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The multifactorial nature of toothwear

Farid Khan and William G. Young

TOOTHWEAR PROCESSES

Attrition, erosion and abrasion describe wear processes (Fig. 1.1). Attrition involves two-surface (tooth-to-tooth) wear. Erosion, less commonly referred to as corrosion, results from acidic dissolution of mineralised tooth structure. Abrasion on a surface comprises wear from externally applied particles or objects.

When a patient presents with a heavily worn dentition (Fig. 1.2), the clinician considers whether the toothwear processes have involved elements of attrition, erosion or abrasion. Whilst the wear facets identified on the lower anterior teeth suggest attrition, numerous high margins on restorations point to involvement of erosion, removing tooth structure adjacent to these restorations. Demineralisation of tooth structure further predisposes to abrasion as evident in cervical regions, many of which have previously been restored. Since placement of these restorations, toothwear processes have continued. This case highlights that interrelationships exist between toothwear processes which potentiate one another.

Although the processes of attrition, erosion and abrasion can be simulated under laboratory conditions, clinically these processes do not occur independently (Fig. 1.3). The coarse particles of foods in primitive diets potentiated the wear facets (Young 1998) of attrition by abrasion (Fig. 1.3a). Modern diets lack such abrasives; however, oral acids that cause erosion demineralise enamel and dentine, potentiating attrition and abrasion (Figs. 1.3b & c). A recent literature review on erosion noted that dietary acids are considered by many researchers probably to be the most common cause of acid erosion (Bartlett 2009). Exaggerated wear facets are the first sign of erosion-potentiated attrition in young adults' permanent teeth. Toothbrush and toothpaste combinations are important considerations, particularly in patients in whom dental erosion has also been identified, for abrasiveness becomes potentiated when tooth structure is demineralised. A combination of these two

Toothwear: The ABC of the Worn Dentition, First Edition. Edited by Farid Khan and William George Young.

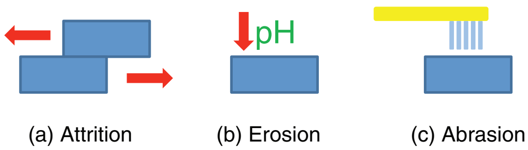


Figure 1.1 The processes of attrition, erosion and abrasion: (a) Attrition is wear between two tooth surfaces. (b) Erosion is tooth surface loss from acids. (c) Abrasion is loss of tooth surface from a foreign body.

processes can lead to severe toothwear (Fig. 1.4). When used on demineralised tooth structure, abrasion from routine use of standard toothbrushes and toothpaste formulations is significant, whilst in the absence of erosion, it is considered to be minimal (Addy 2005). Attritional facets and cuspal-cupped lesions can be found on the same tooth (Fig. 1.5). This suggests that the wear facet worn by the mesiobuccal cusp of the upper first molar has been potentiated or exaggerated by occlusal erosion that has produced the cuspal-cupped lesions.

Figure 1.2 Three processes of toothwear are reported in this case: (a) Incisal attrition on incisors. (b) Occlusal erosion on premolars and molars and around amalgam restorations. (c) Various cervical regions have been restored previously, with further loss of tooth structure since the time of restoration. (From Young, 2001, with permission of Dentil Pty Ltd.)

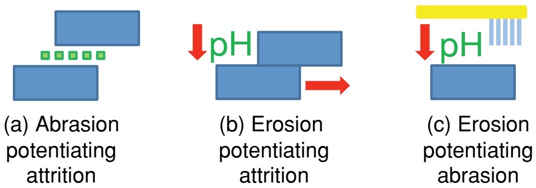


Figure 1.3 Interactions of abrasion, attrition and erosion in toothwear: (a) Acids soften surfaces potentiating attrition. (b) Acids soften surfaces potentiating abrasion. (c) Abrasion from particles harder than enamel and dentine potentiates attritional wear.

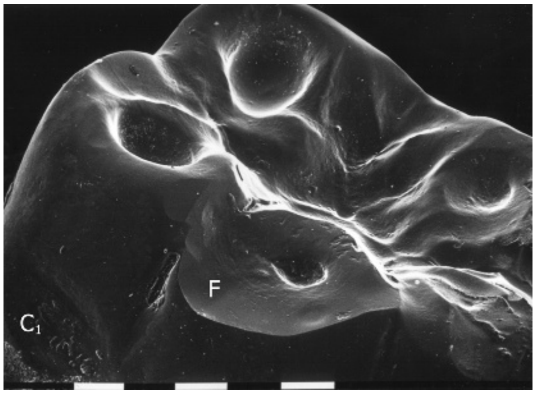


Figure 1.5 An attritional wear facet (F) on a buccal cusp of a lower first permanent molar. On all cusps are the cupped lesions of erosion not necessarily associated with attrition. A shallow buccal cervical lesion (C1) is also present on this tooth (Bar = 1 mm). (From Young & Khan, 2009, with permission from Erosion Watch Pty Ltd.)

