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GUEST EDITORIAL

The implication of laboratory research on tooth wear and erosion

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Introduction

Recently, research on tooth wear has primarily focused on dental erosion. Part of this reason is the relative ease of designing laboratory studies investigating the pathogenesis of erosion. Whereas, the role of attrition in tooth wear has been under-researched possibly because recreating realistic laboratory methods are more difficult. Tooth wear is almost invariably a combination of erosion, attrition and abrasion. Most clinicians in Europe recognize the dominant role of erosion but the role of attrition and abrasion should not be underestimated. This paper will review the literature on prevalence, aetiology, prevention of erosion and attrition, and their combination. The aim of the paper is to reappraise the role of attrition in tooth wear. This paper will not review the role of abrasion associated with cervical wear.

Definitions

The combination of erosion, attrition and abrasion is called tooth wear. Erosion is the chemical loss of hard tissues not involving bacteria, attrition is the wear of tooth against tooth and abrasion is the wear of teeth from other surfaces. Recently, the role of abfraction (Lee and Eakle, 1984) has raised interest into abrasion and the link with attrition but this area is under-researched.

Prevalence

Some of the confusion regarding the relative importance of erosion and attrition has developed from the methods used to quantify it. Tooth wear indices remain the most frequently and conveniently used method to quantify wear in large epidemiological studies. However, early development of these indices attempted to relate the diagnosis to the index (Dahl *et al*, 1989) or to focus on one factor, notably attrition (Oilo *et al*, 1987). It is almost impossible to distinguish between the influence of erosion, attrition or abrasion during a clinical examination without introducing bias into the assessment procedure. Therefore, indices that do not separate the factors are almost certainly safer to interpret. The Smith and Knight index uses a 5-point scale to assess wear on the cervical, buccal, incisal/occlusal and palatal/lingual surfaces (Smith and Knight, 1984). Other similar indices have developed using this model but used simpler determinants at the dentine level (Millward *et al*, 1994a).

The problem with tooth wear indices is as they become more accurate their reproducibility reduces. It is easier to use the Millward *et al* (1994a) method than the Smith and Knight (1984) but the tendency is to focus the assessment to the early dentine level. This is particularly useful in children and young adolescents where the proportion of severe levels is relatively small but may be more difficult to use in older patients. It is far easier to differentiate dentine exposure from that of enamel wear because of the colour difference between the two tissues. The difficulty is that once the wear has passed into dentine distinguishing the range of severity is more difficult. Severe tooth wear exposing the secondary or tertiary dentine is relatively straightforward and reproducible to assess. Recording the middle range of dentine exposure is more difficult to differentiate whilst at the same time maintaining reproducible recordings. As most studies involving children involve early dentine exposure the accuracy of the study is normally good (Millward *et al*, 1994b; Bartlett *et al*, 1998; Al Dlaigan *et al*, 2001b). But as the age of the study population increases it becomes more difficult to either assess the level of wear or predict whether it is normal for a particular age.

One problem is that teeth wear with age, it is a normal process. Therefore, as the age of the sample population increases the amount of dentine exposure will increase and so will its severity (Smith and Robb, 1996). Although, the Smith and Robb study introduced the concept of pathological wear associated with age bands there were some concerns regarding the simplicity of this association together with the sample size (Donachie and Walls, 1996). However, severe wear is more important because of its financial implications of restoring the teeth. There remains a problem with tooth wear indices

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not only in their concept but also in their practicality. However, there is no other simple method to record tooth wear in large samples.

