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DOI:
10.1038/sj.bdj.2018.127

Document Version
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Link to publication record in King's Research Portal

Citation for published version (APA):
O'Toole, S., & Mullan, F. (2018). The role of the diet in tooth wear. *British Dental Journal*. https://doi.org/10.1038/sj.bdj.2018.127

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Download date: 11. Nov. 2026

The role of the diet in tooth wear

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Abstract

An acidic diet has been associated with erosive tooth wear. However, some people who consume dietary acids develop erosive tooth wear and some do not. This review paper provides an overview of the risk factors of dietary acid consumption which increase the likelihood of developing severe erosive tooth wear. Increased frequency of dietary acid consumption, particularly between meals appears to be the predominant risk factor. However, habitually drinking acidic drinks by sipping them slowly or swishing, rinsing or holding acidic drinks in the mouth prior to swallowing will also increase risk of progression. Consuming fruit over long time periods at a single sitting and dietary acids being served at increased temperatures have also been implicated. Additions of fruit or fruit flavourings to drinks and regular consumption of vinegars, pickles, acidic medications or acidic sugar-free sweets are potential hidden risk factors which should

be discussed with patients at risk of erosive tooth wear progression. Behaviour change is difficult to achieve but specific, targeted behavioural interventions and offering alternatives may increase success.

Introduction

The relationship between intake of dietary acids and erosive tooth wear is not straightforward. We know that the prevalence of erosive tooth wear is increasing through epidemiological studies and increased presentation of erosive tooth wear in general practice and specialist referrals [1,2]. At the same time, we are also changing our patterns of eating. Fruits are available to us outside of season and both children and adults are increasing the number of snacks we have per day [3,4]. In 2015, 13.3 billion litres of soft drinks were consumed in the UK with an average intake of 203.6 litres per capita [5]. There is suggestion that the change in dietary habits and the increased prevalence of erosive tooth wear may be linked. However, we all consume dietary acids daily and not everyone develops pathological tooth wear. This will be strongly influenced by biological factors such as salivary flow rates, buffering capacity and salivary composition, which are outside the scope of this paper. However, it will also be influenced by the way that people consume the dietary acids. The aim of this paper is to provide an overview of patterns and influencing factors of dietary acid consumption which increase the likelihood of developing severe erosive tooth wear.

To understand what may or may not influence the erosive potential of the diet, a basic knowledge of chemistry is required. During chemical erosion the hydrogen ions ($H^{+)}$ present in acids become dissociated and interact with the hydroxyapatite crystals in enamel leaving the structure weakened. The chemical erosive potential of a dietary acid depends on the pH value (the H^+ ion concentration), titratable acidity (the total

available H^+ ions as the pH value changes), calcium chelation properties, buffering capacity (the ability to maintain a pH at the current value) and the mineral content, (specifically calcium and phosphate levels) [6]. The pH value is the most widely used predictor of erosive potential, particularly at the start of an erosive challenge [7]. Some, authors have argued that a high titratable acidity is a better indicator of erosive potential during longer exposure [8–10] as clinically the pH remains low for a relatively short time period. The calcium, phosphate and mineral content of the food/beverage also has a direct impact on its erosive potential. An example of this is yoghurt, which can have a pH < 4 but has no erosive potential [11]. The high mineral content maintains the supersaturation of minerals with respect to tooth structure. Following cessation of the acid intake, acid clearance and normalisation of the intraoral pH has been reported to occur rapidly over 2-13 minutes [12–14]. Fruit and citric acid flavourings have both low pH and high titratable acidity. As the H+ ions are released from citric acid, the citrate ion has an ability to bind with calcium known as calcium chelation, rendering it inactive for remineralisation [15]. Citric acid releases H+ ions at pH 3.13, 4.74 and 6.42. This results in the majority of calcium chelation occurring as the pH rises above pH 4. At this pH, up to 32% of the calcium in saliva can be complexed to citrate [15]. This becomes more relevant as we discuss patterns of dietary acid intake.

Identifying acids in the diet

It is important to be able to identify the range of food, drinks and medications which have erosive potential. We are aware that most fruits are acidic with perhaps fruits such as bananas and peaches being on the lower end of the acid spectrum [16]. Citrus fruits have been implicated in multiple epidemiological studies with Jarvinen and co-workers observing that study participants who consumed citrus fruits twice a day were 37 times

more likely to have erosive tooth wear although the confidence intervals were very large[17]. Both chilies and tomatoes are classified as fruits and have erosive potential. One study investigated the erosive potential of the two combined, observing a low pH in a basic north Indian masala sauce[18].