Moreover, erosion has produced the shallow cervical lesion on the buccal surface of this tooth possibly potentiated by toothbrush abrasion.

These interrelationships between attrition, erosion and abrasion highlight that multifactorial processes create a worn dentition (Fig. 1.6). Each patient has a variation in the involvement of attrition, erosion and abrasion. In many patients, it is predominantly underlying erosion that potentiates the secondary effects of attrition and abrasion. Appreciating that different processes are working concurrently allows the clinician to focus diagnostic, preventive and management strategies on all three aetiologies. Thus, tooth tissue loss will continue if its multifactorial nature is not recognised and addressed.

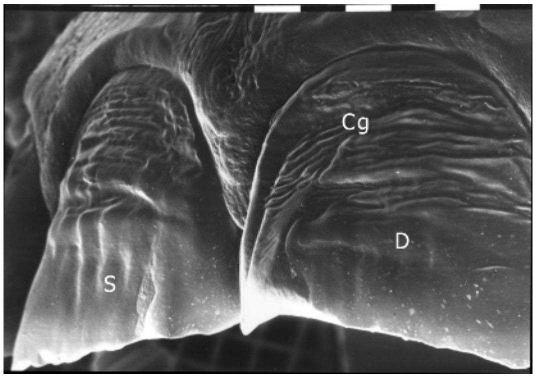


Figure 1.4 Facial surfaces of the central incisors are devoid of enamel in a 31-year-old female gymnast. The dentine is deeply grooved by toothbrush abrasion. The approximal enamel is remarkably intact. Scanning electron microscopy (SEM) (Bar = 1 mm). (From Khan et al., 1999, with permission from the *Australian Dental Journal*.)

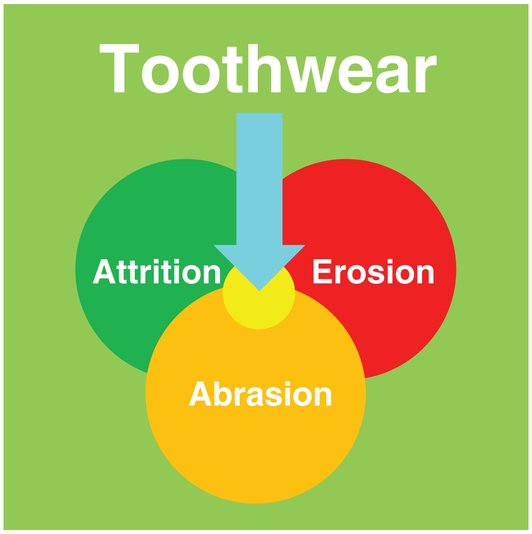


Figure 1.6 Toothwear is best conceptualised as a combination of erosion, attrition and abrasion.

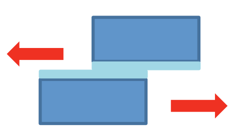


Figure 1.7 Saliva offers protection against attritional wear (a) through lubrication and (b) by raising the pH through buffering and clearance of acids that produce erosion.

SALIVA PROTECTION

Saliva is central in counteracting and balancing toothwear processes, and tooth surfaces are protected against toothwear by salivary buffering capacity, salivary pellicle, acid clearance and washing of the dentition (Dawes 2008). The unstimulated flow rate of saliva and salivary buffering capacity have been directly associated with dental erosion (Zero & Lussi 2005). Both mucous and serous saliva protect against attritional wear through lubrication of the teeth and areas of interarch contact, as well as neutralise acids within the oral environment. Saliva also reduces demineralisation by its content of calcium and phosphate (Fig. 1.7).

INTRINSIC AND EXTRINSIC ACIDS

Acids that demineralise teeth are extrinsic dietary or intrinsic, gastric or plaque in origin. Dietary acids most commonly implicated are ascorbic acid (vitamin C), citric acid, sodium citrate and orthophosphoric acid, because these are used as flavours and preservatives in most acidic beverages. So, soft (Johansson et al. 2002), sports (Milosevic 1997) and energy drinks are sources, with other acids in wines. Hydrochloric acid from gastric juice is the usual intrinsic acid implicated in dental erosion and toothwear (Scheutzel 1996). A study examining 19 professional wine tasters found mild-to-severe dental erosion and found the subjects with severe dental erosion also to have had a history of gastritis or reduced salivary flow rate and/or buffering capacity (Wiktorsson et al. 1997).

