Is your drink eating your teeth?

A recent newspaper article *(1)* about Jacinta Worland a former Australian national and international triathlete highlighted extensive and complex dental treatment such as root canal treatment and crowns on several teeth during her adult years. According to the article she will be spending another $20,000.00 this year on more dental treatment due to "years of drinking litres of sports drinks daily (particularly during competition) and eating fruit gels".

Tooth surface dissolution due to acid attack results in dental decay, dental erosion or both. Preventative strategies such as fluoride products and dietary modification can reduce the impact of dental decay for the general community. Dental professionals however have been concerned for some time about an increasing incidence of dental problems amongst sports participants and increasing rates of tooth wear (loss of dental hard tissue) particularly dental erosion affecting all ages from pre-school children through to adult.

What is tooth wear? What causes tooth wear?

Tooth wear (loss of dental hard tissue) occurs due to mechanical (attrition, abrasion), chemical (erosion) processes acting individually or together *(2)*. In fact erosion is the main cause of the hard, outer covering of teeth softening further wear then occurring by attrition and abrasion *(3)*.

Dental attrition

Tooth wear due to tooth to tooth contact.

Dental abrasion

Loss of dental hard tissue by physical means such as stiff toothbrushes or abrasive substances such as harsh toothpastes coming into contact with teeth.

Dental erosion

The physical result of an acid attack (not due to bacteria) on any exposed tooth surface causing local demineralization of dental hard tissue. This process softens the tooth surface resulting in an irreversible loss of dental hard tissue commencing within 5 minutes of acidic solution contacting the tooth surface *(4)*. This softened surface is then susceptible to further damage.

Signs of dental erosion include:

1. Hollow defects on the cusp tips/loss of surface detail on the chewing (occlusal) surfaces of posterior teeth.
2. Fillings in affected teeth appear to "stick out" of the tooth surface due to surrounding tooth structure being dissolved.
3. Thinning/chipping of the biting (incisal) edges of the anterior teeth.
4. Thinned outer enamel layer of affected teeth so underlying grey/brown tooth colour is more noticeable.
5. Tooth sensitivity to hot/cold or sweet for duration of contact with affected tooth surface.

Non-bacterial sources of acid

Unlike dental decay the acidic attack causing dental erosion is not produced by bacteria in the mouth but from other sources *(5)*:

1. Dietary (herbal teas, carbonated drinks, fruit juices, sports drinks and acidic foods such as citrus fruits, vinegars)
2. General diseases (gastric reflux, frequent vomiting, eating disorders, alcohol abuse, salivary gland disease or obstruction reducing salivary flow)
3. Medication (chewable Vitamin C tablets, medications which reduce salivary flow as a side-effect)
4. Occupational (professional wine taster, battery workshops, abrasive, dusty work environments)
5. Sports (professional swimmers in chlorinated, improperly pH-regulated pools)

How common is dental erosion?

A number of published studies *(6)* note a rising incidence of tooth wear affecting both primary (deciduous) teeth and second (permanent) teeth amongst "first world" populations. Up to 20% of preschool and younger school-age children surveyed in the United Kingdom in the 1990's showed tooth wear on upper front primary teeth the incidence increasing with age *(7).* An Australian survey of eight schools found nearly 70% of 714 students aged 6-15 years had at least one tooth with excessive wear *(8)*, compared with 41% in United States *(9)* and 51% in United Kingdom *(10)*. The increased rate of erosion has been linked to growth in consumption of dietary acidic intake particularly soft drinks, fruit juices and sports drinks.

Dental erosion, diet and food additives

The Australian Beveridge Council reports a steady decline in consumption of less sugared soft drink from 2002 to 2006 but increased consumption of water and diet drinks of 30% since 1997 and bottled water consumption increasing by 62% over the same period. In the USA soft drink consumption increased by 300% from 1965 to 1996 and serving sizes also increased by 100% from 240g to 500g *(11).* Primary teeth are at risk of surface damage from erosive, fruit-based drinks being introduced at an early age rather than milk or water *(12).* Prolonged exposure of primary teeth to acidic baby juices during weaning increases the risk of tooth damage despite clearance and buffering by salivary flow *(13,14)*.

