DOI: 10.1111/j.1365-263X.2009.00975.x

INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY

The *in vitro* erosive potential of a range of baby drinks

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International Journal of Paediatric Dentistry 2009; 19: 325–329

Objective. The aim of this study was to assess the erosive potential of a range of commercially available baby drinks in the laboratory.

Methods. The erosive potential of each product was assessed by measuring its initial pH, neutralizable acidity, and ability to erode primary and permanent enamel. These parameters were compared to those of an orange juice positive control.

Results. The initial pH of the baby drinks ranged from 3.5 to 4.0 with their neutralizable acidity ranging from 5.76 to 16.02 mL of 0.1 M NaOH. The amount of primary enamel removed following 1-h immersion in the drinks ranged from 3.77 to 8.10 microns, while the amount of permanent enamel removed ranged from 1.09 to 4.86 microns. In comparison, the orange juice control (Tropicana smooth) had an initial pH of 3.86, a neutralizable acidity of 37.0 mL of 0.1 M NaOH, and removed 6.39 microns of primary enamel and 5.32 microns of permanent enamel.

Conclusion. All the baby drinks tested were found to be erosive; some of the products were as erosive as orange juice.

Introduction

During recent years, epidemiological studies[1–5] have revealed disturbing trends in relation to tooth wear in preschool and younger school-age children in the United Kingdom. The dental survey which accompanied the national diet and nutrition survey of children aged 1½ to 4½ years[1] reported that, overall, 10% of children had dental erosion on the buccal surfaces of their maxillary incisors, while 19% had erosion on the palatal surfaces. The prevalence of erosion, however, was noted to increase with age. In the same year, Jones and Nunn[2] reported on the dental health of 3-year-old children in East Cumbria. In this study of 135 children, 39 (28.9%) had one or more maxillary incisors affected by erosion.

Tooth wear in younger school-age children has been investigated in the two most recent national (UK) surveys of children's dental health. In the first of these[3], O'Brien reported that over half of the 5- and 6-year-olds examined had been found to have eroded surfaces on one or more primary incisors. Loss of tooth tissue was greatest on the palatal surfaces of the incisors, with 52% of 5-year-olds and 50% of 6-year-olds affected. These observations were substantiated by a contemporaneous study[4] in which Millward and co-workers found that nearly half of the 178 4- and 5-year-old children examined showed evidence of erosion. The results of the most recent national survey of children's dental health[5] suggest that the situation had changed little in the intervening decade. Here, 20% of 5-year-olds showed evidence of tooth wear on the buccal surface of one or more maxillary primary incisors. The palatal surface was again the most commonly affected site, with over half (53%) of children affected.

Acidic drinks, in the form of baby juices, are introduced into a child's diet at weaning. However, despite the fact that the prolonged misuse of baby juices has been shown to give rise to extreme destruction of dental hard tissue[6], their erosive potential has not been characterized.

The objective of this study was to compare a range of commercially available baby drinks with orange juice, the hypothesis being that the former would not be more erosive than the latter.

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Table 1. Contents of test and control products.

Product	Contents
Heinz Apple and Blackcurrant	Apple juice (97%), blackcurrant juice (3%), vitamin C (minimum of 15 mg/100 mL)
Heinz Pear	Pear juice, vitamin C (minimum of 15 mg/100 mL)
Cow & Gate Pear and Peach	Fruit juice from concentrate (peach, pear 68%), water, vitamin C
Cow & Gate Summer Fruits	Fruit juice from concentrate (75% apple, cherry, strawberry, blackcurrant, raspberry), water, vitamin C
Cow & Gate Tropical Fruits	Fruit juice from concentrate (75% apple, apricot, passion fruit, orange, pineapple), water, vitamin C
Tropicana (Smooth) orange juice	100% pure squeezed orange juice

Manufacturers' details:
H.J. Heinz Co. Ltd, Hayes, Middlesex, UK.
Cow & Gate, White Horse Business Park, Trowbridge, Wiltshire, UK.
Tropicana UK Ltd, PO Box 6642, Leicester, UK.

Materials and methods

The test and control drinks and their ingredients, as stated on the manufacturers' labels, are listed in Table 1. Products were chosen on the basis of their ready availability in the United Kingdom. The erosive potential of each drink was assessed by measuring its initial pH, neutralizable acidity, and ability to remove enamel *in vitro*.

