

Dental erosion associated with soft-drink consumption in young Saudi men

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This study reports on the causative factors of dental erosion in selected high- ($n = 19$) and low-erosion ($n = 19$) subgroups of a larger random sample ($n = 95$) of young male Saudi military inductees. By means of a questionnaire, the role of various possible factors related to oral health in general, and to dental erosion in particular, was assessed for each participant. Clinical examination included recordings of severity of dental erosion and fluorosis, presence of buccal cervical defects and first permanent molar 'cuppings', DMFT and DMFS, visible plaque index, and gingival bleeding index. In addition, bitewing radiographs, study casts, and intraoral color transparencies were obtained for each individual. Logistic regression analysis showed a strong correlation between the presence of dental erosion and a high level of consumption of cola-type soft drinks. Other statistically significant associated factors, although of less predictive strength, were type of cleaning aid and gingival bleeding index. In subgroup comparisons, dental problems (primarily pain), number of buccal cervical defects, and number of missing teeth were significantly greater in the high- than in the low-erosion subgroup. □ *Beverages; food habits; military personnel; oral hygiene; tooth erosion*

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Dental erosion is defined as a non-bacteriogenic, acid-induced loss of the surface tooth structure (1), and its etiology, as with other forms of tooth wear, is multifactorial (2-6). Factors that have been implicated as being etiologic in, and associated with, the process of erosion include dietary factors (acidic substances) (7-12), systemic diseases (such as gastric conditions and eating disorders) (13-18), salivary factors (buffer capacity, secretion rate, mucin content, and variations in calcium ion concentration) (9, 19, 20) and occupational exposure (for example, industrial chemical plants (21-24).

Dental erosion was a common feature in ancient populations (25), and it remains prevalent in modern societies (1, 26-28). Epidemiologic studies have reported large differences in prevalence, ranging from a few percentages (1) to 60% (26); apart from sample variations, the differences reported are also likely to have been due to different evaluation criteria and assessment methods applied. The evident lack of consensus in observations on dental erosion continues, with the proceedings of a recent workshop concluding that data on dental erosion remain fragmentary and that there is a definite need for more research in this field (29).

In a previous study of young male Saudi military inductees we reported a high prevalence of dental erosion together with an excessive intake of cola-type soft drinks (30). The specific aim of this study was to analyze the relative contributions of various etiologic factors involved

in dental erosion by means of statistical testing of several variables in selected high- and low-erosion subgroups of the aforementioned sample.

Materials and methods

Population

The study population comprised two subgroups, each of which had been extracted from an original sample of 95 inductees (age: \bar{x} , 20.9 years; range, 19-25 years) randomly selected from the Military Academy, Riyadh, Saudi Arabia (30). Subgroup inclusion criteria were those of the 95 individuals with the lowest (low-erosion subgroup, $n = 19$; \bar{x} , 20.4 years; s , 1.0) and those with the highest erosion indices (high-erosion subgroup, $n = 19$; \bar{x} , 20.9 years; s , 1.2).

Questionnaire

A bilingual questionnaire (Arabic and English) was completed for each participant to assess the role of various possible factors related to oral health in general and to dental erosion in particular. The questionnaire included questions on types of food and beverages consumed and number of daily meals and between-meal sweets and drinks. In addition, general health conditions, medication intake, symptoms of temporomandibular disorders

Table 1. Ordinal scale used for grading severity of dental erosion on buccal and lingual surfaces of maxillary anterior teeth

Grade	Criteria
0	No visible changes. Development structures remain. Macromorphology intact.
1	Smoothened enamel. Developmental structures have totally or partially vanished Enamel surface is shiny, matte, irregular, 'melted', rounded or flat. Macromorphology generally intact.
2	Enamel surface as described in grade 1. Macromorphology clearly changed. Facetting or concavity formation of the enamel. No dentinal exposure.
3	Enamel surface as described in grade 1 and 2. Macromorphology greatly changed (close to dentinal exposure of large surfaces).
4	or Dentin surface exposed $\leq 1/3$. Enamel surface as described in grades 1, 2, and 3. Dentin surface exposed $>1/3$. or Pulp visible through the dentin.

Note: Approximal erosion and presence of 'shoulder' should be recorded.

(TMD), parafunctional habits and oral hygiene activities, subjective complaints, and the subject's perceived need for dental treatment were recorded. A professional translator, who was trained in the use of the questionnaire, performed the interview and completed the questionnaire for each of the participants. The principal investigator (A.-K. Johansson) checked the completed questionnaire for accuracy at the end of each investigation day.

