Current concepts on the management of tooth wear: part 1. Assessment, treatment planning and strategies for the prevention and the passive management of tooth wear

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VERIFIABLE CPD PAPER

IN BRIEF

- Provides an account of how to assess, diagnose and treatment plan a patient with tooth wear.
- Includes an overview of the aetiological factors.
- Describes the passive management of tooth wear and possible monitoring strategies.

PRACTICE

The aim of this series of four articles on tooth wear management is to provide the reader with the necessary information in order to be able to successfully manage cases of tooth wear, regardless of the cause, severity and location of the wear pattern seen. The content will largely focus on contemporary clinical techniques, illustrated where possible by case examples. Emphasis will be placed on 'additive adhesive techniques' utilising fixed prosthodontic protocols; however, cases of tooth wear amongst partially dentate patients involving the use of removable prostheses will also be described. The importance of patient consent and contingency planning will also be discussed. Paper 1 will describe the assessment of the wear patient, including the rationale for the planning of dental care. Also discussed will be the administration of preventative and passive management strategies for cases displaying tooth wear.

INTRODUCTION

The term 'tooth wear' (TW) is a general term that can be used to describe the surface loss of dental hard tissues from causes other than dental caries, trauma or as a result of developmental disorders.[1] It is a normal physiological process that is macroscopically irreversible and is cumulative with age. Lambrechts *et al.* in 1989[2] estimated the normal vertical loss of enamel from physiological wear to be approximately 20-38 µm per annum.

The process of tooth wear has a multifactorial aetiology. Individual aetiological factors may be subdivided into erosion, abrasion, abfraction and attrition. Clinically however, it is difficult (if not at times impossible) to isolate a single aetiological factor when a patient presents with tooth wear. For the latter reason, the term 'tooth surface loss' (TSL) was suggested by Eccles in 1982[3] to embrace all of the aetiological factors regardless of whether the exact cause of wear has been identified. This includes factors such as trauma, developmental conditions such as amelogenesis and dentinogenesis imperfecta, and iatrogenic wear. The content of these series of articles will largely focus on 'tooth wear' by causes other than trauma, caries or developmental disorders.

Where the process of tooth wear is considered to be excessive to the extent that it is associated with functional or aesthetic concerns by the dental patient, is disproportionate for the age of the patient, symptoms of discomfort are present or indeed if the rate of tooth wear is deemed to be so severe that it may be of grave concern to the dental patient or operator, then the suffix of 'pathological' may be added to the term TW so as to distinguish the rate of wear from physiological tooth surface loss.

In a recent systematic review of the results of 186 prevalence studies of tooth wear by all causes, Van't Spijker *et al.*[4] concluded that the percentage of adult patients presenting with severe tooth wear increased from 3% at the age of 20 years to 17% at the age of 70 years, with a tendency to develop more wear with age. Likewise, the results of a large epidemiological study amongst German dental patients reported similar results, where the extent of tooth wear was scored on a scale from 0 to 3 (with higher scores indicating more severe levels of tooth wear), with mean wear scores increasing from 0.6 amongst 20-29-year-olds to 1.4 in 70-79-year-olds (Bernhardt *et al.* 2004[5]).

Whilst the criteria applied for identifying and scoring tooth wear show wide variation amongst different studies, there has been considerable interest shown in studies documenting the prevalence of erosive tooth wear, as it would appear that there has been a staggering increase in the incidence of erosion-related tooth wear amongst children and young adults

CURRENT CONCEPTS ON THE MANAGEMENT OF TOOTH WEAR

1. **Assessment, treatment planning and strategies for the prevention and the passive management of tooth wear**
2. Active restorative care 1: the management of localised tooth wear
3. Active restorative care 2: the management of generalised tooth wear
4. An overview of the restorative techniques and dental materials commonly applied for the management of tooth wear

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Refereed Paper
Accepted 14 November 2011
DOI: 10.1038/sj.bdj.2011.1099
©British Dental Journal 2012; 212: 17-27

Fig. 1 Occlusal view of an anterior maxillary dentition of a patient in their early 30s displaying signs of pathological tooth wear as a consequence of the excessive consumption of carbonated soft drink(s)

Table 1 The pH values of commonly consumed beverages in the UK (Kelleher and Bishop[10])

Manufacturer	Brand	pH value
Pepsi-Cola	Diet	2.95
Coca Cola	Regular	3.15
Coca Cola	Caffeine-free diet	3.30
Lucozade	Sport Orange	3.78
Tango	Diet Orange	2.80
Orange juice		3.50

Fig. 2 Advanced generalised, pathological tooth surface loss in a 79-year-old female, with major attritional and erosive components. Wear has been exacerbated by a recent history of xerostomia. Left: Facial view. Right: Palatal/occlusal view

over the course of the past three decades. Erosion was first included in the UK's Children's Dental Health Survey in 1993.[6] When reassessed in 1996/1997 a trend towards a higher prevalence of erosion in children aged between 3.5 years and 4.5 years was identified (particularly amongst those children who consumed carbonated drinks on an almost daily basis when compared to toddlers consuming these drinks less frequently).[7] The initial Child Dental Health Survey also reported that 25% of 11-year-olds and 32% of their 14-year-olds respectively assessed in their sample displayed signs of erosion affecting the palatal surfaces of their maxillary incisor teeth (which in more severe cases had progressed to involve the dentinal tissues and in some cases the pulp complex).[6] The latter survey also revealed that almost half of the 5- and 6-year-olds studied demonstrated signs of erosion affecting the primary dentition, with almost 25% showing signs of dentinal or pulpal tissue involvement.