The addition of fruit or fruit flavourings to drinks has also increased [5] which can have equivalent erosive potential to that of cola drinks [11]. It is important to specifically ask about additions to their drinks and food. A patient may simply record water without realising the alteration in erosive potential through adding a simple slice of lemon or dash of fruit cordial. Some patients may believe that the addition of small fruit slices to water will dilute the erosive potential. However, it has been shown that fresh lemon or lime has citric acid concentration greater than 6 times the amount of lemonade formulations or lemon dilutables [19]. It is reasonably safe to assume that any dietary food or drink with added fruit or fruit flavouring will be acidic. Fruit flavoured teas such as ginger and lemon tea, berry tea or rosehip tea are also acidic [11]. Fruit flavoured sweets, lozenges or medications have also large erosive potential when consumed regularly.

It may be safer to advise patients to assume that most drinks that are not water, plain sparkling water or milk are acidic. An American study investigated the erosive potential of 379 commercially available soft drinks. They identified 39% were extremely erosive (pH < 3), 54 % were considered erosive (pH = 3-3.99) and only 7 % were identified as minimally erosive (pH ≥ 4,). Lemon juice was found to have the lowest pH (pH 2.25), followed by coca-cola drinks (2.32-2.39)[20]. Importantly, sugar-free drinks are as erosive as their sugar-sweetened counterparts [20]. Plain sparkling mineral water has a

low erosive potential even though it has a low pH from the carbonation because it has a low titratable acidity [20].

A final area to be aware of is the acidic potential of vinegars and pickles. There are diets which advise frequent consumption of vinegars. Jarvenin et al. observed those who consumed apple cider vinegar weekly were 10 times more likely to have severe erosive wear [17]. The erosive effects from the consumption of vinegars and pickled products should not be underestimated. The consumption may vary amongst different international diets, for example Korean kimchi or German sauerkraut. One study on over 2,000 children in the North West of England suggested that excessive consumption of pickles, vinegar and salt & vinegar crisps could result in high rates of tooth erosion [21]. Erosive tooth wear is a progressive disease, therefore prevention led intervention in young people is essential. It has been shown taste preferences for both sweet and sour/acidic tasting foods are related to childhood exposure [22]. As having a taste preference for both fruits [23] and soft drinks [24] has been associated with increased consumption, questioning about taste preferences in young patients may identify those at a future risk of developing erosive tooth wear.

Frequency of dietary acid intake

While the erosive potential of specific dietary acids is important, it is important to look at the overall pattern of consumption. The frequency of dietary acid intake has been recognised as one of the primary risk factors for erosive tooth wear progression [25]. A longitudinal study on 55 adults over 6 years observed that consumption of 4 + dietary acids per day to be associated with tooth wear progression [26]. However, this was recently observed to be influenced by whether they were consumed with meals or between meals, particularly for acidic drinks [25]. Those who consumed acidic drinks

twice a day between meals were over 11 times more likely to have moderate or severe erosive tooth wear. This was halved when drinks were consumed with meals (OR 6.8). Increased consumption of acidic drinks is a risk for erosive tooth wear whether they are consumed between or with meals. In contrast, fruit consumption with meals was not associated with erosive tooth wear and fruit consumption between meals did represent increased risk [25]. It was also observed that one or less dietary acid intakes a day was not associated with erosive tooth wear [25]. If a patient must go above one dietary acid intake per day, it would be prudent to advise them to consume the acids with meals.

Habits

Some people have habits which increase both the duration and force that acids are in contact with the teeth. A well-known example is observed in wine tasters who swish and hold wine in their mouths for prolonged periods and for multiple times a day. Lesser known examples may be long distance drivers who may sip acidic drinks on long drives or video gamers who sip acidic drinks while playing games for long periods. There is a case report of a 9-year-old boy who was allowed a single glass of soft drink a day while he was playing computer games. Unfortunately he held the drink in his mouth for long periods of time prior to swallowing and presented to his dentist with severe wear to the pulp requiring extractions [27]. Although few people will present with these extreme habits, there are patients who will spend long times nibbling on fruits or tend to sip drinks slowly. Those who regularly spent greater than 10 minutes eating fruit at a single sitting were over 12 times more likely to have severe erosive tooth wear in one study [25]. In the same study, participants who spent greater than 10 minutes drinking acidic drinks were 2.9 times more likely to have severe erosive tooth wear. This finding may be attributed to the increased titratable acidity of fruit. Tahmassabi et al. observed

fruit based smoothies to have a titratable acidity 3.5–4 times greater than both coca-cola light and citric acid [28]. However, it may also be attributed to the combined insult of erosion and mechanical forces as the fruit is chewed on the occluding surfaces. The increased pressure and abrasive force applied may accelerate the tooth wear process.