Aetiology

Much of the emphasis on the development of erosion has been directed at the diet. Whilst it is inconceivable to suggest that dietary acids are not involved it also unlikely that acids are acting in isolation. There is sufficient evidence to strongly implicate dietary acids in the progression of tooth wear. The erosive potential of citric, malic, phosphoric acids are accepted widely (Davis and Winter, 1977; Meurman *et al*, 1987, 1990). The evidence from epidemiological case–control studies also strongly implicates dietary acids in the development of erosion (Lussi *et al*, 1991; Al Dlaigan *et al*, 2001a; Dugmore and Rock, 2003). However, most studies involve children who have less severe wear than adults with around 2% of child studies reporting severe tooth wear (Bartlett *et al*, 1998; Al Dlaigan *et al*, 2001b). In these populations the most commonly reported areas with wear are occlusal surfaces of molars and incisal surfaces of incisors (Bartlett *et al*, 1998). As these surfaces are also associated with attrition it can be difficult to extrapolate what is being caused by erosion from what is tooth wear. Al Dlaigan *et al* (2001a) reported the use of a modified Smith and Knight index to record the prevalence of dental erosion in 14-year-old children. They reported 51% of the sample had moderate erosion (dentine exposure) but eliminated from the data the incisal edges of the upper and lower anterior teeth because the cause of this wear was presumed to be attrition. If attrition was acting on some teeth in those children why could it not be active elsewhere in the mouth? Also if over half of the sample have wear is this a normal level?

There is little evidence to suggest the cause of attrition. The role of occlusal interferences in the progression of tooth wear has been generally disproved whilst that of stress appears to be more possible. Most of the work on attrition has been related to mandibular dysfunction rather than the wear itself. There is no data to indicate the prevalence of attrition in the community whereas, that of erosion is a common finding in literature searches.

Site and pattern of wear

Erosion is a surface phenomena unlike caries where the effects are within the subsurface of enamel or dentine. Acids cause surface demineralization of dental hard tissues, primarily by dissolution of the apatite crystals. The severity of the erosion will depend on concentration of hydrogen ions (titratable acidity) and the frequency and duration of acid exposure (Moazzez *et al*, 2000). Acids attack enamel causing demineralization along the enamel prisms. Meurman *et al* (1991) and Meurman and Frank (1991) investigated enamel erosion by immersing bovine and human enamel specimens in acids for various times. The authors reported that erosion started within the prism sheath area and then spreading to the prism core, leaving the honey comb appearance of the interprismatic areas when viewed microscopically. Eventually, the interprismatic areas also become affected.

Clinically, the erosive lesions develop on any tooth surface where the acid contacts. Typically, this presents on the buccal surfaces of the upper incisors, commonly associated with dietary acids or the palatal surfaces of upper incisors more frequently associated with regurgitated stomach juice. The pattern of erosion might be also influenced by salivary flow (Milosevic and Dawson, 1996), pellicle thickness (Duschner *et al*, 2000) or gingival sulcular flow (Lussi *et al*, 2004). The latter may be responsible for the preservation of a thin band of palatal enamel along the gingival margins of worn upper incisors (Lussi *et al*, 2004). Drinking habits are also recognized as major factors in the development of the severity and site of the erosion (Moazzez *et al*, 2000).

Early attrition begins on the occluding surfaces of teeth and these facets develop on the cusps of molars and the incisal edges of the incisors. As the attrition develops the facets expand to involve larger areas of the contacting surfaces. More extreme wear presents as a generalized flattened occlusal surfaces. It is rare to see erosion, attrition or abrasion occurring independently. The combination of erosion, attrition and abrasion are recognized to be more destructive than if they were occurring independently (Davis and Winter, 1980). If erosion, attrition and abrasion occur together the results reported from laboratory studies, investigating erosion, may not accurately reflect the clinical situation.

Laboratory studies and prevention of tooth wear

The advantage of *in vitro* studies is to separate the components of tooth wear and investigate them separately. Most laboratory studies in recent years have focused on erosion rather than attrition. Many erosive studies have investigated the effects of fluoride (Bartlett *et al*, 1994), tooth and chemical characteristics (Meurman *et al*, 1990; Larsen, 1991; Amaechi *et al*, 1999; Larsen and Nyvad, 1999) and measurement (Amaechi *et al*, 1998; Azzopardi *et al*, 2001, 2004). If erosion occurs as a single event the potential for prevention of enamel and dentine with fluoride (Bartlett *et al*, 1994), dentine bonding agents (Azzopardi *et al*, 2001, 2004) or fissure sealants may be possible.