Clinical examination

All clinical investigations were performed by the principal investigator (A.-K. Johansson). Recordings were made of severity of dental erosion, number of buccal cervical defects, visible plaque index (VPI), gingival bleeding index (GBI), DMFT, DMFS, and severity of dental fluorosis. A radiographic examination of four bitewing radiographs was also carried out. Third molars were excluded from all examinations. Maxillary and mandibular alginate impressions were made (Deguprint, Degussa AG, Hanau, Germany) and cast in hard dental stone (Die-Stone, Miles Inc., South Bend, Ind., USA). After GBI and VPI were recorded, the teeth were meticulously cleaned, which included professional supra-gingival scaling and polishing with prophypaste. The teeth were carefully dried with an air syringe before assessing the severities of fluorosis and erosion and obtaining photographic records. Seven intraoral color transparencies

(maxillary and mandibular occlusal, left and right lateral, frontal, palatal-anterior, and lingual-anterior views) were taken of each individual.

Assessment of dental erosion, buccal cervical defects, 'cuppings', and incisal and occlusal wear

An ordinal scale (Table 1) was applied to the grading of erosion (30, 31). The recordings were performed by one examiner (A.-K. Johansson) after a period of examiner training and calibration with two other investigators (A. Johansson and G. E. Carlsson). After several trials it was apparent that it was difficult to achieve reliable differentiation between the different grades of dental erosion in the case of maxillary and mandibular premolars and molars and also for mandibular incisors. As a result, all premolars and molars and mandibular incisors were excluded, and only maxillary incisors and canines were graded. Owing to a further difficulty of distinguishing between attritional and erosive influences on incisal surfaces, only the buccal and lingual surfaces were graded. The final erosion score was obtained from the combined assessments of clinical grading, study cast examination, and evaluation of intraoral transparencies. To assign a severity of erosion, a mean value index of all graded surfaces was calculated for each individual. The presence of 'shoulders' and/or approximal erosion was also assessed.

Intraexaminer concordance in use of the scale for grading erosion was tested by the examiner (A.-K. Johansson) performing two successive blind assessments after an interval of 2 weeks, on each of the buccal and lingual surfaces of 120 teeth, corresponding to 230 buccal and lingual surfaces (10 surfaces ungradeable) in 20 individuals on a randomly selected and ordered basis. As previously reported, intraexaminer concordance for grading the severity of erosion was 78% (30).

Buccal cervical defects were scored clinically for all the teeth in the dentition and recorded as the total number of defects present per subject. Apart from the requirement of clear demarcation, no distinction between different morphologies of defects was made.

All first molars were assessed for the presence of 'cuppings' (concavities with a 'peephole' of dentin exposed, usually on the cusp tip) from color transparencies and study casts and recorded as the total number of affected teeth per subject.

Evaluation of occlusal and incisal wear was performed on a tooth-by-tooth basis on the study casts by two examiners (A.-K. Johansson and A. Johansson), using an ordinal scale, which has been previously described and applied in a similar population (2). Mean indices for the dentition and for the anterior (canines and incisors) and posterior (premolars and molars) teeth were calculated. In cases of disagreement a final grade was mutually reached. The conditions of examiner calibration, the achievement of examiner concordance, and method reliability have been reported previously (2). A few teeth that were

fractured or had extensive restorations were excluded from evaluations of both the erosion and the occlusal and incisal wear assessments.

Assessment of VPI, GBI, DMFT, DMFS, and dental fluorosis

VPI and GBI (32) were recorded for each tooth at its buccal, mesiobuccal, and lingual aspects. DMFT and DMFS were assessed in three ways: a) in accordance with WHO recommendations (33); b) including radiographically detected approximal caries extending to, or beyond, the amelodentinal junction; and c) including radiographically detected approximal caries extending $\geq 2/3$ of the enamel thickness. Severity of dental fluorosis was graded on a tooth-by-tooth basis using combined clinical and color transparency assessments in accordance with the modified TF index (34).

Statistical methods

A Spearman correlation analysis between erosion (1 = low-erosion subgroup; 2 = high-erosion subgroup) and 112 recorded variables and a Mann-Whitney U-test between the subgroups were performed as the exploratory tests of correlations between factors investigated and severity of erosion.