The case presented in Fig. 1.8 shows the toothwear of an elite athlete, 24 years of age. His lifestyle placed him at risk of developing severe toothwear. His rigorous training regimes reduced the salivary protection of his dentition. Subsequent rehydration with acidic sports drinks at times of dehydration affected his dentition. Acidic beverages and foods are important contributors to erosive toothwear in many individuals (see Chapter 3), given their common availability, and yet the pH alone is insufficient to determine their erosive potential, which is instead influenced by a large range of variables including consumption patterns, adhesion and chelating properties of salivary protection, and swallowing and clearance patterns (Lussi et al. 2004). Frequent episodes of reduced saliva protection and acid drinks resulted in severe loss of enamel and dentine in this young adult, principally from dental erosion. Dental erosion in athletes is a growing concern (Sirimaharaj et al. 2002); however, many children and young adults also frequently consume such beverages. Increased consumption of sports drinks and acidic beverages, during the day and also during heavy exercise, is likely contributing to the increasing dental erosion prevalence (ten Cate & Imfeld 1996), particularly in young individuals.

EXAMINATION OF FACIAL, EXTRAORAL AND INTRAORAL SOFT TISSUES

The multifactorial nature of toothwear is further highlighted by benefits from identifying facial, extraoral and intraoral soft tissue features even before a worn dentition is assessed.

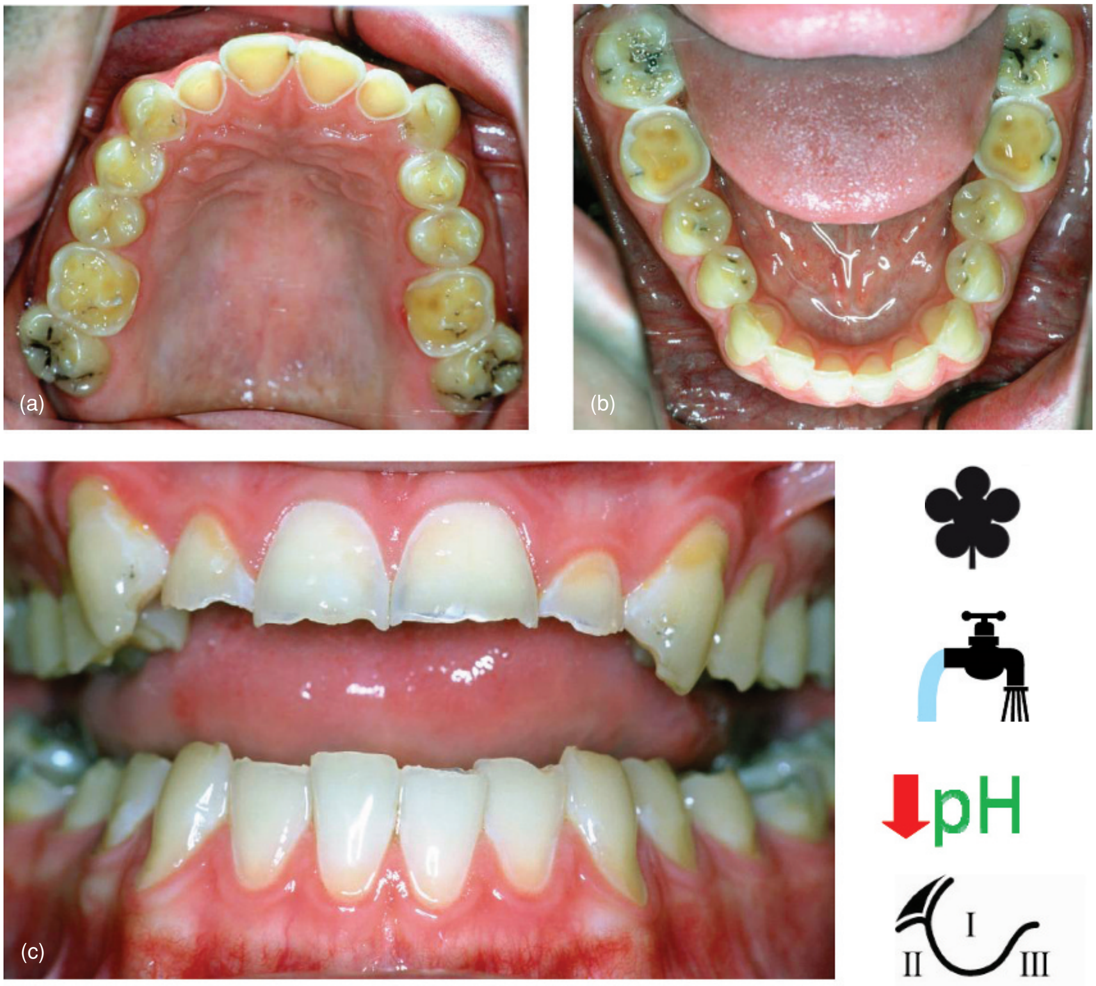


Figure 1.8 A 24-year-old male patient with a long history of athletic training at a professional level. Acidic beverage rehydration frequently occurred subsequent to intense physical training sessions, at times of dehydration and low salivary protection. This allowed rapid loss of tooth structure to occur. (a) Near exposures of the pulpal tissues are evident on the lingual surfaces of the maxillary anterior teeth. (b) Extensive areas of erosion have notably affected his first molar teeth. (c) Cervical lesions are evident on the maxillary and mandibular buccal surfaces of canine and lateral incisor teeth. (From Young, 2003b, with permission of Dentil Pty Ltd.)