Attin *et al* (2005) in their study published in this edition present the results of a laboratory study investigating the effect of adding calcium and fluoride to drinks to protect enamel from acids. Whilst the findings of this study support the inclusion of these minerals there is a need to remember that tooth wear clinically is a combination of erosion, attrition and abrasion. The results of this work are partly supported by laboratory and *in situ* studies where a calcium enriched drink had reportedly less erosive potential than standard drinks (Hughes *et al*, 1999a,b;West *et al*, 1999). The *in situ* study measured the amount of erosion on extracted teeth using profilometers. The study design allowed the combination of abrasion and erosion to be assessed but no allowance could be made for attrition or its combination with erosion. Whilst abrasion and erosion are important it is the effect of attrition that is likely to be more important in the progression of tooth wear in the mouth.

If erosion occurs as a single event the potential for fluoride enriching or remineralization of enamel or dentine may be possible since the surface of the enamel surface would remain intact. However, if a surface protected with fluoride was immediately denuded by abrasion or attrition the lesion would need to start again. As tooth wear is multifactorial this eventuality is more likely that any process occurring independently.

Although Attin's study supported the hypothesis that calcium and fluoride might be protective other studies have concluded differently. Larsen and Nyvad (1999) in a study on product variation of orange juice reported that fluoride was unlikely to reduce dental erosion. The addition of fluoride to enamel produces fluorhydroxyapatite which has a lower solubility than hydroxyapatite. The authors suggested that the relatively strong acids associated with erosion will overcome the effect of the fluoride and result in demineralization (Lussi *et al*, 2004). Sorvari *et al* (1994) showed that a fluoride varnish could offer some protection of enamel from acids erosion. The authors observed a deposit or precipitation upon the enamel surface which might offer protection from further acid attack. But would the deposit withstand either abrasion or attrition? It seems unlikely.

Laboratory and an *in situ* investigations using dentine bonding agents to protect teeth from erosion have shown some promise (Azzopardi *et al*, 2001, 2004). Whether these materials are sufficiently robust to prevent tooth wear involving erosion, attrition and abrasion is unknown.

Not only is prevention important but can enamel and dentine remineralize after erosion? Certainly the evidence from dental caries strongly implies that this occurs (Edgar and O'Mullane, 1996). But with tooth wear this is not so clear. If remineralization is feasible the role of saliva would presumably become important. There is evidence from laboratory studies that acid softened enamel can reharden after exposure to remineralizing solutions (Gedalia *et al*, 1991). Ganss *et al* (2001) reported that reapplication technique of fluoride on enamel and dentine reduced erosion. What effect would fluoride have on erosion occurring with abrasion and attrition? The main problem with investigating the effects of saliva on erosion is the variability of the collection and measuring techniques. It is not known if whole saliva is protective or whether resting or stimulated saliva is more important. Milosevic and Dawson (1996) reported that in vomiting and non-vomiting bulimics the bicarbonate levels and salivary viscosity were significantly different to a matched control group. The findings of this study were also supported by others working on bulimics (Rytomaa *et al*, 1998). Gudmundsson *et al* (1995) found in their study that the buffering capacity of saliva in 62 patients with erosion was statistically different to a control group. Whereas, Bartlett *et al* (1998) found no salivary differences between adolescents with or without tooth wear. Nor did Meurman *et al* (1994) in a study of 117 patients with erosion and reflux disease. These differences might reflect the varying nature of saliva or the varying nature of the methods used to measure it. Or perhaps that saliva is not so important in tooth wear as it is in caries because of the nature of the process.

The only accepted method to prevent attrition is with hard acrylic splints. Whilst there are not definitive studies to prove the preventive affect it is likely that if a patient wears an appliance separating their teeth the lack of contact means reduced wear. The most important factor in the success of this prevention is the compliance of the patient.

Conclusion

The data from child studies and adults suggest that early tooth wear involving mild dentine exposure is common. But severe wear of dentine is relatively uncommon. There is tendency for research to concentrate upon erosion in laboratory studies as it is easier to study whereas it does not occur in isolation in the mouth. Researchers need to be cautious in interpreting laboratory studies to the clinical situation. The role of attrition needs more investigation as it is likely that the clinical problem is a combination of erosion, attrition and abrasion. Methods aimed to prevent the wear should not ignore the role of attrition and abrasion.