The importance of the dynamic interaction between the acid and the dental surface is observed in those with aggressive drinking habits such as sipping, swishing, holding or rinsing drinks in the mouth prior to swallowing. One clinical study investigated different forms of drinking coca-cola light (long-sipping, short sipping, holding and gulping) by placing electrodes on dental surfaces. The authors observed larger drops in pH when drinks were held in the mouth, but a sustained lower pH when long-sipping was performed [29]. Figure 1 shows a person who had a habit of swishing drinks in the mouth. Movement of the buccal mucosa can increase the force at which the acid is directed at the buccal surfaces. Excessive erosive wear was combined with tooth brush abrasion wear in this case.

These habits are more common than one would expect. From experience of questioning over 700 participants about whether they sip, swish, swallow or rinse drinks in their mouth prior to swallowing, the most common response is a return question of why anyone would do such a thing? However, those with a habit will be surprised that everybody doesn't do something similar in order to "taste the drink properly". A few will be unsure and then come back a few weeks later having noticed that they do actually tend to sip, swish, rinse or hold drinks in their mouths prior to swallowing. If severe erosive tooth wear is observed in a patient with limited dietary acid intake, the presence of a habit which increases the duration and/or force of the contact between the dietary acid and dental surface should be considered.

Quantity of dietary acid intake and specific diets

Most epidemiological studies have focused on the frequency of acid intake, with limited assessment of quantity of acid intake. Quantity of dietary acid intake is relatively difficult to assess as portion size is often subjective and difficult to measure [30]. Perhaps the most sophisticated method to-date has been performed by Sovik et al. when the quantity was assessed via a self-administered questionnaire after participants were asked to report the quantity of each drink in litres. Acidic beverage consumption was categorised into low (0-0.24 L/day) moderate (0.25-0.74 L/day) and high (0-.75-5 L/day) consumption [31]. A higher prevalence of erosion was observed in those with increased quantity consumption. Another cross-sectional study performed on young Icelandic adults dichotomised quantity data into > 1 L and < 1 daily. A relationship with erosive tooth wear was observed when greater than 1 litre of carbonated drinks were consumed [32], although limited information is given on the method of data collection in this study. Studies have also measured quantity in litres consumed per year [33,34]. The interpretation of this as a meaningful guideline to patients is difficult and gives no indication as to frequency. The only study, to the authors' knowledge, investigating quantity of fruit intake and erosive wear was performed in an investigation of prevalence of erosion in those consuming a raw food diet [35]. The quantity of fruit intake, via a self-administered questionnaire, was assessed with picture accompaniments providing guidance as to portion size. An increased prevalence in those with a median fruit intake of 9.5 kg (Range 1.5-23.7 kg) per week was observed [35]. Those on a raw food diet demonstrated a prevalence of erosion close to 98% and were twice as likely to have severe erosion than control participants [35]. Vegetarians have been reported to consume an increased quantity of fresh fruit on a daily basis [35,36]. A case-control study on twenty-six age and sex matched lactovegetarians by

Linkosalo & Markkanen 1985 reported that 30% of vegetarian subjects had “grave” erosive defects whereas age and sex matched controls exhibited no “grave” erosive defects. However, we do not know if this is due to increased frequency or increased quantity of dietary acid consumption. Unlike frequency, the evidence for an association between quantity of acidic foods and drinks and erosive tooth wear is not as conclusive.

Temperature

A further item which should be considered is the temperature at which the dietary acid is being consumed. Barbour et al. 2006 reported a linear relationship between increasing temperature and softening followed by erosive wear in vitro [37]. Airoldi et al used temperature sensors to investigate the intraoral temperature changes when drinking hot tea and observed that the highest temperatures reached when drinking hot tea were present on the buccal surfaces of the upper incisor surfaces [38]. These are surfaces which some studies have reported to be strongly associated with dietary erosive tooth wear [26,39]. A randomised controlled in situ clinical trial also observed increased erosive tooth wear when the temperature of a fruit drink was increased [40]. Few studies have investigated this epidemiologically, however, Correr et al. 2009 reported a significant association with temperature of fruits ingested and presence of erosive tooth wear in 12 year olds [41]. These studies are of clinical relevance as hot lemon with water, hot fruit teas and fruit flavoured hot medications may all have increased erosive potential. Figure 2. demonstrates an example of a patient who drank hot tea with lemon flavouring multiple times throughout the day. It may be prudent when giving dietary advice to patients to discuss the influence of temperature.