Much can be learned of lifestyles, general medical conditions, temporomandibular joint (TMJ) disorders and salivary gland pathology by considering signs and symptoms relevant to toothwear. For the clinician, a schematic approach for examination of facial, extraoral and intraoral features adds diagnostic information relevant to the aetiology of the patient's condition. Icons applicable to these features are included to trigger the clinician's mind during the examination (Fig. 1.9). These icons are used throughout this text alongside clinical photographs of interesting cases to indicate additional findings. Visual inspection and manual palpation are all

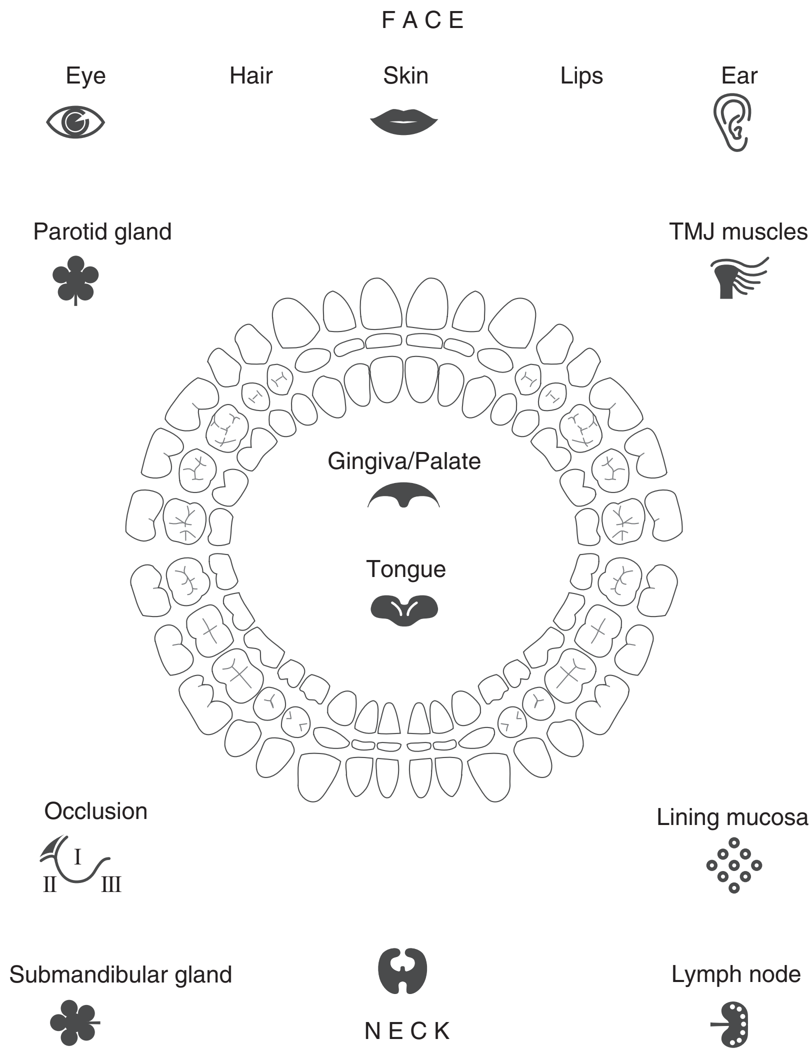


Figure 1.9 The icons for examination of the face, the oral soft tissues and the teeth, as utilised on standardised examination sheets applied clinically for patients with worn dentitions. (From Young & Khan, 2009, with permission of Erosion Watch Pty Ltd.)

the clinical skills the clinician needs to make additional important observations. The icons remind us to record the relevant ones. The odontogram (Fig. 1.9, centre) describes each tooth as an icon. Three surfaces of each tooth are represented, as approximal surfaces are almost never significantly affected by toothwear and consequently the clinician need only record the severity of wear on the occlusal and cervical surfaces illustrated. Detailed methods for examination of the worn dentition are provided in Chapter 4.