In another extensive UK-based study by Dugmore and Rock in 2004,[8] where 1,753 children were examined at the age of 12 years and observed for a period of two years thereafter, 59.7% were reported to have evidence of tooth wear at the commencement of the study, of which 2.7% had dentine exposure, which rose to 8.9% over the course of the two year observation period.

Erosive tooth wear is caused by acidic substrates which may be either of an intrinsic origin or an extrinsic source. The consumption of soft drinks in the UK has increased seven fold between the 1950s and 1990s (Shaw and Smith, 1994[9]), with adolescents and children accounting for 65% of all purchases, with a reported per capita intake of 15 litres per person. Figure 1 shows a case of a patient in their early 30s displaying signs of pathological tooth wear, as a result of the copious consumption of carbonated drinks.

Table 1 lists the typical pH values of commonly consumed beverages in the UK. Other factors which may be responsible for the high rates of erosive tooth wear described by the above studies include regurgitation, which may be involuntary, associated with conditions such as hiatus hernia, or voluntary regurgitation as seen amongst patients presenting with eating disorders such as anorexia nervosa or bulimia nervosa.

Dental erosion may also be induced by environmental influences, such as that seen amongst those workers exposed to acids in the work place.

It is beyond the scope of this paper to provide a comprehensive account of the nomenclature, epidemiology and aetiology of specific factors relating to tooth surface loss; however, it is vital that the clinician has a good appreciation of these factors, as the identification of the aetiological factors is critical to successful prevention.

As most dental practitioners will be aware, the management of a patient presenting with pathological tooth surface loss is by no means always a straightforward matter. However, patients are ever increasingly presenting with signs of tooth surface loss to their respective dental practitioners, largely on account of a combination of changing dietary and lifestyle habits (particularly amongst younger patients) and also by virtue of elderly patients retaining more of their teeth into later years.

Figure 2 provides an example of severe pathological generalised tooth wear in a 79-year-old female patient, possibly as a result of a combination of gastric erosion, xerostomia and a parafunctional tooth grinding habit.

Aspects which compound difficulties associated with tooth wear management include:

- Challenges associated with deriving an accurate diagnosis
- Uncertainties in knowing at what precise stage to implement active restorative intervention (as opposed to simple passive management and monitoring)
- A lack of understanding on how to restore such severely worn dentitions, with the aim of ultimately attaining a functionally and aesthetically stable restored dentition

- A lack of knowledge relating to the availability of contemporary materials and their respective techniques of application.

PATIENT HISTORY

The successful management of any case of tooth wear is based on deriving an accurate diagnosis, having a clear understanding of the basic principles of occlusion, and a good working knowledge of available materials and techniques to treat such cases using both active and passive means.

It is important to identify, and where possible prevent the aetiological factor(s) from further inflicting damage upon the teeth or upon dental restorations. Treatment planning for cases displaying tooth wear can often be fairly complex. The formulation of a comprehensive treatment plan relies on an accurate history and examination of the patient. The management of tooth wear depends to an extent on the ability of the patient's understanding of the condition in order to provide information to allow the clinician to arrive at a differential diagnosis. In some cases it may take several visits to determine the underlying cause, as patients may be reluctant during their initial consultation to disclose sensitive information.

According to Holbrook and Arnadottir,[11] in order to prevent or reduce non-carious destruction of tooth substance it is important to:

- Recognise that the problem is present
- Grade its severity
- Diagnose the likely cause or causes
- Monitor progress of the disease in order to assess the success, if any, of any preventative measures.

The accuracy and importance of the *chief complaint* must be first evaluated. Common complaints associated with dentitions displaying tooth wear include concerns relating to:

- Aesthetic impairment (fractured, unattractive teeth/restorations or tooth discoloration)
- Difficulties with function, such as the efficiency of mastication or lip/cheek or tongue biting
- Less commonly, comfort (pain and sensitivity).[12]

A detailed history of the chief complaint should be ascertained and documented. An accurate and up-to-date medical history must be obtained. The medical history may reveal underlying conditions which preclude the provision of complex treatment plans, and may also provide a valuable insight into the aetiology of the wear pattern observed to be present.

Medication, such as the frequent use of asthma inhalers containing steroid or effervescent medication, may contribute to dental erosion.[13] It has been suggested that the pH values of common asthma medications range from 4.31 (Bricanyl, powder form), to 9.30 (Ventolin, aerosol form). Medications in tablet form such as aspirin (salicylic acid) and chewable vitamin C preparations (ascorbic acid) as well as various iron preparations have also been associated with dental erosion.[14] Other drugs through inducing xerostomia may also be causative (by virtue of reducing the protective effect offered by saliva) such as diuretic agents and antidepressant drugs.

The presence of a gastro-oesophageal reflux as seen in patients diagnosed with anorexia nervosa, bulimia nervosa or those with hiatus hernia, sphincter incompetence, oesophagitis, or increased gastric pressure (and volume) may also be associated with considerable erosive wear.[15] It has been reported that female patients are affected by eating disorders more frequently than males at a ratio of 10:1.5.[16] Cyclical vomiting syndrome and voluntary regurgitation (rumination) have also been reported as aetiological conditions respectively.

Pregnancy may also increase the risk of developing tooth wear, as it has been suggested that an increase in abdominal pressure may predispose the patient to regurgitation,[17] whilst morning sickness may be associated with frequent episodes of vomiting, which may further exacerbate the wear pattern seen. A history of heartburn or reflux is a key factor to note, although in subclinical cases there may be a lack of patient awareness.[16] Gastric reflux may also be associated with oesophageal carcinoma.

