower and upper incisors from the age of 10 to the age of 70 based on 1239 permanent upper and lower incisors from 346 patients. It was determined that the physiological TSL of lower incisors and upper incisors was 0.024 mm and 0.017 mm per year, respectively [43]. Other studies have defined the physiological TSL in premolars to be 0.015 mm per year and in molars as much as 0.029 mm [29]. Moreover, it seems that TSL is periodic with phases of progression and remission [44]. If TSL exceeds these determined normal values, or depending on the age of the patient, there is severe TSL. The dentist must diagnose this in good time in order to be able to initiate a patient-oriented and target-oriented treatment strategy.

Based on the studies that are listed in Table 1, non-cariogenic TSL can be diagnosed at any age, depending on the genetic predisposition, consumer habits and behavioral patterns.

Clinical guidelines

Pathological TSL can lead to increased tooth sensitivity, an impaired esthetic appearance or give rise to functional problems [34]. In order to be able to decide if TSL has to be treated, it is necessary to assess it using standardized criteria; in this respect, patient age, the degree of TSL and the course of TSL (episodic or progressive) can play a considerable role. Especially among the elderly, increased TSL is considered physiological, in spite of the fact that the vertical dimension can remain unchanged due to the process being gradual (thesis according to Dawson [11]). For instance, the restoration of the presumed loss of vertical jaw relation, with the intention of changing the esthetic appearance of the patient, can represent overcompensation and potentially trigger parafunctional activities or functional complaints [36].

Nevertheless, in case of pathological changes, dental treatment may be indicated. Particularly severe TSL, which is accompanied by a severe loss (≥ 1/3) of the clinical crown as well as dentin exposure, often represents an indication for therapeutic intervention [34].

Rapid progression may be clinically observed as markedly reduced remaining tooth hard substance or massively reduced tooth crowns. Clinical symptoms may include increased tooth sensitivity of the affected teeth due to exposure of dentin with pulp involvement. Vertically, a massively reduced dental crown may correlate with a lack of occlusal space, which in turn, limits the therapeutic options. Based on the authors' experience, a reduced vertical dimension can be accompanied by impaired masticatory efficiency, a negative smile line, or even increased interocclusal space. For these reasons, it can be assumed that the recon-

Score per sextant	Meaning	
0	No tooth surface loss	
1	Initial loss of tooth texture	
2	Distinct defect, hard tissue loss < 50 %	
3	Hard tissue loss ≥ 50 %	
Risk assessment	**Total score (Sum of scores)**	**Treatment**
No risk	≤ 2	– regular check-ups and aftercare (repeat at 3-year intervals)
Low Risk	3–8	– motivation and instructions regarding correct oral hygiene and dietary advice – close monitoring and aftercare as well as routine clinical examinations (every 2 years)
Moderate Risk	9–13	– oral hygiene instructions as well as remotivation and dietary advice – develop strategies to eliminate the associated causes – fluoridation measures or other strategies in order to increase resistance of the tooth surface – regular monitoring of the wear with study casts, photos or silicone impressions – repetition at least every 6 to 12 months
High Risk	≥ 14	– oral hygiene instructions as well as oral hygiene remotivation and dietary advice – develop strategies to eliminate the respective causes – fluoridation measures or other strategies in order to increase resistance of the tooth surface – repeat at 6–12 month intervals – regular monitoring of the wear with study casts, photos or silicone impressions – repetition at least every 6 to 12 months – restorative intervention may be necessary

Table 3 Basic Erosive Wear Examination (BEWE) [5].

structive measures for restoring function, phonetics and esthetics become more elaborate the later the therapeutic intervention is begun [35].

Diagnosis

The dental care and treatment of patients with non-cariogenic TSL is lengthy and demanding. However, a structured approach facilitates the clinical decision-making process and treatment. In this context, TSL and, if possible, the corresponding subtype should be diagnosed [52]. Afterwards, an analysis of the extent of the loss is meaningful [52]. Clinical examinations as well as laboratory techniques such as the superimposition of digital images are available for this purpose [33].