Eye contact is the first event of examination. Trust and empathy are established and concern is communicated between the patient and the

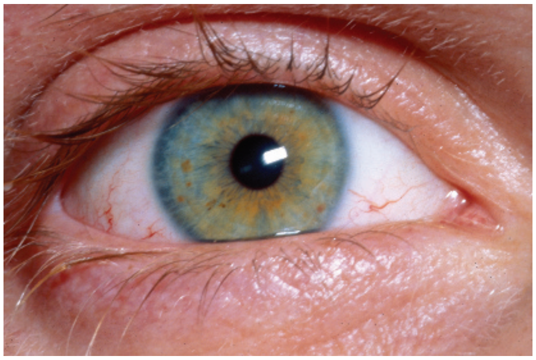


Figure 1.10 Lacrimal duct aplasia with epiphora in congenital dysfunction of major salivary glands. (From Young et al., 2001, with permission of *Oral Surgery, Oral Medicine, Oral Pathology*.)

Figure 1.11 Sun-affected damaged lip from a lifetime of dehydrating outdoor work in a 60-year-old construction worker with a heavily worn dentition.

clinician. Yet, for the clinician concerned with toothwear, the patient's eyes can communicate insights into medical conditions and syndromes that explain why the patient is at risk. The lacrimal glands produce tears which have many similarities to saliva. Hence, conjunctivitis and dry mouth in Sjögren's syndrome are obvious examples wherein both lacrimal glands and saliva fail to protect mucosal surfaces. Examination of the eye and discussion with the patient might reveal lacrimal duct aplasia with epiphora (Fig. 1.10), as found in this patient with congenital dysfunction of major salivary glands, who experienced severe dental erosion (Young et al. 2001).

The skin of the lower lip is particularly susceptible to sun damage, as the vermilion border is usually not pigmented in Caucasian people in the subtropics. Outdoor work frequently damages the patient's skin (Fig. 1.11). Actinic cheilosis is often identified on the lower lips of patients who are regularly exposed to the sun in their sports activities and outdoor occupations. This may indicate a lifestyle involving frequent work-related dehydration, which by reducing saliva protection against acids in the mouth, puts patients at risk of toothwear.

The patient's facial hair gives clues to hormonal status. Thus, *lanugo* – a fine, fair, facial hair – is noticed at puberty in both boys and girls. It is also found in patients with the hormonal upsets of *anorexia nervosa* and as a result of hormone replacement therapy at the menopause. Thus, lanugo may alert the clinician to consider this further when compiling a clinical history.

Evidence of skin irritation or presence of eczema (Fig. 1.12) may be evident periauricularly or on any part of the body and may suggest syndromic associations as in cases of hereditary ectodermal dysplasia. Hearing loss in young patients may be part of a syndrome. In congenital rubella syndrome, the patient has glaucoma, bilateral hearing aids, and a congenital heart defect as a triad (Young et al. 2001). This triad of signs has considerable relevance to dental treatment, as considered further in Chapter 6.

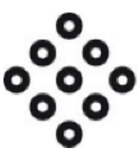
The TMJ can click, or even lock, when the patient opens and closes their mouth. The muscles of mastication may be painful to palpation in TMJ pain–dysfunction syndrome. When the teeth are clenched, the masseter muscles tense and become prominent. Behind this muscle and in front of the ear lies the preauricular crease (Fig. 1.12).

Figure 1.12 Eczema around and behind the ear of a patient with ectodermal dysplasia.

Figure 1.13 White lines on the buccal mucosa (*linea alba*) and lateral indentations of the tongue indicate parafunctional habits. (From Young, 2001b, with permission of Dentil Pty Ltd.)

When the parotid glands are enlarged and prominent, the preauricular creases are obliterated. The firm glands can be felt behind the clenched masseter muscles, denoting sialadenosis.

Indentations of the lateral borders of the tongue indicate that the patient presses their tongue against the lingual surfaces of the teeth during parafunctional habits (Fig. 1.13).



The lining mucosae are studded with minor mucous glands. Lining mucosae cover the undersurfaces of the tongue, the floor of the mouth, the labial sulci and the soft palate. When saliva covering these surfaces is viscous, frothy and white, it is slow-flowing saliva. When thrush (*Candida albicans*) is found on these surfaces, it indicates loss of immunity conferred by saliva against this microorganism. *Linea alba*, white calluses on the buccal mucosae along the occlusal plane, occurs in patients who have parafunctional habits, such as bruxism (Fig. 1.13).

Gingivitis and gingival recession may indicate poor oral hygiene and periodontal changes or toothbrush trauma. The gingivae and the hard palate contain virtually no salivary gland tissue, except at the back of the vault where the hard palate joins the soft palate.

Occlusion of the teeth may show deep overbite, overjet or open bite between the anterior teeth. Crossbite may be found in the posterior quadrants. Angle's class I, II or III malocclusion is delineated from the relationship of the mesiobuccal cusp of the maxillary first molar to the mesio- and distobuccal cusps of the mandibular first molar. All variations in occlusion have significance for finding exaggerated wear facets.

