



The prevalence of dental erosion in a United States and a United Kingdom sample of adolescents

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Abstract

Purpose: A high prevalence of tooth surface loss due to erosion is well recognized in the United Kingdom (UK), but not in the United States (US). This could be due to prevalence or perception or a combination of both. The aim of this study was to measure the prevalence of erosion of the upper permanent incisors in US and UK samples of 11-13 year old children.

Methods: Convenience samples of 129 subjects were examined in the US and 125 in the UK by two trained examiners. The palatal and buccal surfaces of the upper permanent incisors were assessed for the presence of erosion. Subjects also completed a questionnaire investigating any association between the presence of erosion and possible etiological factors.

Results: The prevalence of erosion was 41% in the US and 37% in the UK samples, this difference was not statistically significant. Similarly no statistically significant difference was found between the sexes. The erosion present was confined to enamel in the vast majority of subjects. The questionnaire did not detect any link between the presence of erosion and possible etiological factors.

Conclusion: The results of this study suggest that dental erosion is common in both US and UK adolescent populations. There is a need for a larger study to investigate this issue further. (*Pediatr Dent* 22:505-510, 2000)

Tooth surface loss or tooth wear can arise as a result of erosion, abrasion, and attrition.¹ Erosion is the loss of dental hard tissue by a chemical process, which does not involve bacteria.² Abrasion is the pathological wearing away of tooth substance by a foreign body independent of occlusion. Attrition is the loss of tooth substance as a result of tooth to tooth contact. Accepting that these processes are not seen in isolation, history and clinical appearance can lead to the identification of the predominant etiological cause of tooth surface loss.^{1,3,4} Teeth affected by erosion become rounded, lose their surface characterisation, and any restorations present become proud. Once dentine is exposed, "cupping" of "lesions" on occlusal surfaces may be seen. Figures 1 and 2 present an example of erosion of the upper permanent incisors in a 12-year-old British boy. In the case of attrition, wear will occur evenly and only on surfaces in tooth to tooth contact. Figures

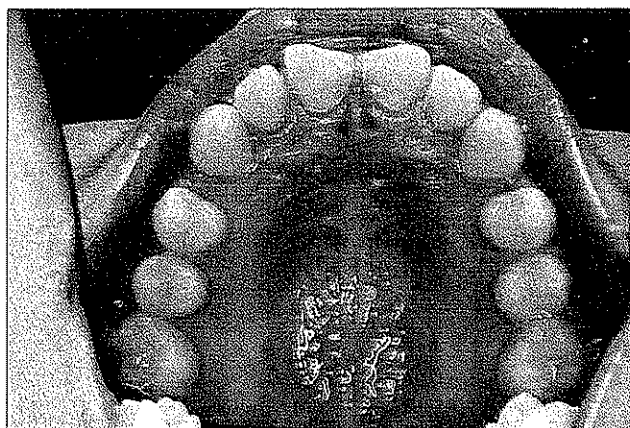


Fig 1. An example of erosion of the palatal surfaces of the upper permanent incisors.

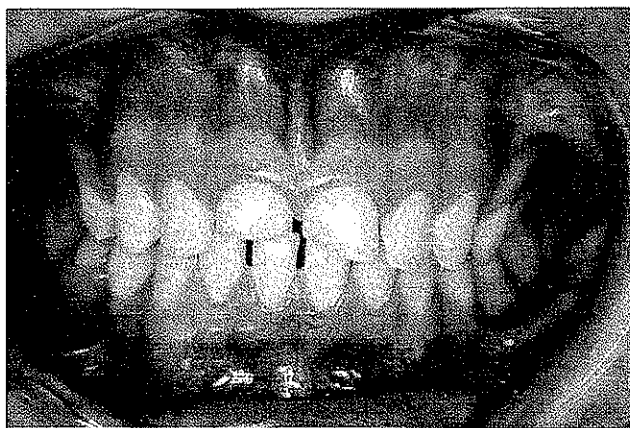


Fig 2. An example of erosion of the buccal surfaces of the upper permanent incisors (same subject as Fig 1).

3 and 4 present examples of abrasion and attrition, respectively, for comparison.