Indices convey the quantitative loss of tooth substance and make it easier for the dentist to record the progression of the loss. The „Tooth Wear Index“ (TWI) by Smith and Knight (Table 2) represents the most widely used and best evaluated scientific index for recording TSL [35]. The TWI is suitable for assessing the severity of TSL [48] as well as for regular follow-up examinations. Depending on the extent of TSL, five grades of loss can be differentiated. TSL is recorded separately for each tooth surface in relation to the anatomical structures. It is not possible, however, to make a statement about the etiology of tooth wear using this index.

Several years ago, Bartlett presented an alternative index [5]. When using the „Basic Erosive Wear Examination“ (BEWE), the percentage of tooth wear is determined with respect to the tooth and sextant. Depending on the extent, it is differently evaluated (Table 3), with the most severe finding per sextant always being documented. By adding the points for each sextant, the total score and possible treatment options are revealed [5].

In the current S3 guideline on bruxism, published by the cooperation between the German Society for Functional Diagnostics and Therapy (DGFDT) and the German Society for Dental, Oral and Maxillofacial Surgery (DGZMK), the Tooth Wear Evaluation System (TWES) is described, which enables both a

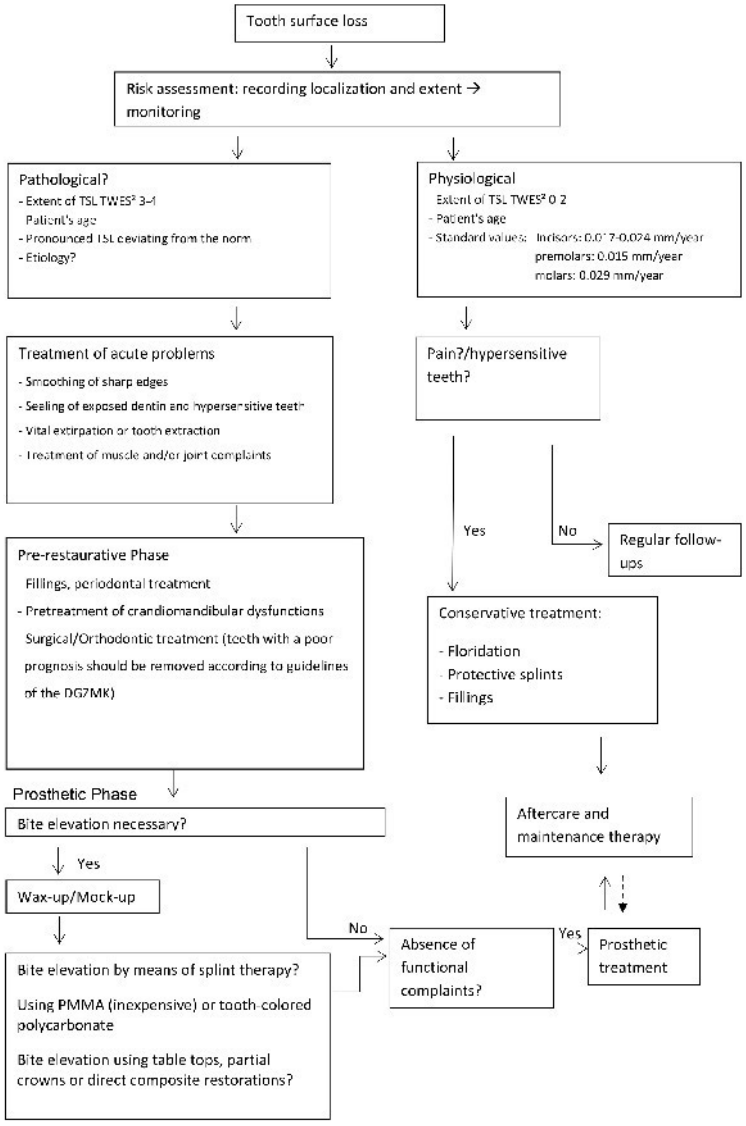

Figure 5 Decision tree for possible treatment options in patients with TSL.

qualitative (Table 4) and quantitative appraisal (Figures 1–4) of TSL. With the help of the TWES, the TSL can be detected (qualitatively), the severity assessed (quantitatively), the probable causes diagnosed, and the condition and possible progression monitored. The degree of severity determines the ensuing treatment, whereby Wetselaar and Lobbezoo differentiate between diagnostic modules for general practitioners and specialists (Table 5) [52].

Risk assessment is an important aspect for evidence-based and patient-oriented decision making. In patients with severe TSL, conservative treatment methods such as preventive measures and regular follow-ups should be carefully weighed against the risk of further substance loss or the possible failure of the existing restorations.