Measurement of initial pH

The initial pH of each drink was measured using a digital pH meter (Hanna Instruments, Woonsocket, RI, USA). At the start of each session, the electrode was calibrated using test solutions of known pH (Hanna Instruments). Twenty millilitres of each freshly opened drink was placed in a glass beaker on a thermostatically controlled electric hotplate at 37 °C. Before reading its pH, each sample was agitated (using a magnetic stirrer) for 1 min. Each drink was tested three times to give a mean measurement. Between readings, the electrode was rinsed in distilled water to ensure that no cross-contamination occurred.

Measurement of neutralizable acidity

The neutralizable acidity of each drink was measured by placing 20 mL of the product in a glass beaker placed on a thermostatically controlled electric hotplate at 37 °C. Then, 0.1 M sodium hydroxide solution was gradually pipetted into the beaker until the pH reached neutrality. Each sample was stirred continuously. The volume of sodium hydroxide required to increase the pH of the sample to neutrality was recorded; this process was repeated three times for each drink to give a mean measurement.

Measurement of enamel loss in vitro

All measurements of enamel loss were made using profilometry according to the method of West *et al.*[7]. Specimens of primary enamel were derived from recently extracted, caries-free, primary canines. These were collected from children of either gender who were undergoing their extraction for relief of crowding. The source of permanent enamel was extracted unerupted third molar teeth. At the time of extraction, donors were resident in areas where the water supplies contained less than 0.3 ppm fluoride. However, details of previous residence were not available, and it is also likely that fluoride-containing toothpastes were being used. Thus, the level of fluoride incorporation into enamel was anticipated to be low, but was not further characterized.

Following extraction, each tooth was carefully scraped of any remaining tissue with a scalpel. It was then rinsed in copious amounts of distilled water. Finally, the crown was sectioned from the root and cut vertically to produce approximately equal sections of enamel. In order to minimize variation in enamel prism orientation, every attempt was made to cut sections from the same coronal area.

Each section was embedded in a vacuum-formed polyurethane mould filled with a low exotherm epoxy resin (Stycast 1266, Emerson & Cuming, Westerlo, Belgium). When the epoxy resin had cured, the specimen was removed and, using an automatic lapping and polishing unit (Kemet International Ltd, Maidstone, UK), ground to fit a stainless steel jig. This had been specifically constructed to hold the specimen precisely during profilometry and ensure that a stable horizontal platform was maintained. Using abrasive discs of decreasing coarseness (Kemet International Ltd), a smooth, flat area of enamel was exposed, care being taken to remove the minimum amount of tissue. This process was monitored by profilometry, employing a Mitutoyo Surftest SV-2000 [Mitutoyo (UK Ltd), Andover, UK]. After its baseline profile had been recorded in duplicate, each specimen was given a unique reference number, which was recorded on its reverse side in indelible ink. It was then stored in isotonic saline at room temperature in an eppendorf tube marked with the same reference number. Immediately before use, an area of enamel was delineated by placing PVC insulating tape (RF Components Ltd, Corby, UK) over the specimen, leaving a 2-mm-wide zone of hard tissue exposed (an approximate enamel area of 10 mm^2).

Five specimens of enamel were randomly allocated to each product and placed in a large glass beaker with 250 mL of the drink. The beaker was then placed in a thermostatically controlled water bath at 37 °C, and the mixture was stirred for 1 h. Following exposure, the specimens were removed from the drink and rinsed in copious amounts of distilled water. They were subsequently dried and the tapes removed. Profilometry was employed to determine surface enamel loss (in μm) in triplicate. Means were calculated from these triplicate measurements.

Statistical methods

Statistical analysis of the results for pH, neutralizable acidity, and *in vitro* enamel erosion was carried out using one-way analysis of variance and by Tukey's test. The threshold for statistical significance was set at $P < 0.05$.

Results

Table 2 presents the initial pH, neutralizable acidity, and *in vitro* enamel erosion data for all six products. The pH values recorded for each of the test drinks fell in a narrow band of 3.5–4.0 and was similar to the positive control, which had a pH of 3.86.

The neutralizable acidity of the five test drinks ranged from 5.76 to 16.02 mL of 0.1 M sodium hydroxide. In contrast, the neutralizable acidity of the orange juice control was considerably higher (37 mL) and statistically different from that of the baby drinks at the $P < 0.001$ level.