There is concern regarding an apparent increase in the prevalence of erosion in children and adolescents in the United Kingdom (UK) and other European countries, while data is not available on the prevalence of erosion in these age groups in the United States (US).^{5,6} The only data for the United States

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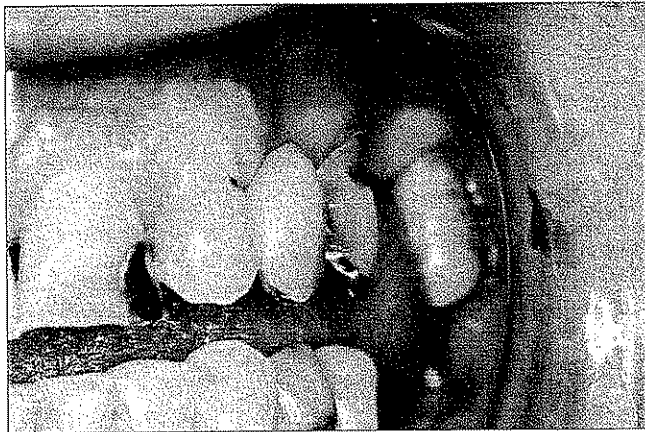


Fig 3. An example of abrasion at the cervical region of these teeth.

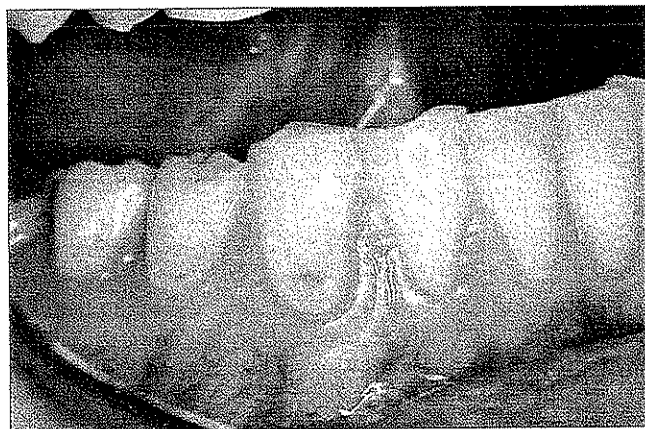


Fig 4. An example of attrition effecting the incisal/occlusal surfaces of these teeth. Please note there is probably an erosive and abrasive component to the tooth surface, as seen on the labial surfaces.

available is for adults reporting a prevalence of approximately 25% of teeth examined to have evidence of erosion, however this paper actually examined the prevalence of cervical abrasion cavities rather than true erosion.⁷ Anecdotally, it has been suggested that erosion is far less common in children and adolescents in the US than the UK. The differences may be real or may reflect differences in awareness of the condition. The 1993 UK Survey of Child Dental Health in the United Kingdom, the first UK survey to assess erosion on a National basis, reported 27% of 12-year-old children to have erosion of the upper incisors of the palatal surface.⁸ Erosion is thought to have a multi-factorial aetiology including host and environmental factors. The principal causes of erosion are presented in Table 1.⁹⁻¹¹

The aim of this project was to assess and compare the prevalence of dental erosion in US and UK samples of adolescents. A subsidiary aim was to investigate any relationship between potential etiological factors and the presence of erosion.

Methods

The subjects consisted of convenience samples of adolescents (age 11-13 years) attending one school in Perth, Scotland, UK and two schools in Maryland, USA. In the US, one school was in an area with water fluoridation (School 1) and the other in an area without water fluoridation (School 2). The school in the UK was in an area without water fluoridation. Following approval by the relevant ethics committees for the project, the

Table 1. Aetiological Factors Associated with Dental Erosion

| | |
|--------------------------|--------------------------------------|
| Host factors | |
| | Salivary flow and buffering capacity |
| | Acid reflux/regurgitation |
| | Vomiting |
| | • Bulimia/anorexia nervosa |
| Tooth factors | |
| | Acid resistance |
| | Anatomy |
| Extrinsic factors | |
| | Diet |
| | • Acidic beverages |
| | • Acidic foods |
| | Medication |
| | • Vitamin C |
| | Poorly regulated swimming pools |

subjects in the UK were examined in September 1998 and the US sample in April 1999.