A logistic regression model was obtained by using the subgroups as the dependent variable. Independent variables were those that could provisionally be judged to have a causative association with the occurrence of erosion on the basis of those that had been found to be significantly correlated in the initial correlation analysis. In addition, those variables that did not show significant correlation in the initial analysis but were considered important in a possible covariational relationship with the severity of erosion were included in the model as further independent variables (35).

Thirty-five independent variables were used in the model. These were related to age; consumption of cola (including cola consumption before enlistment), coffee, tea, juice, water, and yoghurt (milliliters per week); consumption of apples, citrus fruits, dates, grapes, tomatoes, vegetables, hard cheese, and candy (number of intakes or items of fruits, candy per week); oral hygiene habits (type of cleaning aid, duration of cleaning, cleaning technique, frequency, use of toothpaste); systemic diseases (including gastric diseases, dry mouth, acid regurgitation, and vomiting); medication; and parafunctional habits. Clinical indicators included the GBI and VPI index (%) and severity of dental fluorosis. For each of the categoric variables, the regression used the deviation of the last category from the others.

All statistical analyses were performed on an IBM Personal Computer, using the Statistical Package for Social Sciences (SPSS, Release 6).

Results

As expected, the difference in the distribution of erosion scores of all the maxillary anterior teeth between the low- and high-erosion subgroups was clearly evident (Fig. 1A). Mean cola consumption in the low-erosion subgroup (2484 ml/week) was significantly lower than in the high-erosion subgroup (4811 ml/week; $P < 0.01$). Of the 112 variables tested by means of the Spearman test for correlation with severity of erosion, 18 were statistically significant (Table 2). The remaining 94 variables may be summarized as dietary items (such as fruits, vegetables, juices; 41 variables), other questionnaire responses (for example, age, bruxism, biting habits; 6 variables), awareness of oral health (dental problems, perceived treatment need; 9 variables), oral hygiene habits (brushing frequency, dentifrice usage; 7 variables), general health (gastric problems, medication, other illnesses; 12 variables), clinical assessments (such as caries and plaque indices, dental fluorosis; 19 variables).

Those variables that differed significantly between the subgroups were type of cleaning aid used ($P < 0.05$) (Fig. 1B) and cleaning technique ($P < 0.05$) (Fig. 1C), reported dental problems ($P < 0.05$) (Fig. 1D), number of permanent first molars with 'cuppings' ($P < 0.05$) (Fig. 1E), number of buccal cervical defects ($P < 0.01$) (Fig. 1F), and number of missing teeth ($P < 0.05$) (Fig. 1G). GBI was significantly higher in the low- (\bar{x} , 24.8%; s , 13.0; range, 2–46) than in the high-erosion subgroup (\bar{x} , 11.5%; s , 8.7; range, 0–30) ($P < 0.01$). The numerically higher DMFT in the high- (\bar{x} , 12.7; s , 6.3) than in the low-erosion subgroup (\bar{x} , 9.4; s , 5.8) was not statistically significant ($P = 0.13$).

Table 2. Significant variable correlations to subgroups (1 = low erosion, $n = 19$; 2 = high erosion, $n = 19$) in accordance with Spearman correlation analysis (r); significance (sig.), * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Variable	r	Sig.
Beverages		
Pepsi Cola (ml)	0.53	***
Cola (all types; ml)	0.53	***
Pepsi Cola (frequency)	0.52	***
Cola (all types; frequency)	0.51	***
Soft drinks, incl. cola (ml)	0.47	**
Soft drinks + juices (ml)	0.46	**
Soft drinks, incl. cola (frequency)	0.44	**
Soft drinks, incl. cola + juices (frequency)	0.42	**
Questionnaire		
Dental problems	0.34	*
Oral hygiene		
Cleaning technique	0.37	*
Cleaning aid	0.37	*
Clinical assessments		
Wear (dentition)	0.56	***
Wear (anterior teeth)	0.55	***
Gingival bleeding index	-0.54	***
Buccal cervical defects (yes/no)	0.50	***
Buccal cervical defects (no.)	0.49	**
'Cuppings' (first molars)	0.43	*
Wear (posterior teeth)	0.37	*

Table 3. Logistic regression results: regression coefficient (B), standard error (s_x), significance (P), and odds ratio (e^B)

Observed	Predicted		
	Low erosion	High erosion	
Low erosion	16	3	84% (specificity)
High erosion	2	17	89% (sensitivity)
			87% (overall)