In addition to using an index to quantify the extent of TSL, further parameters should be considered for deciding if a prosthetic restoration is indicated. One such parameter includes the wishes and motivation of the patient. In the course of clinical treatment, the authors often found that patients with TSL desire restorative treatments because they regularly complained of hypersensitivity, pain when drinking and eating, and esthetic deficits. With time, it is not unusual for the affected patients to train themselves to adopt a relieving posture when eating. Thorough consideration is needed to determine if the increased sensitivity is due to TSL, or rather, to carious lesions or periodontal defects. The decision-making process for choosing the ideal treatment should also take the rate of progression, patient age and etiology of TSL into account.

Based on current scientific studies, the authors of this article have developed a decision tree to help provide dentists with a guideline for differentiated decision making in patients with TSL (Figure 5). It is important to note that restorative treatments are not always indicated. Especially in patients with non-cariogenic TSL, prevention and aftercare are of utmost importance. The dental therapist should always try to identify the cause of TSL in order to counteract before opting for an invasive treatment. In patient cases where restorative treatment is needed, a wide variety of treatment options and materials are available; these will be discussed in greater detail in the second part of this review [15, 16, 37].

Conclusion

Tooth surface loss is a physiological process per se. Etiologically, it represents the sum of cumulative, multifactorial events which ultimately lead to irreversible loss of tooth substance. The factors which influence this process are not only exogenous, but also endogenous. Moreover, these factors have varying degrees of manifestation. Important parameters include patient age, enamel thickness, enamel hardness, saliva flow rate and composition, the pH value of the oral cavity, as well as, malpositions of teeth. Over time, various indices have been developed for risk assessment, among which, the Tooth-Wear-Index (TWI) and the Tooth Wear Evaluation System (TWES) have become well-established. When deciding if a prosthetic treatment should be performed, various factors such as the extent of TSL in relation to patient's age must be taken into account. The decision tree, which has been developed by the authors, is intended to

Clinical signs of erosion	
According to Gandara and Truelove [17]	**According to Ganß and Lussi [18,20]**
– "Cupping" of occlusal surfaces, (incisal grooving) and „crater" formation – Wear of non-occluding surfaces – Raised restorations – Broad concavities on the smooth surfaces of enamel – Increased incisal translucency – clean, non-tarnished appearance of amalgam restorations – persisting cervical enamel projections in the gingival sulcus – Hypersensitivity	– Rounding of cusps and fissures – Raised restorations – Flattening of elevations, formation of concavities in greater width than depth – persisting cervical enamel projections in the gingival sulcus – No plaque, discoloration or subgingival tartar – Smooth, silky shimmering or silky-glossy appearance, sometimes dull surface
Clinical signs of attrition	
– Glossy wear facets – Degree of enamel and dentin wear is comparable – Consistent wear on occluding surfaces – Possible fractures of cusps and restorations	– Flat, smooth as glass – Matching features on antagonist teeth
Indentations in cheeks, tongue or lips*	
Clinical signs of abrasion	
– Normally, cervical localization – Lesions are rather broad than deep – Mostly premolars and canines are affected	
** Additional feature according to Wetselaar und Lobbezoo*	

Table 4 With the help of the qualification module of the TWES, the dentist is able to recognize the problem of tooth surfacee loss [52].

help implement a systematic assessment of TSL in patients and to identify possible treatment options.

Conflicts of interest

The authors declare that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

Diagnostic modules – basic diagnostic for general practitioners
Module Qualification Module Quantification Module Quantification – clinical crown length Module recording of tooth wear (intra-oral photographs, dental casts)
Diagnostic modules – extended diagnostics for specialists
Module Quantification– finer-grained occlusal/incisal and non-occlusal/non-incisal Module Oral History, questionnaires Module salivary analysis
Treatment/management modules
Module complaints of the patient vs. reasons for clinician to start treatment/management Module start of treatment/management Module level of difficulty

Table 5 Tooth Wear Evaluation System (TWES) [52]; with the TWES, it is possible to detect tooth surface loss (qualification) and to evaluate its severity (quantification). Additionally, possible causes can be diagnosed and a possible progression can be recorded.

(Fig. 1–5, Tab. 1–5: A. Roesner)

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