Limiting the damage of dietary acids

As foods high in calcium or phosphate have low erosive potential irrespective of their pH [11], it has been suggested that consuming foods high in calcium or phosphate alongside a dietary acid can limit the damage caused [42]. This buffering effect may explain the observation that regular consumption of acids with meals almost halved the risk associated with that frequency of acid intake [25]. A recent meta-analysis on the impact of the diet on tooth wear in children did observe an association between yoghurt

and milk consumption and less tooth wear [43]. However, we do not know if this is a result of the children having the high calcium foods alongside dietary acids or having high calcium foods instead of dietary acids. Researchers have also attempted to modify erosive drinks by adding calcium or fluoride which does reduce their erosive potential although does not completely eliminate it [44]. In addition, consuming milk, fluoride products and even antacids following an acid challenge has been shown to reduce erosive tooth wear in vitro and in situ [45]. Other suggestions for neutralising the acid exposure include following the exposure with eating cheese or chewing sugar free gum. Chewing sugar free gum stimulates salivary flow (which enhances oral clearance) and has been shown in the laboratory to reduce wear from erosion [46]. However it is unknown if the physiological impact of chewing on eroded surfaces could potentially increase wear from abrasion [47]. All of these measures limit rather than prevent damage and the authors would argue that decreasing frequency of dietary acid intake should be the primary focus of advice.

Dentine hypersensitivity

There are indications that the presence of dentine hypersensitivity may also be related to acids in the diet. There is a relationship between erosive tooth wear and the presence of dentine hypersensitivity [25,48,49]. In one of the largest epidemiological studies investigating erosive tooth wear and dentine hypersensitivity on over 3,000 adults in 9 European countries, a relationship between dentine hypersensitivity and intraoral acids was observed [49]. A further clinical study questioned 350 participants on time passed since their last dietary acid consumption and performed clinical dentine hypersensitivity testing. They observed a relationship between clinical dentine hypersensitivity and dietary acid consumption in the previous hour [50]. Laboratory

studies have also confirmed the presence of increased tubule patency with dietary acids [51]. The similar aetiologies underlying both conditions indicate that if a patient presents with either dentine hypersensitivity or erosive tooth wear, similar dietary risk factors should be addressed.

Is giving dietary advice effective?

Giving dietary advice in general practice can be challenging. Advice may not always be welcomed and some patients may feel it as an intrusion. Furthermore, there is a gap in receiving advice and adherence to advice across all health disciplines with actual behaviour change being notoriously difficult to achieve [52]. One longitudinal study investigating tooth wear progression over 6 years observed that dietary behaviour had not changed despite being provided with "extensive dietary counselling" [26]. A Cochrane review investigating dietary advice provision in dental practice suggested there is evidence, albeit limited, that one-to-one dietary advice interventions can change behaviour [53]. Motivational interviewing has also been attempted in dental practice and there is evidence demonstrating success [54]. However, motivational interviewing techniques require intensive training and are reliant upon a good repertoire between the patient and the clinician and are time consuming for a general practice setting. However, key techniques for giving effective dietary advice in both general practice and hospital settings have been identified. Evidence suggests that, setting a clear goal (i.e reduction of cola drinks between meals), planning how you are going to achieve this goal (i.e If I want a coca cola then I will have a sparkling water instead) and self-monitoring (i.e keeping a record of each day you successfully did not have cola drinks between meals and trying to beat this the next week) has been observed to be effective across health interventions [55]. This type of goal setting, planning and monitoring

behaviour has already been reported to be effective in improving periodontal outcomes [56].

Conclusion

There is an established role between dietary acids and erosive tooth wear. Addressing this preventable aspect of erosive tooth wear may help to delay progression from other less preventable tooth wear factors such as gastro-oesophageal reflux disease, vomiting eating disorders and parafunctional habits. Reducing dietary acid intake may also help to reduce dentine hypersensitivity symptoms. However, the relationship between provision of advice and behaviour change is not straightforward. Individualised help to set a goal and incorporate planning and self-monitoring may make the behaviour change more effective.

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Figure 1: This patient rinsed acidic drinks around their mouth. This wear is primarily erosive with a small abrasive component. Image courtesy of Prof. David Bartlett.



Figure 1. This patient sipped hot tea with lemon flavouring several times a day. Image courtesy of Prof. David Bartlett.

Table 1. Summary of questions to ask patients to identify risk factors associated with erosive tooth wear.

Questions to ask patients when you suspect dietary erosive tooth wear

1. How many dietary acids are being consumed on a daily basis including fruits, anything with a fruit flavouring, acidic drinks, acidic sweets and medications?
2. How many of these are between meals?
3. Is greater than 10 minutes being spent consuming any dietary acid at a single sitting?
4. Do they sip, swish, hold or rinse the dietary acid in their mouths prior to swallowing?
5. Do they consume dietary acids at an increased temperature eg hot water with lemon, stewed fruits, fruit teas?