Variable	B	s_x	df	P	e^B
Cola consumption	0.001	0.001	1	0.023	1.001
GBI	-0.238	0.113	1	0.035	0.788
Cleaning aid			3	0.163	
Type 1	-0.533	1.252	1	0.670	0.587
Type 2	-3.614	1.748	1	0.039	0.027
Type 3	2.201	1.69	1	0.083	9.031
Constant	-0.792	1.881	1	0.674	

With regard to the use of toothpaste, 10 of those in the low-erosion subgroup reported not using any, and 9 reported occasional or more frequent use; the corresponding figures in the high-erosion subgroup were 5 and 14, respectively, the difference being close to statistical significance ($P = 0.10$). Only use of fluoride-containing toothpaste was reported.

Analysis by logistic regression identified three variables of significance: cola consumption (milliliters per week), GBI, and type of cleaning aid (scale: 0 = no cleaning; 1 = miswaak only; 2 = toothbrush only; 3 = combination of toothbrush and miswaak). The correlations of cola consumption and of type of cleaning aid with the high-erosion subgroup were both positive, whereas the correlation with GBI was negative. With cola consumption entered in the first step in the model, the specificity and sensitivity were 79% and 68%, respectively (overall, 74%), whereas with the GBI entered in the second step, specificity and sensitivity, combined with cola consumption, were 79% and 74%, respectively (overall, 76%). When type of cleaning aid was entered in the third step of the model, the specificity was 84%, and the sensitivity 89% (overall, 87%) (Table 3A, Fig. 2). With regard to the cleaning aid (categorical variable), type 1 represents the deviation of the last category (combination) from the first (no cleaning); type 2 represents the deviation of the last from the second (miswaak); and type 3 represents the deviation of the last from the third category (toothbrush). The significant correlation between severity of erosion and cleaning aid can therefore be attributed to type 2 (that is, deviation of combination from the miswaak) (Table 3B).

Discussion

The representative nature of the sample from which the

present subgroups were extracted has been discussed in our previous paper, with the conclusion that the group of young male military inductees comprising the original random sample ($n = 95$), for the purpose of the present investigation at least, is representative of young Saudi men in general (30). The degree of severity of erosion in the high-erosion subgroup may be illustrated by the finding that no fewer than 66% of the recorded surfaces of the maxillary anterior teeth in this group were graded as 2 or greater (Fig. 1A). Furthermore, this subgroup represents the upper 20th percentile of the total randomly selected sample. In extrapolating this observation to the general population of young Saudi men, the implications for oral health, owing to such a high prevalence and severity of erosion, must be considered very serious. A trend towards increasing prevalences of dental erosion has been shown in some population groups; in several recent reports on its occurrence in English children increasing severities of dental erosion even in the very young have been reported (36–38). Whereas our findings in ongoing studies of Saudi children strongly support this, the need for broader corroboration of this trend is acknowledged.

Soft-drink consumption in the present sample consisted almost exclusively of cola-type soft drinks, with its level of consumption in the high-erosion subgroup being approximately 250 liters per year, as in the previously reported total sample (30). This alarmingly high level of consumption far exceeds that found in most Western countries (39–41) and may be attributable to climatic differences and/or dissimilar lay public dietary awarenesses. In this regard, the extremely hot Saudi climate compared with most other parts of the world must, in part, account for the higher consumption of soft drinks here. The large volume of soft drinks consumed by the study sample would be an important factor in oral health status in general, and the experience of dental erosion in particular. Similar