Other factors contributing to the development of xerostomia are sometimes indirectly causative. Certain cases will necessitate referral to the patient's general medical practitioner.

A past dental history will provide useful information as to the patient's previous level and experience of dental care. Oral hygiene habits should be ascertained. Of particular interest to tooth wear are factors such as the type of toothbrush used, the intensity, the frequency and timing of toothbrushing as well as the abrasivity of the dentifrice being used.

A poorly motivated patient or one with negative views towards dental care or indeed a phobic patient may not be the best candidate at first instance when considering complex treatment provision. It is also crucial to establish (where relevant) any previous experience of removable appliance/prosthesis wear experience.

The patient's social history can reveal further insight into the aetiology, such as lifestyle stresses or occupational details which may also have a bearing on their ability to attend for treatment plans which sometimes take numerous visits to execute.

Habits such as smoking, alcohol consumption or dietary trends should be documented. A detailed dietary analysis is often advocated if it is suspected that a poor diet has played a role in the aetiology of the tooth wear pattern seen. Of particular relevance to diet/beverages and tooth surface loss are the copious consumption of citrus fruits, pickles, vinegar (acetic acid), coarse food, cola, fruit juices and carbonated drinks. The frequency and quantity of daily intake, the duration of consumption and the method of eating/drinking should be established. Watson and Burke[16] have suggested that patients affected by tooth wear should undertake a three day consecutive comprehensive diet diary.

Excessive alcohol consumption may also have a significant role in cases of pathological erosive wear, as binge drinking is often followed by vomiting. The presence of other habits which may be aetiological by nature such as that of pipe-smoking, pen/pencil biting, and holding objects between teeth should also be determined. The use of recreational drugs such as LSD and ecstasy has also been shown to be associated with erosive tooth wear.[18]

Erosive tooth wear has also been reported to occur amongst frequent swimmers[19] as a consequence of being exposed to chlorine in swimming pools; erosive wear affecting the labial surfaces of maxillary anterior teeth has also been described to occur amongst copper mine workers, who may be exposed to ambient sulphuric acid used in the mining of this metal.

EXAMINATION OF THE WEAR PATIENT

For the patient presenting with tooth wear, the extra-oral examination must include a meticulous assessment of their temporomandibular joints and associated musculature. The examination should include the undertaking of bilateral muscle and joint palpation. The presence of any joint or muscle tenderness, clicking, crepitation, mandibular deviation on opening or closure or any associated aches/pain should be noted. The maximum jaw opening should be recorded (that less than 40 mm between incisal edges is considered to be restricted). The presence of parotid gland enlargement is often seen in bulimic patients[17] and may be an important feature to note.

Figure 3 shows an example of a patient displaying 'overclosure' as a result of loss of occlusal vertical dimension as a consequence of pathological tooth wear.

The facial vertical proportions should also be carefully examined. This should include an assessment of the freeway space (FWS), by determining the patient's resting vertical dimension (RVD) and occlusal vertical dimension (OVD), with the aid of callipers or by the use of a Willis gauge.

Other techniques that can be used for the evaluation of vertical dimension include the use of phonetic assessments (particularly the sibilant sounds), facial soft tissue contour analysis, jaw tracking and the use of electrical muscle stimulation techniques (Rivera-Morales and Mohl[20]).

The smile line and lip line should also be noted, as well as any midline discrepancies.

The intra-oral examination must include a detailed soft tissue assessment. The presence of buccal keratoses, scalloping of the tongue or signs of xerostomia may give clues to the possible aetiology. Saliva has a vital role in the protection of enamel from erosion by acid, both by supplying the components of the acquired pellicle that coats the enamel surface and thereby conferring some level of protection, and also by virtue of its buffering capacity, promoting the remineralisation of the enamel surface following acid attack.

The level of oral hygiene should be recorded together with the undertaking of a Basic Periodontal Assessment (BPE). The latter may indicate the undertaking of a full depth six point periodontal chart.

A dental chart should be completed, detailing the presence or absence of teeth, dental caries, restorations, failed restorations, fractures, abrasions and erosive lesions.

Once diagnosed, the location of tooth wear (localised, anterior/posterior or generalised) and severity of the tooth surface loss should be recorded (as being restricted to enamel only, into dentine or severely affecting the teeth or series of teeth).

A number of indices have been proposed for the above purpose. The Tooth Wear Index of Smith and Knight[21] is most commonly described in literature.

A comprehensive occlusal assessment is mandatory. The latter must include an overall examination of the general alignment of teeth within their respective arches. Of importance are the presences (or absence) of:

- Crowding
- Rotations
- Tilting
- Drifting
- Spacing
- Over-eruption
- Mobility.

The overbite and overjet should also be measured and recorded.

The presence of a stable centric occlusion (CO) should be determined, and tooth contacts in the intercuspal position (ICP) described. The ease with which the patient can be manipulated into their retruded arc of closure should also be established. Where a patient cannot be readily manipulated into centric relation (CR), due to protective neuromuscular reflexes, the use of deprogramming devices should be considered; commonly used examples of such deprogramming devices range from the use of cotton wool rolls and wood spatulas, to more elaborate appliances such as anterior bite planes (Lucia jig) or full coverage stabilisation splints. The first point of tooth contact in CR, hence the retruded contact point (RCP) should be identified and the presence of any 'slides' (and the direction of the latter) from CR to CO established. It is also important to note whether the slide from CR to CO has a larger vertical or horizontal component. The latter may be vital in providing the space requirements for dental restorative materials, when considering a re-organised approach.