The submandibular glands, when enlarged, are best appreciated by bimanual palpation. The fingers of one hand are placed below the

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lower border of the mandible and pressed into the submandibular triangle of the neck. A finger of the other hand feels along the lingual sulcus in the floor of the mouth. Normal salivary glands are difficult to feel, but the volume of enlarged, slightly firm submandibular glands can be appreciated both in the floor of the mouth, behind the mylohyoid muscle, and in the submandibular triangle. This enlargement is sialadenosis. It is neither a lumpy tumour nor a tender inflammation. A tender lump may be an inflamed lymph node within the gland.

The lymph nodes of the neck are palpated to rule out inflammation or tumour. In sialadenosis, the lymph nodes are normal.

The thyroid gland is palpated as part of the neck examination. Changes in this gland relate to hormonal changes and therapy, but no specific link to salivary gland dysfunction has been made.

TOOTHWEAR IN CHILDREN

Few of these facial features and salivary gland or soft tissue changes observed in adults are found during the examination of the child-patient with toothwear. Eye and ear changes are rare. The skin of the face and lips may show lanugo found at puberty in boys and girls. The major salivary glands are underdeveloped in young children. They may be affected at puberty, but are more usually normal. The temporomandibular joints and muscles of mastication are affected only if severe trauma has altered their growth. Tongue indentations and linea alba are rarely found, even in children whose parents give testimony of night grinding habits. Rarely oral thrush may be found on the tongue, palate and gingivae.

Consequently, the best indicator of excessive toothwear in children is a reduction in occlusal vertical dimension within the deciduous dentition. As shown in Fig. 1.14, the patient's permanent anterior teeth and permanent first molars are relatively unaffected by wear. However, the deciduous canines and molars attest to occlusal surface loss from erosion potentiated by attrition. On the upper teeth, the surfaces most affected are the occlusal and palatal slopes. On the lower teeth, it is the occlusal and buccal surfaces that are most worn. When the clinician encounters this clinical presentation in the mixed dentition, caution must be exercised before concluding that the pattern of wear is the result of bruxism. This 11-year-old patient gave a history of early childhood gastric reflux and ongoing asthma with long-term medications, which reduced saliva protection against intrinsic acids and those in frequently consumed soft drinks and other acidic beverages. Patients of all ages may be affected by intrinsic acids, and 60% of the population may experience reflux at some stage in their lives (ten Cate & Imfeld 1996). However, longer term exposure to intrinsic acids is required to result in significant toothwear. As conceptualised in Fig. 1.15, the most severe lesions on the deciduous teeth are on surfaces least protected by saliva from the major glands. Intrinsic and extrinsic acids would further affect certain parts of the dentition and particular tooth surfaces more than others. Further investigation is warranted to identify multifactorial aetiology. The presentation of and reasons for toothwear in children and appropriate management approaches are further considered in Chapters 2 and 3.

TOOTHWEAR AND DENTAL CARIES

It is rare for the clinician to encounter active dental caries in patients with worn dentitions. This is because erosion, attrition and abrasion are not caused by bacteria. In fact, the metabolic activities of cariogenic organisms that convert simple sugars to acids are inhibited by the low pH found on the surfaces susceptible to dental erosion, as key enzymes in *Streptococcus*

Figure 1.14 This 11-year-old male patient has (a) incisal attrition, chipping and mild thinning of enamel across the anterior teeth. (b) The maxillary teeth show heavily worn surfaces on deciduous canine and molar teeth with near exposures of the pulp. (c) The lower permanent canine and incisor teeth have erupted, but as yet were unworn. Near exposures on the heavily worn lower deciduous molar teeth are evident. (From Young, 2001a, with permission from the *Australian Dental Journal*.)

mutans cease to metabolise at pH values of 4.2 or below at which they become increasingly unviable (Meurman & ten Cate 1996). In the case illustrated in Fig. 1.16, the astute clinician would have no problem discriminating buccal cervical lesions on the lower anterior teeth with undermined enamel edges as arrested caries of dentine from shallow cervical erosions. This 19-year-old female patient was a professional dancer, who consumed fluoridated water in the first 12 years of her life and had no other active caries lesions. In her early teenage years, the patient commenced binge eating of sugary snacks between ballet rehearsals. This presumably caused the observed dental caries. However, a few years subsequently, attacks of self-induced vomiting and high consumption of soft drinks increased the higher influence of intrinsic and extrinsic acid consumption. This changed the nature of her oral pathology.