A number of tooth wear indices are available for epidemiological studies; however, the one used in the UK National survey was chosen because it allowed comparison with this large national survey.⁸ The buccal and palatal surfaces of the upper incisors are assessed separately for loss of surfaces characteristics, and/or exposure of dentine. The depth and area of loss of tooth tissue was assessed for each tooth - the codes and criteria are presented in Table 2. Training of the examiners (one from the US and one from the UK) consisted of the examination of photographs and discussion of the codes and criteria. Since

Table 2. Tooth Wear Codes and Criteria (After O'Brien, 1995)

| Code | Criteria |
|--------------|---|
| Depth | |
| 0 | Normal |
| 1 | Enamel only, loss of surface characterisation |
| 2 | Enamel and dentine, loss of enamel exposing dentine |
| 3 | Enamel into pulp, loss of enamel and dentine resulting in pulpal exposure |
| 9 | Assessment cannot be made |
| Area | |
| 0 | Normal |
| 1 | Less than one third of surface involved |
| 2 | One third, up to two thirds of surface involved |
| 3 | More than two thirds of the surface involved |
| 9 | Assessment cannot be made |

Table 3. Area and Depth of Erosion by Surface for Each Examiner

| Surface | Site | Examiner | Depth codes | | | | | Area codes | | | | |
|---------|------|----------|-------------|-----|---|---|-----|------------|-----|----|----|-----|
| | | | 0 | 1 | 2 | 3 | 9 | 0 | 1 | 2 | 3 | 9 |
| B | UK | 1 | 305 | 135 | 0 | | 60 | 305 | 111 | 14 | 10 | 60 |
| | | 2 | 320 | 119 | 0 | | 60 | 320 | 100 | 16 | 4 | 60 |
| | USA | 1 | 278 | 113 | 0 | | 125 | 278 | 109 | 4 | 0 | 125 |
| | | 2 | 297 | 93 | 0 | | 126 | 296 | 94 | 2 | 0 | 124 |
| P | UK | 1 | 359 | 136 | 0 | | 5 | 359 | 82 | 27 | 27 | 5 |
| | | 2 | 336 | 158 | 2 | | 4 | 336 | 105 | 39 | 16 | 4 |
| | USA | 1 | 325 | 181 | 2 | 1 | 7 | 326 | 158 | 25 | 0 | 7 |
| | | 2 | 351 | 155 | 3 | 1 | 6 | 351 | 150 | 9 | 0 | 6 |

there was a gap of several months between the UK and US examinations, before embarking on the US examinations the two examiners discussed the criteria and viewed the photographs again.

Each subject was examined independently by two examiners (CD and MW). The teeth were examined using a medical examination light ("Versatile Light" Daray lighting, Bedfordshire, UK) in the UK and using a battery-operated hand held light source in good natural light in the US. All teeth were examined wet. The palatal surfaces were examined using a size 4 front reflecting dental mirror.

A sub-sample of subjects was examined twice by each examiner to determine intra-examiner reproducibility. The examiners were blind to subject selection and identity for this examination.

A dietary history and reported symptoms of gastroesophageal reflux were elicited prior to the examinations by questionnaire adapted from the interview used by Bartlett et al 1998.¹² The questionnaire addressed issues including the consumption of carbonated, non-carbonated and fruit juice drinks, heartburn, vomiting and acidic taste in the mouth. This

information was then compared to the clinical picture to investigate any relationship to etiological factors.

Tooth surfaces were excluded if they had an orthodontic bracket in place, a large restoration, or dental caries. Possible differences were examined using the Chi-squared test and the Mann-Whitney U test. The reproducibility of the examinations was assessed using the Cohen's kappa statistic.