Additives such as carbonic acid (the reaction product of water and carbon dioxide when drinks are carbonated), malic acid, tartaric acid, ascorbic acid (fruit acid 300), citric acid (food acid 331) and phosphoric acid (food acid 338) are found in sports drinks and soft drinks *(3,5)* to provide tartness which encourages drinking and enhances taste *(15)*. Phosphoric acid is a major component of both "regular" and "diet" cola drinks which are associated with dental erosion. Citric acid the predominant acid in non-cola drinks is also added to wine to stop fermentation. Wine also contains tartaric acid the main acid naturally found in grapes.

What determines erosive potential of acidic solutions?

Dental decay and tooth erosion are the clinical effects of tooth mineral dissolution. The hard, outer layer covering teeth is enamel composed of calcium, phosphate, and hydroxide. The underlying material dentine is a softer material consisting of apatite, collagen and water. The structure of both enamel and dentine are weakened by acidic attack.

The erosive potential of drinks is determined by:

1. pH - enamel is at risk of mineral dissolution when pH of solution in contact with it is less than 5.5 (**critical pH)**. Dentine is also demineralised (weakened) by acid. The enamel layer in primary teeth is thinner making them particularly vulnerable *(12)*.
2. acid buffering capacity (titratable acid content)*(16)* - the greater the buffering capacity of the drink the greater the volume of saliva required to neutralise the acid. The titratable acid content is directly affected by food additives such as citric acid (food acid 331) combines with and removes the calcium in the tooth weakening it. Altering the amount and type of these additives used in drink formulations could reduce their erosive potential *(15)*.
3. frequency and duration of exposure - when acidic liquid contacts tooth surface a sudden, rapid drop of pH occurs at the tooth surface which then slowly rises over the next 20-30 minutes (recovery phase) due to neutralization and clearance of acidic solution by normal salivary flow. During this time the mineral content which has been dissolved is replaced if adequate saliva (containing calcium and phosphate) is available. Another exposure to acidic solution during this time causes another rapid drop in pH extending the total period of tooth surface demineralization. Swishing the solution around the mouth retains the acid solution in the mouth prolonging contact time between acid solution and tooth surface.
4. sugar content - high sugar content provides energy. In cola "premix" however it makes colas "stick" more to teeth than saliva posing a risk to teeth *(16).*

What protects tooth enamel and dentine from damage by acidic solutions?

Normal salivary flow rates in healthy individuals can eliminate acid drinks from the mouth returning the oral cavity pH to 6.5-7 within 2 minutes *(17)*. Saliva controls the pH of the oral cavity protecting the teeth from erosive beverages by *(18)*:

1. dilution and clearance of potentially erosive liquids from the mouth.
2. neutralization and buffering of dietary acids due to bicarbonate.
3. maintaining a supersaturated state in contact with the tooth surface due to the presence of calcium and phosphate for remineralization.

Sports drinks/powders

The market for sports drinks is lucrative and continues to grow with a broad range available *(21,22)*. Sports drinks are not only being consumed by electrolyte-depleted athletes but also individuals who are just thirsty. Sports drinks are not appropriate for all ages nor following any physical activity irrespective of its duration. The salt and caffeine content in sports drinks is of concern for children consuming these products as it is with soft drinks, cola drinks, energy drinks and gels *(23)*.

Low pH does not affect gastric emptying or absorption rate *(25)* yet for commercially prepared sports drinks the pH is 2.4 - 4.5 well below the critical pH (5.5) hence the concern about damaging teeth*(27)*. Additives such as citric acid (food acid 331) increases the volume of saliva required to neutralise the acid, while improving the taste *(3,5)* and increase the effectiveness of anti-microbial preservatives extending the product shelf-life *(17)*.

Some sports drinks are also sold as powders. Variations in measuring powder and water during preparation affects the concentration, osmolarity *(24)* and possibly pH of the mixture *(22)*.

Sports/Energy Gels

These products are described as a mix between an energy bar and a sports drink in a treacle/honey-like consistency packaged in discrete, individual sachets providing concentrated carbohydrates and caffeine. Sports/energy gels pose a significant risk of dental decay to athletes due to gel consistency and content. Gels provide no fluid so athletes using them are advised to drink 500-600ml of water (not sports drink) when consuming them. The salt and caffeine content in sports and energy gels is of concern for children consuming these products as it is with soft drinks, cola drinks and energy drinks *(23)*.