Fig. 3 Demonstrates a typical appearance resulting from loss of occlusal vertical dimension; note the presence of an 'inverted lip profile'

Tooth contacts during lateral excursive (canine guidance or group function) and protrusive movements of the mandible should be determined. If present, any working side/non-working side occlusal interferences should be described.

Where the patient may be partially dentate, an evaluation of the denture bearing areas must be undertaken, as well as the fit of any removable prostheses.

SPECIAL TESTS

Radiographs

Good quality, accurate long cone periapical radiographs are advocated for any teeth displaying signs of wear and also for any teeth where active restorative intervention may be being considered. It is important to establish the presence of any signs of alveolar bone loss.

Other factors, such as the root surface morphology, anatomy of the pulp chambers of affected teeth, quality of pre-existing endodontic treatment(s), presence of dental caries, widening/disturbance of the lamina dura, presence of retained roots or any signs

of periapical pathology (radiolucencies or radio-opacities) should also be assessed. Teeth with poor root morphology, poor bone support, and unfavourable crown:root ratios or those with signs of pathology, along with endodontically treated teeth with guarded prognoses, are all poor teeth to undertake complex restorations upon, particularly where an increase in the crown:root ratio may be being contemplated.

Articulated study casts

Good quality study casts poured in vacuum mixed die-stone should be mounted on at least a semi-adjustable articulator in centric relation. Study casts will permit an assessment of the occlusion in the absence of soft tissue/muscular interferences. The impact of tooth over-eruption can be more readily assessed together. Tooth contacts in CR, during lateral excursive and protrusive movements, and the presence of occlusal interferences can be more easily determined. The space gained by manipulating the mandible into CR can be noted and the effect of 'opening the bite' on the articulator on the residual dentition also seen, along with the effect of any trial occlusal adjustments. The vertical and horizontal components of the slide from CR to CO can also be examined at this stage.

Sensibility tests

These should be undertaken for all affected teeth. Loss of vitality is often seen amongst teeth which display signs of severe wear. It is important to establish the health status of the dental pulp prior to embarking upon any complex prosthodontic rehabilitation. Sensibility tests commonly used in general practice for the latter purpose may involve the application of ethyl chloride, warmed gutta percha or electric stimuli to the tooth (however, the 'true' vitality status of a tooth can strictly be only established with the use of Doppler flow techniques).

Intra-oral photographs

Including anterior, posterior (left/right) views and occlusal views of both arches are very important. Images should be appropriately stored.

Salivary analysis

This can be undertaken for both stimulated and un-stimulated secretion rates and respective buffering capacities.

Fig. 4 Study casts of a patient displaying tooth wear, mounted in centric relation on a semi-adjustable articulator (left); right: diagnostic wax up fabricated in accordance with an accurate occlusal-aesthetic prescription. The information derived from the wax up has been used to guide the placement of restorative materials

Diagnostic wax mock-ups

Diagnostic mock-ups may be fabricated with the desired final occlusal scheme and aesthetic requirements as prescribed by the operator. They form a useful visual aid and communication tool, to assist in the evaluation of aesthetics, tooth shape, length, and inclination. Furthermore, the wax up once duplicated by the means of a stone model can be used to fabricate a vacuum formed PVC matrix that can initially be used to demonstrate the proposed changes intra-orally by the application of a provisional crown and bridge material into the vacuum formed matrix. The matrix helps fabricate definitive restorations using direct resin composite. The wax mock-up can used as an aid to help form tooth reduction guides, assist with the fabrication of provisional restorations, or used to form a polyvinylsiloxane (PVS) index, which helps form direct resin composite restorations, as described in detail below.

Figure 4 is an example of a set of articulated study casts poured in improved die stone mounted in centric relation on a semi adjustable articulator of a tooth wear case. The image on the right shows a diagnostic wax up fabricated in accordance to a detail occlusal/aesthetic prescription for the same case. This case has been initially stabilised by the addition of resin composite to the anterior segments. The placement of resin composite has been guided by the use of a silicone index derived from the diagnostic wax up. The posterior segments have been restored by the means of conventional indirect restorations, placed at the newly established occlusal vertical dimension.

DIAGNOSIS OF TOOTH SURFACE LOSS

The diagnosis of a patient presenting with tooth wear should include a description of the type(s) of lesions observed, together with an account of their extent/location and severity.

Sub-classification of tooth wear lesions

There are four sub-classifications of tooth wear lesions:

- Attrition
- Erosion
- Abrasion
- Abfraction.

Attrition may be defined as the physiologic wearing away of tooth structure as a result of tooth-to-tooth contact, as in mastication, with possible abrasive substance intervention (Eccles[3]). Lesions due to attrition are most commonly observed to occur on the incisal and occlusal contacting surfaces. The early clinical manifestation of attrition is the appearance of a small polished facet on the cusp or ridge, or the slight flattening of an incisal edge. As the lesion progresses, there is a tendency towards the reduction of the cusp height and flattening of the occlusal inclined planes, with concomitant dentine

exposure. In severe cases there may be a marked shortening of the clinical crown height of the affected tooth/teeth respectively.[1] Figure 5 illustrates severe wear where the pattern of wear stems largely from an attritional tooth grinding habit.