Results

In the US, 129 of the 226 (57%) subjects invited to participate were examined. This consisted of 102 from School 1 and 27 from School 2. Fifty-eight of these subjects were male and 71 were female. In the UK sample, 125 (50%) invited were examined, comprising 51 males and 74 females. Table 3 presents the area and depth of erosion by site, surface and examiner. The results for the prevalence of erosion are presented where both examiners agreed that erosion was present on the same surface. The prevalence of erosion was 41% in the US subjects and 37% in the UK. This erosion was confined to enamel in all but one of the US subjects. There was no statis-

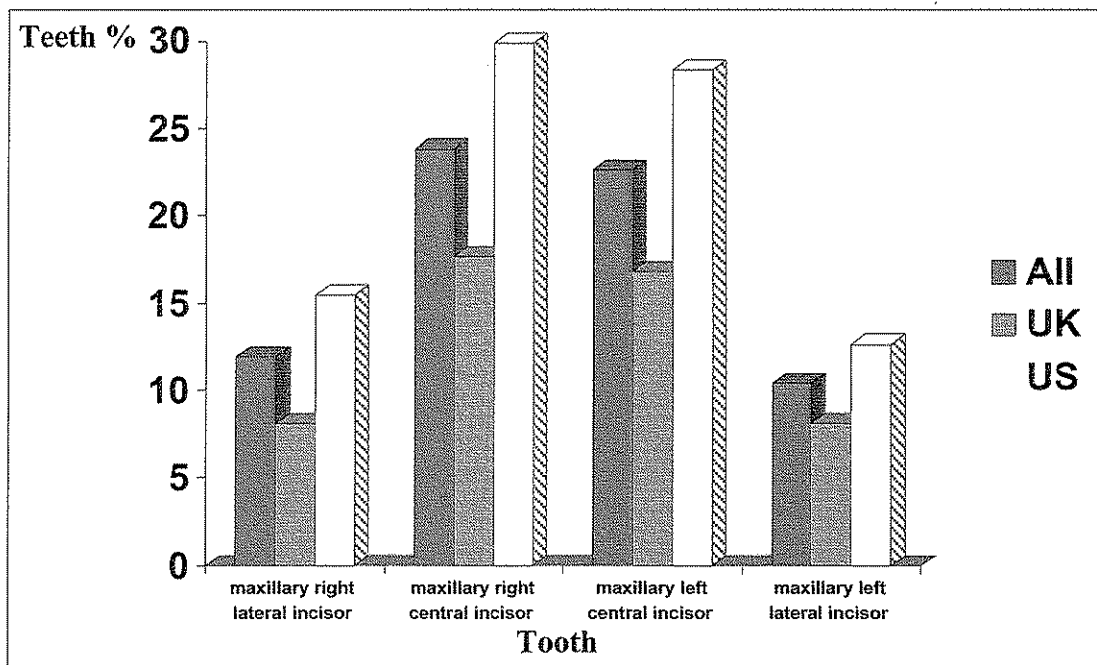


Fig 5. The prevalence of erosion by tooth for the buccal surfaces of the upper permanent incisors N=254 subjects.