Dental decay

The oral cavity contains many bacteria some converting acid from sugars and carbohydrates from food in the mouth. Teeth in the mouth are covered by a biofilm (dental plaque) which contains these bacteria retaining them in close proximity to the tooth surface. The duration of acid attack lasts for 20-25 minutes until all food debris is diluted and washed away by saliva. Frequent, prolonged acid exposure to tooth surface weakens the tooth surface by loss of mineral unless remineralization from saliva can occur.

Risk of dental decay risk is increased by:

1. any food which is “sticky” or has a honey-like consistency adheres to the tooth surface delaying clearance from the mouth by swallowing, tongue action and flushing by saliva. While this material is retained in the mouth it provides substrate for acid production by oral bacteria.
2. frequent or continual consumption of food with a high sugar content provides abundant substrate for acid production by oral bacteria extending acid attack on exposed tooth surface.
3. reduced salivary flow delays clearance of substrate (food debris) from the mouth extending the duration of acidic attack on exposed tooth surface.

Recovery snacks and dental decay

Replenishing muscle and liver glycogen stores is an integral part of post-training and post-competition recovery. High glycaemic index foods which are carbohydrate-rich, easily digested and rapidly absorbed into the bloodstream are

preferred. Typical examples include several cups of a sports drink, soft drink (not cola), fruit juice, confectionery (jelly beans, jelly snakes), a sports bar, several tube of sports gel, honey/jam sandwiches, several dried fruit strips, dried fruit *(26)*. Post-training or post-competition athletes are dehydrated with minimal salivary flow. During each recovery snack session an athlete's teeth may be subject to an intense, prolonged acid attack from both dietary acid beverages/foods in addition to acid produced by oral bacteria from the dietary sugar and carbohydrate.

Water

Sales of bottled water continue to grow becoming a status symbol often being drunk in preference to tap water. The Australian water supply is generally of good quality so that tap water is safe to drink and preferable due to the optimal fluoride content which in bottled water is minimal or variable *(27)*. A tooth surface exposed to an acidic beverage continues to soften despite immediately drinking an equal volume of water *(4)*. Water does not neutralize an acidic beverage (as it contains no bicarbonate) nor reharden tooth surface by remineralization (as it contains no phosphate or calcium). In any event water provides incomplete mechanical clearance of the acidic beverage from the mouth.

Risks for sports participants

1. "water chaser" myth – a mouthful of water following a mouthful of sports drink does not prevent dental erosion. Water may flush some of the solution away but no acid neutralization or remineralization occurs as water contains no bicarbonate, calcium or phosphate.
2. reduced salivary volume and quality **-** saliva contains bicarbonate which neutralizes the acidic solution, calcium and phosphate to re-mineralize softened tooth surface *(11,16,17,28)*. Prolonged high-intensity exercise reduces salivary flow *(29)* lowering saliva bicarbonate content compromising the ability of saliva to neutralise acidic solutions at tooth surface *(17)*. It can take up to 30 minutes for pH in the mouth to return to a normal level with low salivary flow rates *(30)* meanwhile surface damage continues.
3. low pH liquids – liquids with pH less than 5.5 include sports drinks, energy drinks (2.4 - 4.5), commercial fruit juices (3.4 - 3.6), carbonated mineral water, cola and non-cola soft drinks (2.5 - 3.6) *(17)*. These products also contain food additives which determine the volume of saliva required to neutralise the acid (titratable acid content) *(15)*. Changing some of these additives could reduce the product's erosive potential *(17)*.
4. frequent exposure to low pH liquids - minimizing net fluid loss amongst sports participants is achieved by frequent and regular drinking/sipping. During training and competition participants may have a dry mouth due to mouth breathing or be dehydrated reducing salivary flow allowing acidic solution residue to remain in contact with tooth surface to maintain a low pH. Frequent sipping of low pH liquid at intervals of 15-25 minutes causes another rapid drop in pH extending time for tooth surface demineralization to occur.
5. carbohydrate and sugars in sports gel provide ideal substrate for acid production by oral bacteria. The "sticky" consistency adheres to tooth surface further delays clearance from the mouth particularly when salivary flow is low. Gels are consumed 45-60 minutes into the event when the athlete could be experiencing some of the effects of dehydration.
6. water must be consumed with gel. If low pH fluid (sports drink) is consumed instead of water the pH at tooth surface is kept low for much longer further increasing the risk of tooth damage. The tooth surface is initially softened by sports drink while the acid producing oral bacteria convert gel carbohydrate to acid prolonging the total time available for surface demineralization.
7. toothbrushing within 30 minutes of consuming sports drink may cause further damage as tooth surface is still soft. The frequent use of highly abrasive toothpastes (e.g. smokers toothpaste) by some health/aesthetic conscious individuals may also result in the removal of the outer layer of tooth enamel *(31)*.