References

Al Dlaigan YH, Shaw L, Smith A (2001a). Dental erosion in a group of British 14-year-old school children. Part II: Influence of dietary intake. *Br Dent J* **190**(5)**:** 258–261.

Al Dlaigan YH, Shaw L, Smith A (2001b). Dental erosion in a group of British 14-year-old, school children. Part I: Prevalence and influence of differing socioeconomic backgrounds. *Br Dent J* **190**(3)**:** 145–149.

Amaechi BT, Higham SM, Edgar WM (1998). Use of transverse microradiography to quantify mineral loss by erosion in bovine enamel. *Caries Res* **32:** 351–356.

Amaechi BT, Higham SM, Edgar WM (1999). Factors influencing the development of dental erosion in vitro: enamel type, temperature and exposure time. *J Oral Rehabil* **26**(8)**:** 624–630.

Attin T, Weiss K, Becker K, Buchalla W, Wiegand A (2005). Impact of modified acidic soft drinks on enamel erosion. *Oral Dis* **11:** 7–12.

Azzopardi A, Bartlett DW, Watson TF, Sherriff M (2001). The measurement and prevention of erosion and abrasion. *J Dent* **29:** 395–400.

Azzopardi A, Bartlett DW, Watson TF, Sherriff M (2004). The surface effects of erosion and abrasion on dentine with and without a protective layer. *Br Dent J* **196**(6)**:** 351–354.

Bartlett DW, Smith BG, Wilson RF (1994). Comparison of the effect of fluoride and non-fluoride toothpaste on tooth wear in vitro and the influence of enamel fluoride concentration and hardness of enamel. *Br Dent J* **176:** 346–348.

Bartlett DW, Coward PY, Nikkah C, Wilson RF (1998). The prevalence of tooth wear in a cluster sample of adolescent schoolchildren and its relationship with potential explanatory factors. *Br Dent J* **184:** 125–129.

Dahl BL, Oilo G, Andersen A, Bruaset O (1989). The suitability of a new index for the evaluation of dental wear. *Acta Odontol Scand* **47:** 205–210.

Davis WB, Winter PJ (1977). Dietary erosion of adult dentine and enamel. *Br Dent J* **143:** 116–119.

Davis WB, Winter PJ (1980). The effect of abrasion on enamel and dentine after exposure to dietary acid. *Br Dent J* **148:** 253–256.

Donachie MA, Walls AWG (1996). The tooth wear index: a flawed epidemiological tool in an ageing population group. *Community Dent Oral Epidemiol* **24:** 152–158.

Dugmore CR, Rock WP (2003). The progression of tooth erosion in a cohort of adolescents of mixed ethnicity. *Int J Paediatr Dent* **13**(5)**:** 295–303.

Duschner H, Hermann G, Walker R, Lussi A (2000). Erosion of dental enamel visualised by confocal laser scanning microscopy. In: Addy M, Embery G, Edgar WM, Orchardson R, eds. *Tooth wear and sensitivity*. Martin Dunitz: London, pp. 67–73.

Edgar WM, O'Mullane DM (1996). *Saliva and oral health*. 2nd edn. British Dental Journal: London.

Ganss C, Klimek J, Schaffer U, Spall T (2001). Effectiveness of two fluoridation measures on erosion progression in human enamel and dentine in vitro. *Caries Res* **35**(5)**:** 325–330.

Gedalia I, Dakuar A, Shapira L, Lewinstein I, Goultschin J, Rahamim E (1991). Enamel softening with coca-cola and rehardening with milk or saliva. *Am J Dent* **4:** 120–122.

Gudmundsson K, Kristleifsson G, Theodors A, Holbrook WP (1995). Tooth erosion, gastroesophageal reflux, and salivary buffer capacity. *Oral Surg Oral Med Oral Pathol* **79:** 185–189.