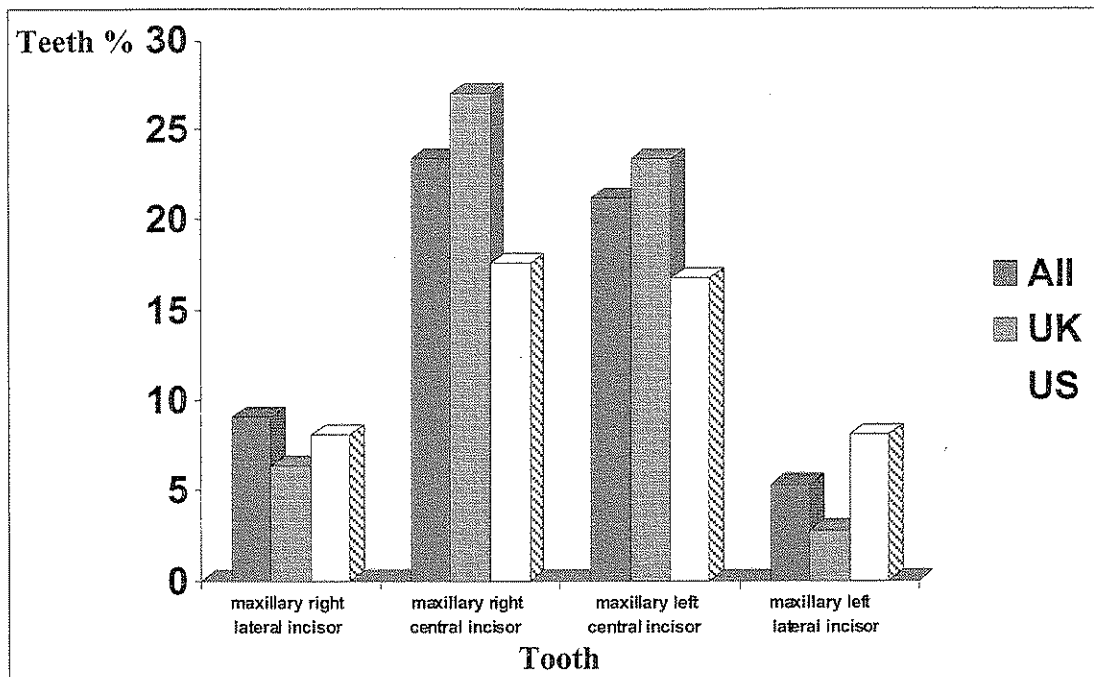


Fig 6. The prevalence of erosion by tooth for the palatal surfaces of the upper permanent incisors N=254 subjects.

tically significant difference between the prevalence of erosion in the US or UK samples.

Similarly, no statistically significant differences in the prevalence of erosion by sex were found. Table 4 presents the prevalence of erosion by sex for the two samples.

Figures 5 and 6 present the prevalence of erosion by tooth for the buccal and palatal surfaces respectively.

As both examiners saw all subjects the sample size for assessment of inter-examiner reproducibility was 100%. Eleven percent of the sample was re-examined by both examiners to determine intra-examiner reproducibility in the US and the equivalent figure was 17% in the UK. Table 5 presents the reproducibility of the examinations. These values represent "fair agreement" in the case of the inter-examiner reproducibility in the UK and at least "moderate" agreement for the other comparisons.¹³

Table 4. Prevalence of Erosion by Sex (%)

| | Perth, UK | Maryland, US | Overall |
|---------|-----------|--------------|---------|
| Males | 45.1 | 39.7 | 42.2 |
| Females | 31.1 | 40.8 | 35.9 |

Table 5. The Reproducibility of the Examinations (Cohen's kappa)

| | Perth, UK | Maryland, US | Overall |
|----------------|-----------|--------------|---------|
| Inter-examiner | | | |
| | 0.39 | 0.61 | 0.51 |
| Intra-examiner | | | |
| Examiner 1 | 0.65 | 0.50 | 0.58 |
| Examiner 2 | 0.62 | 0.59 | 0.62 |

Note that the examiners cannot be identified from this table.

It was hoped to investigate the hypothesis that residence in a fluoridated area helped reduce the prevalence of erosion. Unfortunately, the small number volunteering at the school in the non-fluoridated community (27 subjects) rendered meaningful analysis of this hypothesis impossible.

One hundred and twenty nine questionnaires were returned in the US and 162 in the UK. However, in the UK only 125 of the subjects returning questionnaires were available or consented to examination. No association between possible etiological factors addressed in the questionnaire and the presence of erosion was found. Table 6 presents the results for all the returned questionnaire for the two samples separately. The results indicate that there were some differences in the prevalence of potential etiological factors between the UK and US samples.

Discussion

The results of this study suggest that erosion is as prevalent in the US as in the UK among adolescents. The prevalence of erosion in this Perth, UK, sample is slightly higher than that reported for the UK national sample in 1993. Possible reasons for this include sampling variation, or regional variation, there being reason to believe that erosion is more prevalent in Scotland.⁸ Comparison with other studies is difficult because of the different indices used, but the prevalence reported appears of a similar magnitude.^{12,14}

Regarding the site of erosion, the prevalence on the buccal surfaces was higher than that previously reported - the reason for this is unclear. The low prevalence of erosion extending into dentine is similar to that previously reported. However, it must be noted that for those individuals with extensive erosion, who may suffer sensitivity and pain, a lifetime of restorative dentistry is required, with significant cost implications.¹⁵ Although erosion was confined to enamel in the vast majority of these subjects, at present data is unavailable as to the prognosis for those exhibiting enamel erosion at this age.