Erosion has been defined as the loss of tooth surface by a chemical process that does not involve bacterial action.[3] It is caused by the chronic exposure of dental hard tissues to acidic substrates which may be of an intrinsic or extrinsic source. Erosive lesions typically manifest as bilateral concave defects without the chalkiness or roughness normally associated with bacterial acid decalcification. In its early stages, erosion affects the enamel layer, resulting in a shallow, smooth, glazed surface that usually lacks developmental ridges and stain lines and are usually free from plaque deposit.[1]

With progression, dentine exposure will occur and the lesion may take on a rather dulled appearance. In more severe cases there may be evidence of 'cupping' of both the occlusal surface of posterior teeth and the incisal edges of anterior teeth. Extrinsic erosion is often seen to occur on the labial surfaces of maxillary anterior teeth, typically in the form of scooped out depressions, whilst lesions initiated by intrinsic acid sources are most often seen on the palatal surfaces of the maxillary anterior teeth, resulting in a concave depression of the entire palatal surface.[1] The term perimolysis has been used to describe the classical lesions seen as a result of chronic vomiting, localised to the palatal surfaces of the maxillary anterior teeth. Figure 6 is an example of classical erosive lesions seen in a 30-year-old female patient from the result of a previous history of gastric reflex affecting the palatal surfaces of the maxillary anterior dentition.

Abrasion is the physical wear of tooth surface through an abnormal mechanical process independent of occlusion. It involves a foreign object or substance repeatedly contacting the tooth (Shafer *et al.*[22]). The site and pattern of lesion is usually determined by the offending object. A common cause of abrasion is the habit of overzealous tooth brushing. Lesions are typically rounded or 'V' shaped ditches seen on the buccal/labial surfaces in the region of the cement-enamel junction, as depicted by Figure 7. Canine and premolar teeth seem to be most commonly affected. Notching of the incisal edges on maxillary central incisor teeth is often seen as a result of habits such as the biting of tacks, nails, pins, threads, a pipe stem, hair pins or a wind instrument.

Fig. 5 An example of pathological tooth wear, with a multi-factorial aetiology, where attritional wear has a significant aetiological role

Fig. 6 Example of a case showing erosive wear resulting from chronic gastric reflux affecting the palatal surfaces of the upper anterior teeth

Fig. 7 Selection of views to demonstrate tooth wear by abrasive tooth brushing habits. Note the 'V' shaped appearance of these lesions

Fig. 8 Two examples of wear seen on the cervical area of the 24 which are also in occlusal contact on excursion

Fig. 9 Lesions on the cervical areas of the lower teeth, abrasion being the most likely major component

Abfraction has been defined by Imfeld[23] as the loss of hard tissue from eccentric occlusal loads leading to compressive and tensile stresses at the cervical fulcrum area of the tooth. Tensile stresses weaken the cervical hydroxyl-apatite, which has the effect of producing classical wedge shaped defects with sharp rims at the cement-enamel junction. Lesions are less commonly seen amongst teeth which may display signs of mobility, but are often typified by the presence of recurrently failing cervical restorations. The extent of the lesions is dependent on the size, duration, direction, frequency and location of the forces concerned. Lesions due to abfraction have also been described in the literature as 'cervical stress lesions'.[24] Figure 8 provides an example of two separate cases of suspected abfractive wear on maxillary premolar teeth; both patients had a tendency towards bruxism (please note that these teeth are involved with guiding the mandible during a working side lateral excusive movement for each patient respectively).

The pattern of wear lesions seen may provide critical clues for the clinician in helping them to identify the cause.

Figure 9 is another example of a patient displaying signs of cervical tooth wear, where a combination of abrasion and abfraction are likely to be occurring; these sites may become very susceptible to dental caries in vulnerable patients.

Hattab *et al.*[1] suggest that of the above listed conditions, erosion seems to be the most common cause of tooth surface loss, with regurgitation erosion causing the most severe damage. However, it is important to point out that patterns of tooth wear seen amongst differing cultures may be quite variable.

Table 2 Tooth Wear Index by Smith & Knight[21]

Grade	Criteria
0	No loss of enamel surface characteristics
1	Loss of enamel surface characteristics
2	Buccal, lingual and occlusal loss of enamel, exposing dentine for less than one third of the surface Incisal loss of enamel Minimal dentine exposure
3	Buccal, lingual and occlusal loss of enamel, exposing dentine for more than one third of the surface Incisal loss of enamel Substantial loss of dentine
4	Buccal, lingual and occlusal complete loss of enamel, pulp exposure or exposure of secondary dentine Incisal pulp exposure or exposure of secondary dentine

SEVERITY OF TOOTH WEAR

It is also important to establish the severity of tooth wear seen. Whilst seemingly arbitrary, it is worthwhile subdividing cases into those where the severity of tooth wear may be considered to be normal or 'physiological' for that person's age, or excessive, unacceptable or 'pathological' in relation to what is considered to be acceptable for an individual of a certain age grouping.

However, it has been argued that for 'pathological tooth wear' to have a meaning, normal levels of wear for different age groups must be defined in order to permit a comparison. Such information is yet to be made available though.[4] Furthermore, it is yet to be established whether the pathogenesis of tooth surface loss is episodic or indeed progressive throughout life.

For cases of physiological wear, particularly where there may be no aesthetic or functional detriment, or any associated symptoms of discomfort, management strategies as discussed below may be limited to prevention and monitoring only. In contrast, those with pathological tooth wear may, in addition to preventive protocols and regimes, be in need of active restorative/operative intervention.

Tooth wear resulting from inherited developmental conditions should also be differentiated, such as that resulting from amelogenesis imperfecta or dentinogenesis imperfecta.

A number of indices have been proposed to grade the severity of tooth wear seen, by recording the surface characteristics of teeth with a numerical score. The most popular is that of the Tooth Wear Index, by Smith and Knight.[21] An index such as this, as shown in Table 2, can be used to compare wear rates between individuals and also monitor the progression of wear for the patient concerned.