The distribution of both the lesions of erosion and caries (Fig. 1.17) can in part be explained by loss of saliva protection from dehydration. Acids from sugars, produced by dental

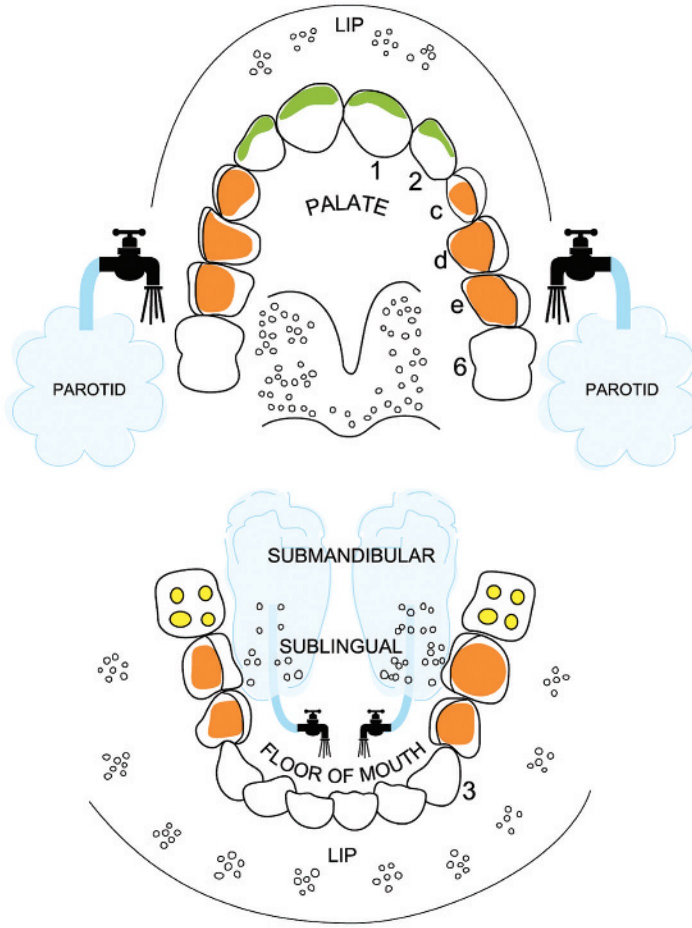

Figure 1.15 Conceptualisation of the 11-year-old patient shown in Fig. 1.14. Mild attrition is present on his incisors (green). Two deciduous canines and eight molar teeth are severely worn (orange). The two permanent lower molars show the amount of erosion (yellow) that occurred since age 6, when they erupted into his mouth. Mucous is secreted from the inner surfaces of the lips, cheeks, back of the palate, and sublingual glands. Serous saliva flows from the parotid glands through ducts that open on the inner surface of the cheeks (taps). In the floor of the mouth serous and mucous saliva are mixed from the submandibular ducts (taps) with mucous from the sublingual gland. (From Young, 2003a, with permission of Erosion Watch Pty Ltd.)

plaque bacteria at sites of caries, usually do not contribute to demineralisation on surfaces susceptible to dental erosion. Also, these surfaces are normally protected by saliva. Reduced saliva flow in anorexia nervosa and bulimia (Milosevic & Dawson 1996) placed this patient, in recent years, at risk of both gastric and dietary acids that cause erosion but not dental caries. Patients with poor oral hygiene are at greater risk of developing dental caries and/or periodontal disease. Most patients with moderate or severe toothwear, however, present with good oral hygiene and low levels of plaque accumulation. Dental erosion from intrinsic acids involves the strongest acids with a pH as low as 1, whilst soft drinks and fruit juices may

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Figure 1.16 A 19-year-old female ballet dancer with bulimia, whose (a) incisal edges and (b) palatal surfaces show evidence of erosion. Occlusal erosion was present on her (c) canine, premolar and molar teeth. Arrested caries is evident at the cervical margins of her lower anterior teeth (a & c). (From Young, 2001a, with permission from the *Australian Dental Journal*.)

have a range around pH 3, but the critical pH at which teeth dissolve should be more appropriately considered a range (Dawes 2003) depending on the concentration of calcium and phosphate in saliva (see Chapter 5). The pH ranges involved in dental caries are higher than those in dental erosion, and these processes are generally independent and significant lesions of both are infrequently found in the one dentition. When found, careful history-taking may reveal changes in diet, health or lifestyle that account for the presence of both dental erosion and dental caries within a patient's mouth, having occurred at different stages in the patient's life. Oral health promotion internationally has reinforced the risk of dental caries due to high sugar consumption across most populations. However, public awareness of dental erosion is still limited (Lussi et al. 2006).