Table 6. Subjects' Responses to the Questionnaire of the Potential Aetiological Factors Questionnaire.

| Question | Perth, UK | Maryland, US | Statistical significance |
|--|---|---|--------------------------|
| 1. Do you drink carbonated drinks? | Yes= 149 No= 13 | Yes= 120 No= 7 | n.s. |
| 2. Do you drink fruit/still (non-carbonated) drinks? | Yes= 160 No= 2 | Yes= 117 No= 10 | $P<0.005$ |
| 3. Do you eat fresh fruit regularly? | Yes= 126 No= 36 | Yes= 101 No= 25 | n.s. |
| 4. Do you eat spicy foods? | Yes= 76 No= 85 | Yes= 79 No= 45 | $P<0.05$ |
| 5. Do you have heartburn? | Frequently= 4 Rarely=35 Never = 89 Don't know=27 | Frequently= 3 Rarely= 37 Never =74 Don't know= 9 | n.s. |
| 6. Do you have regurgitation? | Frequently= 5 Rarely= 67 Never = 66 Don't know= 18 | Frequently= 1 Rarely= 37 Never = 70 Don't know= 15 | $P<0.05$ |
| 7. Do you vomit? | Frequently= 3 Rarely= 124 Never = 26 Don't know= 4 | Frequently= 1 Rarely= 96 Never = 24 Don't know= 4 | n.s. |
| 8. Do you have stomach ache? | Frequently= 23 Rarely= 117 Never = 15 Don't know= 5 | Frequently= 5 Rarely= 106 Never = 13 Don't know= 2 | $P<0.05$ |
| 9. Do you wake with a sour taste? | Frequently= 7 Rarely= 34 Never = 105 Don't know= 13 | Frequently= 7 Rarely= 46 Never = 73 Don't know= 0 | $P<0.05$ |
| 10. Do you grind your teeth? | Frequently= 10 Rarely= 29 Never = 121 Don't know= 14 | Frequently= 10 Rarely= 51 Never = 66 Don't know= 0 | $P<0.001$ |

Statistical significance indicates a difference in reported behavior/ experience between the US and UK sample. N varies depending on number responding.

The questionnaire study did not identify any causal relationships and this is likely because of the relatively small sample size.¹⁴ Statistically significant differences between the reporting of potential causal factors of erosion were found between the US and UK samples and indicated a higher prevalence of those factors in the UK sample. The questionnaire was adapted from an interview, some of the questions being fairly complex. The subjects did not report or appear to experience any difficulties completing the questionnaire. However, the relatively high number of don't knows to the questions investigating "heartburn" (13% of responses) and "regurgitation" (12% of responses) may reflect lack of familiarity with these terms.

In the UK carbonated drink consumption has been implicated as a major cause of erosion.¹⁴ Since carbonated drink consumption per capita is higher in the US than UK, it would be expected that erosion would also be more prevalent if there was a simple (linear) cause and effect relationship. Reasons which have been proposed to explain why erosion is not prevalent in the US, include the lower temperature that drinks are consumed in the US compared to the UK, resulting in less titratable hydrogen ions and therefore less erosive potential. It

is also suggested that the more frequent use of drinking straws in the US, if these are placed to the back of the mouth, causes less fall in pH and protects the incisor teeth.¹⁶ Whether these factors are of importance, the initiation and progression of erosion is multi-factorial, host factors (Table 1) such as the buffering capacity of the saliva being one important factor.^{17,18} It may be that there is a specific group of individuals in any population who are susceptible to erosion. If so, attempts should be made to develop an erosion risk model in order to identify these susceptible groups and assist in targeting preventive measures prior to significant loss of tooth tissues.

Recognised preventive and treatment regimes exist to address the care of those with erosion.^{5,19} The key to any treatment is the identification of the etiology.

The high prevalence of erosion in US populations has not been recognised or reported previously. This is difficult to explain, but G.V. Black stated in 1908 that once aware of erosion a practitioner will see it in many patients, therefore it may be simply an issue of recognition.²⁰ This is one of the reasons why in this study the authors opted to use two examiners, one from the US and one from the UK, thus reducing bias from prejudice of perceived disease prevalence.