It is worth noting that the Tooth Wear Index by Smith and Knight has received criticism as it does not relate the aetiology to the outcome of wear seen on the teeth.[4] Other indices applied less commonly to assist with the diagnosis and monitoring of tooth wear include: tooth wear index, index for grading severity of occlusal wear and the index for grading severity of dental erosion.[1]

In 2010, Bartlett[25] presented a paper describing an index based on the BPE to record the severity of tooth wear for patients seen in the primary care setting. The index known as BEWE (Basic Erosive Wear Examination) was formed in collaboration with European colleagues. Their objective was to construct an index for the recording of tooth wear, which would be simple to use, easy to record, and would provide the dental practitioner with the opportunity to record that tooth wear had been examined and considered. BEWE records the severity of wear on a scale from 0 to 3 for each sextant, hence 0 (no wear), 1 (initial loss of surface texture), 2 (less than 50% loss of surface) and 3 (greater than 50% loss of surface). The tooth most severely affected in a particular sextant is the one for which the score is based on. On completion of the BEWE, an aggregate score is reached for all sextants. The latter score can be used as a guide to the clinical management of the patient concerned. However, further studies are needed to assess the sensitivity and specificity of the BEWE index.

Table 3 The ACE classification (Vialati & Belser)[26]

Class	Palatal enamel	Palatal dentine	Incisal edge length	Facial enamel	Pulp vitality	Suggested therapy
Class I	Reduced	Not exposed	Preserved	Preserved	Preserved	No restorative treatment – prevention only
Class II	Lost in contact areas	Minimally exposed	Preserved	Preserved	Preserved	Palatal composites
Class III	Lost	Distinctly exposed	Lost ≤2 mm	Preserved	Preserved	Palatal onlays
Class IV	Lost	Extensively exposed	Lost greater than 2 mm	Preserved	Preserved	Sandwich approach
Class V	Lost	Extensively exposed	Lost greater than 2 mm	Distinctly reduced/lost	Preserved	Sandwich approach (experimental)
Class VI	Lost	Extensively exposed	Lost greater than 2 mm	Lost	Lost	sandwich approach (highly experimental)

Recently, Vailati and Belser[26] have introduced the anterior clinical erosive classification (ACE) based on their clinical observation of the upper anterior teeth. This classification system has been proposed to not only assess the severity of hard tissue loss but also to provide a guide to the treating clinician on how to appropriately restore the affected teeth. The classification, as shown by Table 3, establishes six levels of wear according to the level of dentine exposure in the palatal contact areas, the preservation of the incisal edges, the length of the remaining clinical crown, the preservation of enamel on the labial surfaces, and the vitality of the pulp. The 'sandwich approach' as listed in Table 3 refers to the application of a resin-based material to treat the palatal surface wear, followed by the application of a labial/facial ceramic veneer, as will shown by case example in paper 2.

LOCATION OF TOOTH SURFACE LOSS

Finally, the pattern of tooth surface loss seen should be sub-classified into being either localised or generalised tooth wear.

In the case of localised tooth wear, it is important to specify the region affected, such as anterior, posterior, mandibular or maxillary.

Mandibular anterior teeth are relatively less affected by the process of erosion than the maxillary anterior dentition. This may be due to intrinsic acids being held by the tongue against the palatal surfaces of anterior maxillary teeth, whilst the lower teeth are buffered in secretions from the submandibular and sublingual salivary glands. Posterior teeth are protected by secretions from the parotid glands. Several prevalence studies have shown that the most common sites are the occlusal surfaces of molars and the incisal edges of anterior teeth.

For cases of localised wear, it is also worth considering whether there may be space available for the placement of restorative materials in either the intercuspal position (centric occlusion) or when the mandible is manipulated into its retruded arc of closure (centric relation). It is also important to identify the presence of guiding contacts in lateral and protrusive mandibular movements.

For cases of generalised tooth wear, it is important to categorise the amount of dento-alveolar compensation that might have taken place. The loss of tooth structure may or may not result in an increase in the Freeway space (FWS). Following an evaluation of the existing vertical dimension of occlusion (OVD) patients presenting with generalised wear may be assigned to three categories according to Turner and Missirlian:[27]

- Category 1 – excessive wear with loss of vertical dimension of occlusion
- Category 2 – excessive wear without loss of vertical dimension of occlusion, but with space available
- Category 3 – excessive wear without loss of vertical dimension, but with limited space.

A slower rate of wear with secondary supra-eruption of the dento-alveolar processes are thought to be responsible for contributing to the occurrence of patients in categories 2 and 3. The above classification has a paramount bearing on the restorative strategy adopted, as discussed in detail in paper 3.

TREATMENT PLANNING FOR CASES OF TSL

Treatment planning for cases displaying TSL follows the same basic paradigm as for the planning for the provision of restorative dental care for any other condition.

The first step involves the management of any **acute conditions**. This could include the simple adjustment of a sharp cusp or incisal edge, to the application of a de-sensitising agent or glass ionomer cement over an area of exposed dentine. Pulpal extirpation, or in severe cases a dental extraction, may need to be considered. In some cases where aesthetics may have been compromised, a composite resin bandage can be provisionally applied. Where there may be an underlying parafuctional tooth grinding habit, an acute exacerbation of temporomandibular joint pain dysfunction may exist, which will require immediate attention.

The next stage is that of **prevention**, which will be discussed in detail in below.

Stabilisation of any underlying dental pathology should be subsequently undertaken, such as caries control, the management of active periodontal disease and oral mucosal lesions. Teeth of hopeless prognosis will need to be extracted.