Product labels and "tooth friendly" sports drinks

Labeling of sports bars, gels and drinks must comply with Food Standards Australia and New Zealand (Standard 124, Clause 8, Schedule 1) *(16)*. The food label lists ingredients, additives (often identified by number rather than name) and nutritional information. Ideally information about acid buffering capacity (low acid buffering is better for your teeth) and product pH (preferably near or above pH 5.5) should be readily available to indicate "tooth friendly" drink(s).

Minimising dental problems

1. Tap water is appropriate for children and athletes participating in low intensity activity. Sports drinks should be used carefully by athletes only for intense physical activity of more than 60 minutes duration.
2. "Water chaser" after a sports drink does not protect teeth. Water does not neutralize acidic beverage (as it contains no bicarbonate) nor remineralize tooth surface. Water offers incomplete mechanical clearance of the acidic beverage from the mouth.
3. When preparing sports drinks from powders do not use less water than specified in the instructions.
4. Reduce the consumption/frequency and contact time of acidic beverages. Swallow acidic drinks immediately do not hold or swish them in your mouth. Drinking acidic beverages via a straw also reduces contact with teeth.
5. Do not use sports drinks as a mouthwash. Do not rinse your mouth with sports drink before inserting your mouthguard.
6. Mouthguards should only be rinsed in water.
7. Drink water with sports/energy gels not sports/energy drinks.
8. The teeth of dehydrated athletes consuming several high glycaemic index foods during post-training or post-competition recovery may also be risking dental decay from reduced salivary flow compromising tooth surface protection.
9. Cleaning teeth should be delayed for at least 30 minutes after consuming a sports drink or post-training, post-competition recovery to enable tooth surface rehardening to occur.
10. Do not consume acidic foods or beverages immediately before bed.
11. Fluoride, bicarbonate and calcium added to sports/softs drinks reduce their erosive potential but may also affect the taste.
12. Discuss your training, hydration regime with your dental professional. Regular dental review will detect early damage to teeth minimizing problems.
13. Use neutralising products, fluoride varnishes, gels or rinses, remineralising agents such as CPP-ACP added to chewing gum, lozenges, mouthwashes or milk to re-harden tooth surfaces.

John Banky, Dental Surgeon, Melbourne
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1. Teutsch D. Awful tooth about sports drinks. **The Sun Herald** March 7th 2010; 13
2. Magalhaes AC, Wiegand A, Rios D, Honorio HM, Buzalaf MAR. Insights into preventive measures for dental erosion. **Journal of Applied Oral Science** 2009;17;75-86
3. Young G. The oral medicine of tooth wear. **Australian Dental Journal** 2001**;**46;236-250
4. Seow WK, Thong KM. Erosive effects of common beverages on extracted premolar teeth. **Australian Dental Journal** 2005;50;173-178
5. Ten Cate JM, Imfield T. Etiology, mechanisms and implications of dental erosion. **European Journal of Oral Science** 1996;104;149-244
6. Moss SJ. Dental erosion. **International Dental Journal** 1998;48;529-539.
7. Hinds K, Gregory JR,. National Diet and Nutrition Survey; children aged 1½ to 4½ years. Report of the dental survey. London HMSO, 1995
8. Kazoullis S, Seow WK, Holcombe T, Newman B, Ford D. Common dental conditions associated with dental erosion in schoolchildren in Australia. **Paediatric Dentistry** 2007; 29; 33-39.
9. Deery C, Wagner ML, Longbottom C, Simon R, Nugent ZJ. The prevalence of dental erosion in a United States and a United Kingdom sample of adolescents"; **Paediatric Dentistry** 2000; 22; 505-510.
10. Al-Dlaigan YH, Shaw L, Smith A. Dental erosion in a group of British 14 year old school children. Part 1: P Prevalence and influence of differing socioeconomic backgrounds. **British Dental Journal** 2001;190;145-149.
11. Cochrane NJ, Cai F, Yuan Y, Reynolds EC. Erosive potential of beverages sold in Australian schools. **Australian Dental Journal** 2010; 54; 238-244.