Exposure to the five test drinks resulted in the loss of between 3.77 and 8.1 microns of primary enamel, while exposure to the control product resulted in the loss of 6.39 microns of this tissue. No statistically significant differences were found between products.

Table 2. Initial pH and neutralizable acidity of, and *in vitro* enamel erosion produced by exposure to test and control products (standard deviation in parentheses).

Baby drink	pH	Neutralizable acidity (mL)	Permanent enamel erosion (μm)	Primary enamel erosion (μm)
Heinz Apple and Blackcurrant	3.5 (0.01)	16.02 (0.33)	4.86 (1.96)	8.1 (1.78)
Heinz Pear	3.9 (0.01)	11.35 (0.05)	1.09 (0.31)	5.51 (1.37)
Cow & Gate Pear and Peach	4.0 (0.01)	5.76 (0.04)	3.92 (1.01)	3.77 (0.52)
Cow & Gate Summer Fruits	3.68 (0.04)	9.27 (0.21)	3.83 (1.05)	7.43 (1.68)
Cow & Gate Tropical Fruits	3.66 (0.05)	7.41 (0.06)	2.99 (2.06)	6.76 (1.40)
Tropicana (smooth) orange juice	3.86 (0.05)	37.0 (1.10)	5.32 (0.44)	6.39 (2.55)

Manufacturers' details:
H.J. Heinz Co. Ltd, Hayes, Middlesex, UK.
Cow & Gate, White Horse Business Park, Trowbridge, Wiltshire, UK.
Tropicana UK Ltd, PO Box 6642, Leicester, UK.

Exposure to the five test drinks resulted in the loss of between 1.09 and 4.86 microns of permanent enamel, while exposure to the control product resulted in the loss of 5.32 microns of this tissue. The amount of erosion attributable to exposure to the pear drink was statistically significantly less than that recorded following exposure to all other products tested.

Discussion

When predicting erosive potential, it is important to assess not only initial pH but also neutralizable acidity[8]. The initial pH of all the baby drinks tested in this study fell within a narrow range, but consistently below that considered to be the threshold for the initiation of erosion (4.5)[9]. Their neutralizable acidity, however, was variable, presumably because of differing levels of citric, lactic, and malic acids. At less than 20 mL of 0.1 M sodium hydroxide, however, these neutralizable acidity values are comparable with those of many other products that have previously been tested such as alcopops[10,11], ciders[12], and white wines[13].

When considering permanent enamel, the amount of tissue loss produced by the baby drinks was of the order of 1–5 microns over 1 h. This is similar to the amount of tissue loss produced by previously tested drinks[10–13]. That the exposure of primary enamel to these products resulted in more tissue loss should not be surprising as previous studies have shown that primary enamel is eroded more quickly than permanent enamel[14,15].

The erosion results of this *in vitro* study must be interpreted with a certain degree of caution, as they will tend to overestimate the amount of enamel lost compared to the clinical case. First, *in vivo* the enamel surface will be covered by a protective pellicle and/or plaque layer. In addition, all of the drinks tested contain significant amounts of naturally occurring organic acids which will stimulate salivary flow once they are introduced into the mouth. The resultant flushing and buffering effects of the increased salivary flow will help counteract the erosive effects of these products.

The method for assessing enamel erosion can also be criticized, as the contact time between the enamel and the baby drinks was 1 h. However, many of these products will be used in feeding bottles which will maximize the contact time between the product and the oral tissues. Therefore, contact times of an hour, or even more, may be more realistic than initial examination of the method would suggest.

Whereas statistical conclusions should be viewed with caution in the light of the small sample size employed, this study has found that the baby drinks tested are potentially erosive. While, as a profession we should continue to advise that milk or water should constitute the majority of the total drinks given to infants[16], we know that, in certain groups, erosive fruit-based drinks tend to be introduced at a very early age, thereby increasing the time over which primary teeth are exposed to them[17]. Product modification to facilitate a reduction in erosive potential would clearly be a practical way of minimizing the risk associated with baby drinks, but the ability of manufacturers to respond is constrained by government and EU recommendations[18,19].

What this paper adds

- This paper provides new data to characterize the erosive potential of baby drinks commonly available in the United Kingdom.

Why this paper is important to paediatric dentists

- The information which this study has produced will be of use to clinicians when providing preventive advice for parents of children who consume these and similar baby drinks on a regular basis.

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