Hughes JA, West NX, Parker DM, Newcombe RG, Addy M (1999a). Development and evaluation of a low erosive blackcurrant juice drink in vitro and in situ. 1. Comparison with orange juice. *J Dent* **27:** 285–289.

Hughes JA, West NX, Parker DM, Newcombe RG, Addy M (1999b). Development and evaluation of a low erosive blackcurrant juice drink. 3. Final drink and concentrate, formulae comparisons in situ and overview of the concept. *J Dent* **27:** 345–350.

Larsen MJ (1991). On the chemical and physical nature of erosions and caries lesions in dental enamel. *Caries Res* **25:** 323–329.

Larsen MJ, Nyvad B (1999). Enamel erosion by some soft drinks and orange juices relative to their pH, buffering effect and contents of calcium phosphate. *Caries Res* **33**(1)**:** 81–87.

Lee WC, Eakle WS (1984). Possible role of tensile stress in the aetiology of cervical erosive lesions of teeth. *J Prosthet Dent* **52:** 374–379.

Lussi A, Schaffner M, Holtz P, Suter P (1991). Dental erosion in a population of Swiss adults. *Community Dent Oral Epidemiol* **19:** 286–290.

Lussi A, Jaeggi T, Zero D (2004). The role of diet in the aetiology of dental erosion. *Caries Res* **38** (Suppl. 1)**:** 34–44.

Meurman JH, Frank RM (1991). Scanning electron microscopic study of the effect of salivary pellicle on enamel erosion. *Caries Res* **25:** 1–6.

Meurman JH, Rytomaa I, Kari K, Laakso T, Murtomaa H (1987). Salivary pH and glucose after consuming various beverages, including sugar-containing drinks. *Caries Res* **21:** 353–359.

Meurman JH, Harkonen M, Naver H, Koskinen J, Torkko H, Rytomaa I *et al.* (1990). Experimental sports drinks with minimal dental erosive effect. *Scand J Dent Res* **98:** 120–128.

Meurman JH, Drysdale T, Frank RM (1991). Experimental erosion of dentin. *Scand J Dent Res* **99:** 457–462.

Meurman JH, Toskala J, Nuutinen P, Klemetti E (1994). Oral and dental manifestations in gastroesophageal reflux disease. *Oral Surg Oral Med Oral Path* **78** (5)**:** 583–589.

Millward A, Shaw L, Smith AJ (1994a). Dental erosion in four-year-old children from differing socioeconomic backgrounds. *J Dent Child* **61:** 263–266.

Millward A, Shaw L, Smith AJ, Rippin JW, Harrington E (1994b). The distribution and severity of tooth wear and the relationship between erosion and dietary constituents in a group of children. *Int J Paediatr Dent* **4:** 151–157.

Milosevic A, Dawson LJ (1996). Salivary factors in vomiting bulimics with and without pathological tooth wear. *Caries Res* **30:** 361–366.

Moazzez M, Smith BGN, Bartlett, DW (2000). Oral pH and drinking habit during ingestion of a carbonated drink in a group of adolescents with dental erosion. *J Dent* **28:** 395–397.

Oilo G, Dahl BL, Hatle G, Gad A (1987). An index for evaluating wear of teeth. *Acta Odontol Scand* **45:** 361–365.

Rytomaa I, Jarvinen V, Kanerva R, Heinonen OP (1998). Bulimia and tooth erosion. *Acta Odontol Scand* **56:** 36–40.

Smith BGN, Knight JK (1984). An index for measuring the wear of teeth. *Br Dent J* **156:** 435–438.

Smith BGN, Robb ND (1996). The prevalence of tooth wear in 1007 dental patients. *J Oral Rehabil* **23:** 232–239.

Sorvari R, Meurman JH, Alaluusua S, Frank MR (1994). Effect of fluoride varnish on enamel in vitro. *Caries Res* **28:** 227–232.

West NX, Hughes JA, Parker DM, Newcombe RG, Addy M (1999). Development and evaluation of a low erosive blackcurrant juice drink. 2. Comparison with a conventional blackcurrant juice drink and orange juice. *J Dent* **27:** 341–344.