12. Smith AJ, Shaw L. Baby fruit juice and tooth erosion. **British Dental Journal** 1987;162;65-67.
13. Hunter ML, Hood CA,Hunter B, Kingdom A. Reported infant feeding, oral hygiene and dental attendance patterns in children aged 5 years and under referred for extraction of teeth under general anaesthesia. I**nternational Journal of Paediatric Dentistry** 1997;7;243-248.
14. Hunter L, Patel S, Rees J. The in vitro erosive potential of a range of baby drinks. **International Journal of Paediatric Dentistry** 2009;19;325-329.
15. Owens BM. The potential effects of pH and buffering capacity on dental erosion. **General Dentistry** 2007;55(6);527-31
16. www.foodstandards.gov.au/consumerinformation/additives.cfm accessed 5.5.2010
17. Lussi A, Jaeggi T, Zero D. The role of diet in the aetiology of dental erosion. **Caries Research** 2004;38;34-44.
18. Young G. Tooth wear: diet analysis and advice. **International Dental Journal** 2005; 55; 68-72
19. Meurman JH, Rytomaa I, Kari K, Laakso T, Murtomaa H. Salivary pH and glucose after consuming various beverages, including sugar-containing drinks. **Caries Research** 1987; 21; 353-359
20. Mandel ID. The function of saliva. **Journal of Dental Research** 1987; 66; 623-627
21. Venables MC, Shaw L, Jeukendrup AE, Roedig-Penman A, Finke M, Newcombe RG, Parry J, Smith A. Erosive effect of a new sports drink on dental enamel during exercise. **Medicine & Science in Sports & Exercise** 2005; 37; 39-44.
22. Coombes J, Hamilton KL. The effectiveness of commercially available sports drinks. **Sports Medicine** 2000; 29; 181-209
23. Keast RSJ, Riddell LJ. Caffeine as a flavor additive in soft-drinks. **Appetite** 2007; 49; 255-259
24. Mettler S, Rursch C, Colombani PC. Osmolarity and pH of sport and other drinks available in Switzerland. **Sportmedizin und Sporttraumatologie** 2006; 54 (3); 92-95
25. Maughan RJ, Leiper JB. Limitations to fluid replacement during exercise. **Canadian Journal of Applied Physiology** 1999**;** 24; 173-187
26. Andrew K. To snack or not to snack? **Australian Sports Trainers** 1999; 16 (1); 2
27. Larsen MJ, Nyvad B. Enamel erosion by some soft drinks and orange juices relative to their pH, buffering effect and contents of calcium phosphate. **Caries Research** 1999**;** 33; 81-87
28. Gedalia C, Dakuar A, Shapira L, Lewinsten I, Goultshin J, Rahamin E. Enamel softening with Coca-Cola and rehardening with milk or saliva. **American Journal of Dentistry** 1991; 4; 120-122
29. Chicharro JL, Lucia A, Perez M, Vaquero AF, Urena R. Saliva composition and exercise. **Sports Medicine** 1998; 26;17-27
30. Tenuvuo J, Rekola M. Some effects of sugar-flavoured acid beverages on the biochemistry of human whole saliva and dental plaque. **Acta Odontology Scandanavia** 1977; 35; 317-330
31. Amaechi BT, Higham SM. Dental erosion: possible approaches to prevention and control. **Journal of Dentistry** 2005; 33; 243-252.