TOOTHWEAR – A MULTIFACTORIAL PROCESS

Toothwear is best considered a multifactorial process (Fig. 1.18) involving significant variation from one individual to the next (Khan

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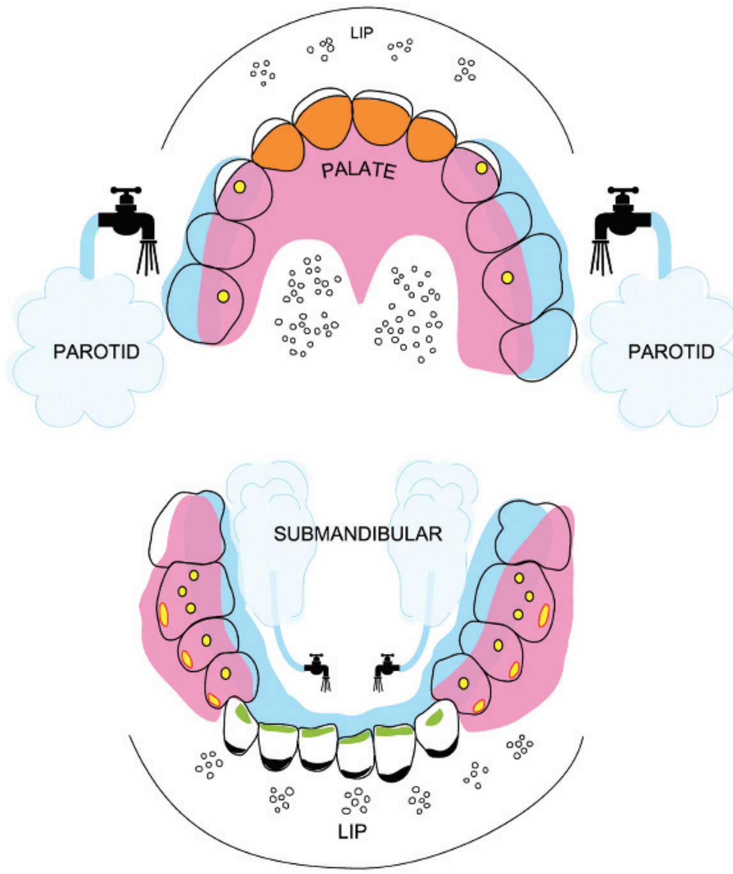

Figure 1.17 Dental caries was present at the necks of the lower incisor, canine and premolar teeth. The lower premolars and molars had erosion on their cusp and shallow erosions cervically (yellow). The upper front teeth were chipped on their edges and denuded of enamel on their palatal surfaces (orange). Mucous from minor salivary glands has failed to protect against decay or erosion, as it contains no bicarbonate buffer. Serous salivary (blue) contains buffer and flows from the parotid and submandibular ducts (taps) to mix with mucous and to neutralise acids. Poor flow of serous saliva fails to neutralise acids on the palatal and buccal surfaces of lower teeth. (From Young, 2003a, with permission of Erosion Watch Pty Ltd.)

et al. 1998). Identifying and understanding the relative involvement of a broad range of contributing factors ensures the clinician will succeed in any restorative or rehabilitative efforts. The interplay of intrinsic and extrinsic acids, of saliva protection, of health and lifestyle issues potentiates attrition, erosion and abrasion, creating lesions in a site-specific manner (Young & Khan 2002). Toothwear starts and can be prevented from early on in life. Identification and management of toothwear in children is a priority, particularly when the deciduous teeth are eroded, although the permanent teeth appear only mildly worn by attrition. This is the early warning sign for the clinician. Prevention must start early on to prevent possible immense restorative challenges in later life. Although progression of toothwear is generally slow, some individuals will experience rapid tooth structure loss (Bartlett 2005), and monitoring

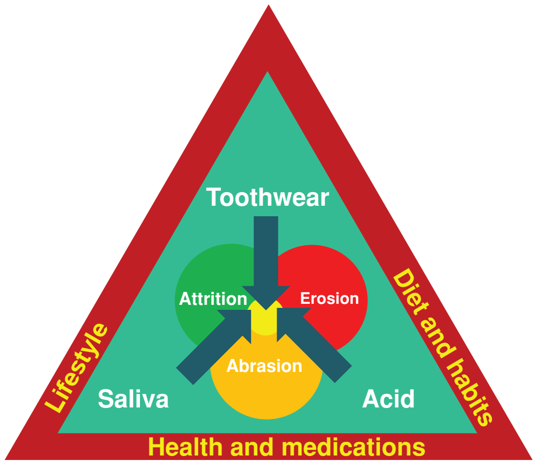

Figure 1.18 Toothwear can be conceptualised as a combination of erosion, attrition and abrasion over considerable time, interplaying with varying levels of extrinsic acid, intrinsic acid and salivary protection, each affected by lifestyle, diet, habits, health and medications.

toothwear over time with diagnostic study models is important to provide a reference baseline for subsequent comparisons (see Chapter 8). Those at risk need to be identified and managed comprehensively with dietary, lifestyle and preventive strategies, using adjuncts where appropriate. Focus must continue on prevention and control of all toothwear processes and aim to limit influence of potential accelerating factors to avoid, in later life, the development of a dentition in need of comprehensive rehabilitation, which remains a complex clinical challenge (Johansson et al. 2008).

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