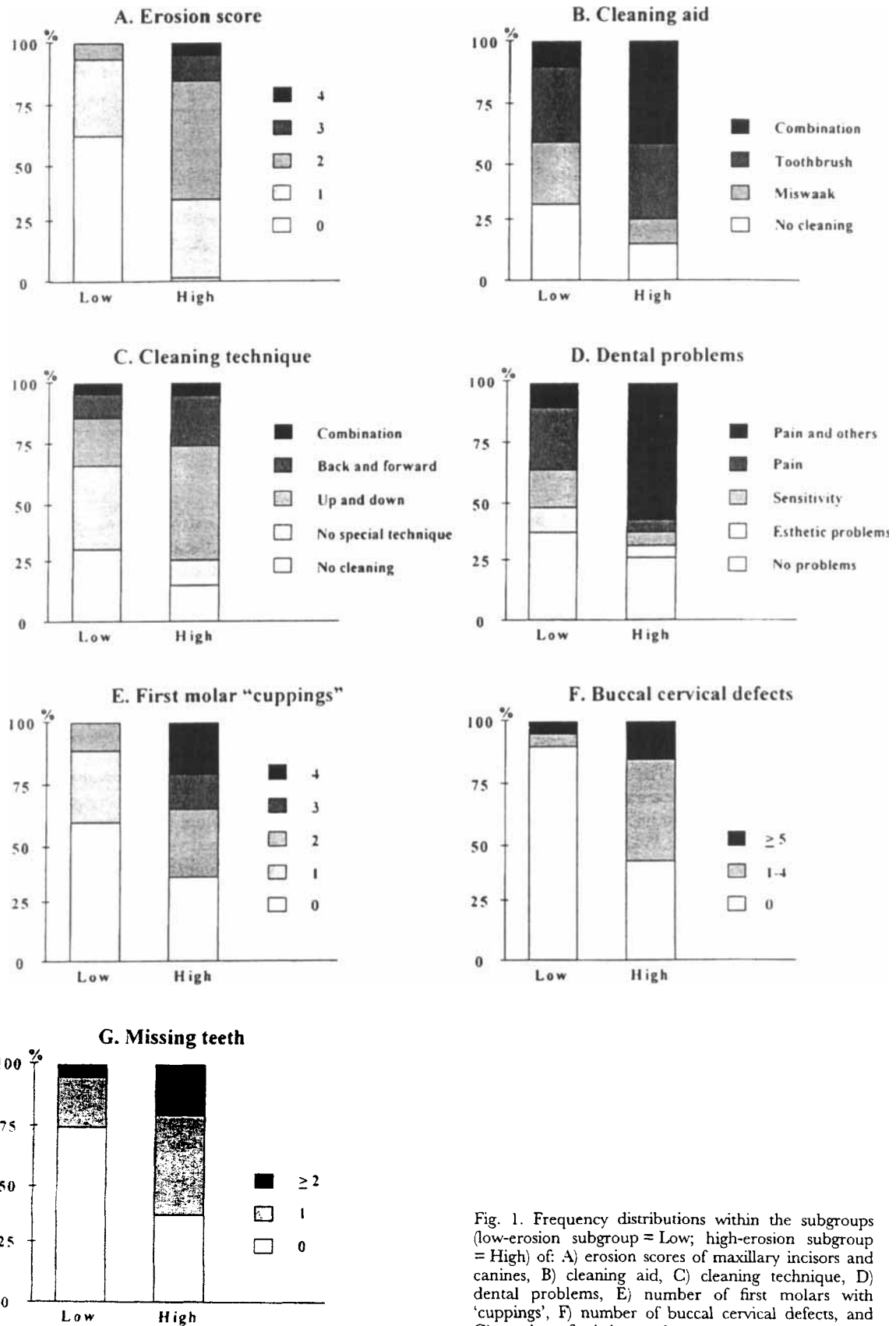


Fig. 1. Frequency distributions within the subgroups (low-erosion subgroup = Low; high-erosion subgroup = High) of: A) erosion scores of maxillary incisors and canines, B) cleaning aid, C) cleaning technique, D) dental problems, E) number of first molars with 'cuppings', F) number of buccal cervical defects, and G) number of missing teeth.

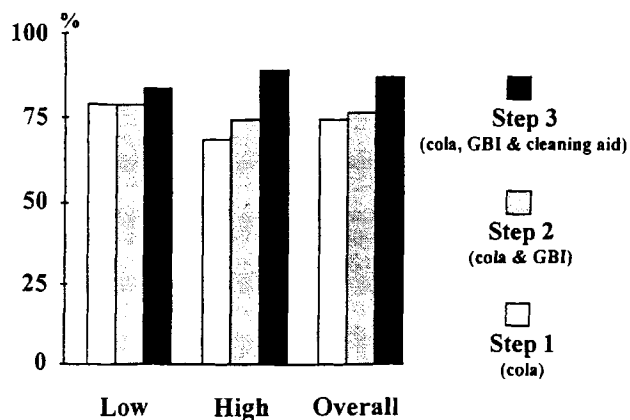


Fig. 2. Percentage increase of correct classification of subjects into low- (Low) or high- (High) erosion subgroups on the basis of the three identified significantly correlated variables in accordance with logistic regression analysis. Cola was entered into the regression as the first variable (step 1), followed by the gingival bleeding index (GBI) (step 2) and type of cleaning aid (step 3).