Having successfully stabilised the affected dentition and instituted a successful preventative programme, the next phase would involve the placement of **definitive dental restorations** including any **definitive complex restorations**.

The final stage involves **monitoring and maintenance**, the importance of which has been discussed in detail later.

It is important to institute **review stages** in passing from one stage of the treatment plan to the next, so as to assess the efficacy of the completed stage.

PREVENTION OF TOOTH WEAR

It has been argued that the prevention of tooth wear is not the same as preventing a condition such as dental caries. Dental

caries is a condition which will affect most people in the world to some extent during their lifetime. Tooth wear, however, until recently has been regarded as being a problem that affects individual patients rather than being a community-based problem.[11] Whilst TW is undoubtedly on the increase, it is difficult to predict which individuals will be affected, making primary prevention difficult to achieve.

Several researchers appear to support the view that once tooth wear has been diagnosed, wear progression appears to occur at a relatively slow rate, particularly in cases where preventative advice has been successfully implemented.[28,29] However, sporadic bursts of wear activity may occur amongst these patients associated with lifestyle changes and personal circumstances, which may have the potential to produce severe wear. This concept supports the need for a 'screening tool', which will help to detect clinically significant pathological wear and help to monitor wear progression over an extended period of time (particularly where practitioners within a given dental practice may change over such a given long period of time).

With a perceived upsurge in the prevalence of wear stemming from erosive agents, most research into the efficacy of preventative strategies has focussed on the prevention of erosive wear. Other forms of tooth wear appear to have received less attention.

It has been suggested that in the case of erosive lesions,[30] the presence of stains on previously affected surfaces (which would otherwise be removed by the effect of acid) and the absence of dentine sensitivity may indicate periods of quiescence.

Listed below are some commonly used agents/methods used to help with the prevention of tooth wear:

1. Fluoride – Whilst the benefits of fluoride in reducing the efficacy of soft drinks in promoting erosive tooth wear has been reported by a multitude of *in vitro* studies, this claim has not been substantiated consistently by *in vitro* clinical analysis. In 1987, Sorvari *et al.*[31] showed that the addition of fluoride to potentially erosive sports beverages reduced their erosive potential. Similar results have been reported by *in vitro* studies involving the addition of fluoride and xylitol to orange juice.

Topical fluoride application has been shown to protect against subsequent tooth wear following an acid challenge, which is particularly beneficial where tooth wear has culminated in dentine exposure. A neutral sodium fluoride mouth rinse or gel should be recommended, which when used daily will help combat acid damage, such as Fluoriguard mouthrinse, Colgate and Gel-kam, Colgate.

The avoidance of toothbrushing shortly after acid exposure (commonly practised after vomiting) will also help to reduce the rate of tooth surface loss. Mouth rinses with low pHs should not be recommended.

Munoz *et al.*[32] have shown that remineralising toothpastes such as Enamelon increase the surface hardness of teeth exposed to acidic substances and have a greater effect than conventional fluoride containing toothpastes alone.

2. Desensitising therapy – Where dentine hypersensitivity is a concern for the patient, the use of a 0.7% fluoride solution in the dental surgery followed by the home application of 0.4% stannous fluoride has been shown to be clinically beneficial.[33] Potassium containing toothpastes are also considered to be appropriate for the management of sensitive dentine. Such agents may be applied with the aid of a custom fabricated bleaching tray (containing reservoirs). Tooth Mousse ACP (GC), contains 'Recaldent' which is an ingredient derived from casein (part of a protein found in bovine milk) that promotes remineralisation. This is a useful product for the passive management of tooth wear cases, when administered using a modified bleaching tray.

3. Beverage modification/dietary counselling – The addition of calcium lactate has been shown to reduce the erosive potential of Coca Cola, whilst the addition of citric acid, which has occurred more recently with the introduction of brands such as Pepsi Cola with a 'twist of lime', has the effect of increasing their respective erosive potential (*in vitro*). The addition of calcium to drinks such as Ribena Toothkind (Glaxo-SmithKline, Middlesex, UK) has also been shown to render the drink less erosive than blackcurrant drinks without added calcium (Hughes *et al.*[34]).

A reduction in the quantity and frequency of the consumption of fruits, fruit juices, carbonated drinks or any other acidic substrate would be beneficial advice. Patients should also be instructed to limit their consumption of erosive foods/beverages to meal times.

Consuming hard cheese or dairy products after the ingestion of an acidic beverage has also been suggested to be beneficial in promoting the re-hardening of enamel.[22] Chewing gum containing carbamide can provide a rapid rise in salivary pH, which may assist in reducing the effect of the erosive agent.[35] Sugar-free chewing gum and fluoride containing or carbamide containing chewing gums, may also help to stimulate salivary flow. The latter play an important role in protecting vulnerable tooth surfaces from the effects of erosive agents. TridentWhite from Cadbury (UK) is a chewing gum containing recaldent (as described above) which may also prove beneficial for the preventative care of tooth wear cases.

A number of preparations have been developed for patients who may be suffering from the effects of xerostomia to promote flow, such as Proflyin (Propylactor AB, Sweden) and Xerodent (Dumex-Alpharma, Denmark) to promote salivation. Xerodent has the added benefit of containing fluoride.

Current research appears to be focussing on the role of TiF_4 and SnF_2 in the protection against erosive lesions, with initial data by means of clinical evidence showing signs of promise (Hove *et al.*[36]).