One potential design-flaw in the present study was the use of different illumination at the UK and US examinations. Although this is not ideal, it has been demonstrated for caries diagnosis and identification of sealants that provided the illumination source is adequate it is not of critical significance.^{21,22}

While erosion studies have often used one examiner, the present study had the advantage of using two and a subject was assigned to the erosion group only when both examiners were in agreement. The initial stages of erosion are difficult to diagnose and relatively subjective, therefore the inter-examiner reproducibility can be relatively low.⁸ In the present study the figures for both inter-examiner and intra-examiner reproducibility were high compared to the UK national study. The inter-examiner kappa of 0.39 for the examination in Perth is low. However, because both examiners were required to have agreed on the presence of erosion this does not weaken the conclusions drawn for the prevalence data. Indeed, this methodology would tend to lead (if anything) to an under reporting of the prevalence of erosion.

Conclusion

There is a need for a larger study to confirm the findings of this study. Such a study would help identify if erosion is a public health issue in the US. There is also an urgent need to confirm the etiological factors and more importantly protective factors.

The results of this study suggest that dental erosion of enamel is common in both US and UK adolescent populations.

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References

1. Smith BGN, Knight JK. A comparison of tooth wear with aetiological factors. *Brit Dent J* 157: 16-19, 1984.
2. Pindborg JJ. Pathology of the dental hard tissues. 1st Edition. Copenhagen, Munksgaard, 1970.
3. Eccles JD. Erosion affecting the palatal surfaces of upper anterior teeth in young people. *Brit Dent J* 152: 375-78, 1982.
4. Ibbetson, R. Eder, A. Tooth surface loss: Editors' introduction. *Brit Dent J* 186:60, 1999.
5. Nunn, J. Shaw, L. Smith, A. Tooth wear – dental erosion. *Brit Dent J* 180:349-52, 1996.
6. 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 Res* 33: 81-87, 1999.
7. Xhonga FA, Valdmanis S. Geographic comparisons of the incidence of dental erosion: a two centre study. *J Oral Rehab* 10: 269-77, 1983.
8. O'Brien M. Children's Dental Health in the United Kingdom, 1993. London : OPCS. HMSO.
9. Milosevic, A. Tooth wear: An aetiological and diagnostic problem. *Eur. J. Prosthodont. Rest. Dent.* 1:173-78, 1993.
10. Kelleher M and Bishop K. Tooth surface loss: an overview. *Brit Dent J* 186: 61-66, 1999.
11. Zero DT. Etiology of dental erosion – extrinsic factors. *Eur J Oral Science* 104: 162-77, 1996.
12. Bartlett, DW. Coward, PY. Nikkah, C. Wilson, RF. The prevalence of tooth wear in a cluster sample of adolescent schoolchildren and its relationship with potential explanatory factors. *Brit Dent J* 184:125-29, 1998.
13. Landis RJ Koch OG. The measurement of observer agreement for categorical data. *Biometrics* 33: 159-74, 1977.
14. Milosevic, A, Young PJ, Lennon MA. The prevalence of tooth wear in 14-year-old schoolchildren in Liverpool. *Community Dent Health* 11: 83-86, 1994.
15. Hussey, DL. Irwin, CR. Kime, DL. Treatment of anterior tooth wear with gold palatal veneers. *Brit Dent J* 176: 422-25, 1994.
16. Edwards, M. Ashwood, RA. Littlewood, SJ. Brocklebank, LM. Fung, DE. A videofluoroscopic comparison of straw and cup drinking: the potential influence on dental erosion. *Brit Dent J* 185:244-49, 1998.
17. Hall, AF. Buchanan, CA. Millett, DT. Creanor, SL. Strang, R. Foye, RH. The effect of saliva on enamel and dentine erosion. *J of Dent* 27:333-39, 1999.
18. O'Sullivan EA, Curzon MEJ. Salivary factors affecting dental erosion in children. *Caries Res* 34:82-87, 2000.
19. Harley, K. Tooth wear in the child and the youth. *Brit Dent J* 186:492-96, 1999.
20. Black GV. A work on operative dentistry in two volumes. Chicago. Medico-dental Publishing Company, 1908.
21. Deery C and Pitts NB. The differentiation of sealant restorations from preventive fissure sealants. In subjects with clear sealants. *Community Dent Health* 9:385-90, 1992.
22. Todd JE and Walker AM. Adult dental health 1968-1978, volume 1. London, OPCS, HMSO, 1978.