associations of dental erosion with soft-drink consumption have been shown elsewhere (42–47). In a previous study the population-attributable risk (PAR) for consumption of soft drinks was 26% (48), whereas the present sample's greater levels of cola consumption were a much more significant factor in the development of dental erosion, as is demonstrated by the high specificity and sensitivity of cola alone (overall 74%), derived from logistic regression. Owing to their acidity and high sugar content, the erosive potential of cola-type soft drinks is likely to be associated with both volume and frequency of intake (44, 49). On the other hand, and in view of the observation that high cola consumption was also noted in individuals who did not have severe dental erosion as well as in the total random sample (30), it is clear that host factors, such as variations in salivary factors (2, 9, 19), dental hard-tissue quality, and genetics, may play a 'protective' or 'modifying' role.

The significant correlation between lower GBI and high erosion may be explained by the fact that lower GBI, as a measure of oral hygiene activity, reflects the better oral hygiene of those in the high-erosion subgroup. The mechanical effect of the toothbrush or the commonly used miswaak, on 'chemically modified' (that is, cola acidity) enamel could be a possible explanation of the correlation observed. The type of cleaning aid also played a significant role in the regression analysis, with the high-erosion subgroup reporting significantly more frequent use of the toothbrush and the combination of toothbrush and miswaak; in the low-erosion subgroup 'no cleaning' or the use of the miswaak only was most frequently reported (Fig. 1B). It would seem, therefore, that the use of, and type of, cleaning aid may influence erosion, supporting the contention that mechanical effects may aggravate loss of chemically modified dental hard tissue. In addition, the cleaning technique also differed significantly between the subgroups, with the high-erosion one using fairly regular

techniques or combinations thereof, and the low-erosion subgroup more frequently reporting either 'no cleaning' or 'no special technique' (Fig. 1C).

With regard to the effect of a dentifrice on the development of wear, it has been shown that in vitro daily brushing without a dentifrice induced remineralization of acid-etched enamel by deposition of salivary components, whereas brushing with a dentifrice resulted in abrasion of the weakened enamel (50). In addition, brushing with a non-fluoride dentifrice produced more wear than brushing with a fluoride dentifrice (51). In this regard, the use of toothpaste was considerably more common in the high-erosion subgroup, and, although this difference was not significant, it may have contributed to the observed difference in erosion between the subgroups. In view of the present findings and foregoing discussion, it may be concluded that oral hygiene may exacerbate dental erosion.

We previously reported that one or more buccal cervical defects were found in 25% of the total sample (30); this was considerably higher than in, for instance, 8% of a 26- to 30-year-old Swiss population (27). In the present sample 58% of the individuals in the high-erosion subgroup had such defects compared with only 10% in the low-erosion subgroup. It would seem reasonable to assume that there exists an association between the occurrence of dental erosion and buccal cervical defects, although the extent to which a more vigorous oral hygiene activity per se in the high-erosion subgroup accounts for the 'abrasive' defects needs to be taken into consideration. Moreover, in addition to the commonly held view that toothbrush abrasion and erosion are a cause of such defects, it has been suggested that heavy stressing of the teeth (for example, heavy chewing or bruxism) will result in strain microfractures along the buccal cements/enamel junction, possibly making the area more prone to destruction (52, 53). In this regard, biting habits and bruxism were frequently reported in the random total sample (30), which could, aside from the influence of erosion and/or oral hygiene habits, further explain the high frequency of buccal cervical defects in the high-erosion subgroup. That cervical defects are caused by intensive toothbrushing activity and abrasive dentifrices alone has, therefore, to be questioned, and a multifactorial etiology of cervical defects would clearly be more plausible (54).

A significantly higher number of missing teeth and of reported dental problems, predominantly pain, were found in the high-erosion subgroup. This finding further underlines the coexistence of other negative associations with dental erosion, although the extent to which, directly or indirectly, dental caries is primarily responsible, cannot be overlooked.

In summary, the findings in this study have shown that a strong relationship between severity of dental erosion and consumption of cola-type soft drinks exists. In the light of such incriminatory evidence, it is recommended that the concerned local authorities, in their regular public health notices, should advise the public about the negative

consequences of cola-type soft-drink consumption on oral health in general and on the occurrence of dental erosion in particular. The relevance of such advice to other population groups must, however, be tested.

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