4. Habit changes – A change of habit, such as drinking acidic beverages through a wide bore straw and the avoidance of swishing beverages in the mouth, will help to reduce the rate of dental erosion. The avoidance of overzealous toothbrushing, the use of less abrasive toothpastes and refraining from habits such as that of pen/pencil biting will also help.

5. Splint therapy – Where nocturnal bruxism is confirmed, a full coverage hard acrylic occlusal splint should be constructed. An example is a Michigan splint or a Tanner appliance, as shown by Figures 10 to 13. The splint should be fabricated to provide an 'ideal occlusion' incorporating the presence of even centric stops (with at least one centric stop per opposing tooth), a canine guidance (by virtue of the presence of canine risers) to provide posterior tooth separation during lateral excursive and protrusive mandibular movements and

an even/shared anterior guidance on protrusion (provided by an anterior ramp) with posterior teeth disclusion. It is hoped that the latter splint will permit muscle activity to return to normal function by disrupting the habitual pathway of closure into centric occlusion by removing the unwanted guiding effects of cuspal inclines and also by causing tooth separation.[37]

It is important to take great precaution when providing splints to patients with erosion from gastric reflux, as acidic substances may accumulate within the splint and further exacerbate the rate of tooth wear. Splints may be used to protect teeth during episodes of vomiting for the bulimic patient. However, instructions on wear/usage must be precise, so that the splint does not become a reservoir for the acid produced. The use of a splint may be considered beneficial in cases of erosion however, where the splint in the form of a soft vacuum formed appliance can be modified to include reservoirs, into which neutral fluoride gels or alkali in the form of milk of magnesia or sodium bicarbonate solution can be applied respectively.

Figure 14 shows an example of a splint constructed with reservoirs (akin to a bleaching tray with reservoirs) to assist the application of a viscous fluoride gel (Gel-Kam, Colgate) in a case of erosive wear from the frequent consumption of carbonated beverages.

6. Sealant restorations – The application of dentine bonding agents and fissure sealant to eroded areas may be helpful in providing some level of protection and reduce dentinal hypersensitivity. Whilst the results of a study by Sundaram *et al.*[38] showed the longevity of sealants in the form of dentine bonding agents applied to teeth displaying severe wear to be relatively short lived, they may help to reduce the rate of wear on applied surfaces by up to a period of nine months following application Similarly, glass ionomer cements can be readily applied to worn surfaces for the same purposes.

7. Referral to a medical practitioner – This is considered appropriate when the dental operator suspects a case of bulimia or reflux disease. Medication can be used to reduce gastric reflux and acid production, including drugs such as antacids and prescribed drugs such as omeprazole and ranitidine. Where xerostomia may have an underlying role, referral to a specialist in oral medicine may be considered.

Fig. 10 An example of a Michigan splint

Fig. 11 Centric occlusal contacts and anterior guidance marked out with articulating paper

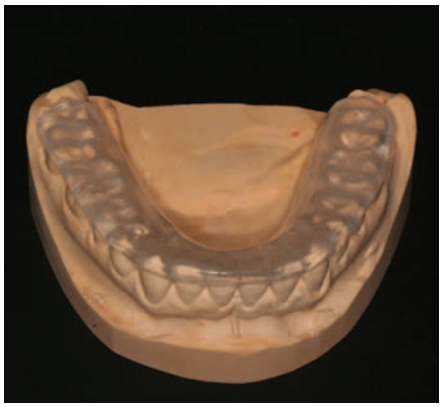

Fig. 12 Example of a lower Tanner appliance

Fig. 13 Patient in left lateral excursion

Fig. 14 Example of a tray splint whereby reservoirs have been introduced to permit the placement of a fluoride gel for the management of erosive wear

MONITORING STRATEGIES

The primary goal for the management of any patient presenting with tooth wear is to prevent further pathological wear, so the wear rate may ultimately return to that of a physiological rate. In many cases of tooth wear, an early diagnosis followed by the implementation of an effective preventative programme may prove to be sufficient as a means of definitive management. It is desirable to avoid restorative intervention where possible, as this will undoubtedly commit the patient to costly, long term maintenance care. For more severe cases however, where active restorative intervention may be indicated, it is prudent to instigate an appropriate interval of time to assess the efficacy of the preventative regime, in particular the elimination of the aetiological factor(s) and the rate of tooth surface loss.

Monitoring the progression of tooth wear is by no means a simple challenge. It can be undertaken by means of high quality sequential clinical photographs and by the means of periodic study casts at approximately 6-12 monthly intervals (ideally formed from impressions taken using PVS materials, cast in vacuum mixed die stone). A sectional silicone index formed from the initial cast can be used as a reference guide. Neither of the latter two methods of monitoring are very sensitive, but can provide a gross subjective estimate of the rate of tooth wear. The correct re-seating of a sectional silicone index can also be particularly challenging, especially for those cases presenting with generalised tooth wear, where there may not be any consistent dental hard tissue reference points for the purposes of index relocation.

A more precise method may include the use of computerised software to map changes in tooth surface profiles. However, practicality and cost implications are drawbacks to consider.

A number of clinical indices as described above can also be used to monitor the progression of tooth surface loss. However, concerns with the ease at which some of these indices can be applied clinically on a routine basis, together with inter-examiner variability are key problems.

SUMMARY

Tooth wear is a condition being increasingly frequently encountered by general dental practitioners. It is vital to accurately assess and diagnose a patient presenting with tooth wear. The majority of such cases can be successfully treated by passive, preventative measures, requiring long term monitoring and maintenance. However, there will undoubtedly be a small proportion of such cases which will require active restorative intervention. The articles to follow in the series will consider the active restorative management of the wear patient in considerably further detail.

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