Title: Tooth Enamel Erosion - Clark Township

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Introduction

In September, 1980 Elihu Savad, DDS noted marked loss of tooth enamel in a 12 year old boy. This represented a definite radiographically visible change from previous examinations prior to that summer. New findings included spacing between the upper incisors, an enamel shoulder or ledge at the gingival level, raised amalgams in the molars and apparent thinning of enamel of the bicuspids. Dr. Savad could not identify any known risk factors for enamel erosion, but learned that the patient was on a local swim team which practiced all summer at the Clark Community Pool. During the summer the patient, as well as other pool members had complained of teeth pain and sensitivity after using the pool. Dr. Savad suggested that other children on the swim team be examined. Four other dentists noted roughness, etching, and/or staining of enamel in the swim team members whom they examined. On November 25, P. Richard Wexler, DDS, who was informed of these findings by Dr. Savad, notified Marie Griffin, M.D., Division of Epidemiology, New Jersey State Department of Health. It was decided that she would begin an investigation along with George Yamane, DDS, PhD, Professor and Chairman, Department of Oral Medicine and Radiology,New Jersey Dental School, and William Z. Abrams, DDS, MPH, Coordinator, Dental Health Program, New Jersey State Department of Health.

Background

The Clark Community Pool Association is a public utility established by local ordinance. Township Council members are also members of the utility. The business administrator is responsible for functioning of the pool which includes the purchase of pool chemicals. Clark Township officially adopted the Swimming Pool Code of N.J. - 1970, in October 1980. Prior to adoption of this code there was no routine inspection program for the pool, but the health officer required that the pool submit weekly bacteriologic samples. No inspection of the pool was conducted during the 1980 operating season.

The seven year old Clark pool is Olympic size with a 500,000 gallon capacity. Depth ranges from 2 to 8 feet. Water is obtained from Elizabethtown Water Company. The water is not fluoridated. The pool is chlorinated on a continuous basis with chlorine gas. It is delivered in 150 pound cyclinders as a liquid which reverts to a gaseous state when released. During the operating season, records indicate that pool maintenance including vacuuming, pH and chlorine readings and chemical additions were done daily between 7 and 8 a.m. by the pool manager and his assistant. However, the information recorded was incomplete. At 9:30 a.m. swim team practice and lessons began and between 11:00 a.m. and 8:00 p.m. the pool was open to the general membership.

In July and August petitions signed by pool members were submitted to the pool advisory committee with complaints of eye irritation, rashes and teeth pain associated with swimming in the pool. In early August a chemist from the Rahway Water Department was sent to the pool by the health officer because a request for assistance with a pH problem. On August 2 and 3, the pool was closed for the repair of the two pumps for the main filter. The pump impellers were found to be corroded and were replaced.

Because of concern that the enamel changes seen in swim team members might be connected with use of the Clark Community Pool, an investigation was initiated. Pool records and operating procedures were reviewed, and swim team members, their siblings and controls from a competing swim team were interviewed and examined to identify risk factors associated with the development of enamel changes.

Methods

Pool Inspection - Pool records and operating procedures were reviewed by representatives from the New Jersey State Department of Health Consumer Health Services.

Case Findings - Clark Community Pool swim team members, siblings within six years of their age, and a group of swimmers from acompeting team were contacted from lists obtained from the respective pools and asked to participate in the study. All who agreed to participate were interviewed in person by one of three interviewers using a standardized questionnaire to determine patterns of pool use, reported symptoms associated with use, consumption of citrus fruits, fruit drinks or juices, carbonated beverages, food obtained or eaten at the pools and dental care practices.

All children were examined by a team of two dentists who were not informed to which pool the children belonged.

Case Definitions - Enamel erosion was defined by the following grades, modified from that used in a study on dental erosion in industry (1):

0 - No involvement. The enamel surface may or may not have developmental ridges, but it has a shiney, glazed, transluscent appearance. Roughness of the surface felt to be due to poor hygiene or presence of braces is also classified 0.

1 - Dull ground glass appearance of the enamel surface (etching), with or without pitting, visibly or felt with an explorer.

2 - Obvious loss of enamel.

3 - Loss of enamel so marked that brownish to yellowish dentin shines through.

Each tooth was graded separtely, and charted. The child was assigned the grade given to the most severely affected tooth.

Case Control Studies - Data were analyzed in a case control manner in three ways: 1) Clark pool members with versus those without enamel changes, 2) Clark swim team versus other swim team members, and 3) Clark swim team and siblings versus other swim teams.

Results

Pool Inspection _ The pool facilities and records were examined in March 1981. Daily records contained between 3 and 10 hourly readings for chlorine and pH between 11:00 a.m. and 8:00 p.m. with occasional notations indicating what chemicals were added (but not what quantity). During July 1980, residual chlorine levels ranged from 0.0 to 1.8 ppm with a daily median of 0.6 ppm and pH ranged from 6.6 to 7.2 with a median a 7.0. After the pump repair August 2 and 3, pH ranged from 7.4 to 8.0.

The pool was filled for the winter which precluded looking for structural damage to the pool itself. A plastic barrel, reportedly used to mix and dilute soda ash, which is used to raise pH, was observed as well as two 50 lb. drums of granular chlorine (HTH,Olin), and 3 to 4 gallons of algaecide. No other chemicals were present. Purchase records indicated that soda ash, HTH, and liquid chlorine (delivered in cylinders) had been ordered for the 1980 season. The pool was not stabilized with cyanuric acid nor was a flocculent employed.

Study Group _ Twenty-seven of the 36 (75%) Clark swim team members agreed to participate along with 10 of their non-team member siblins. Five refused or were not available at the time of the study (including the initial case described), and four were never reached. Eleven swim team members from a competing pool agreed to participate. Ages of the Clark Swim team members ranged from 7 ot 17, median 11, ages of siblings ranged from 5 to 17, (median 9.5), and of the other pool team from 8 to 16, median 10 years. Ten of 27 (37%) Clark team members, 3 of 10 (30%) siblings and one of eleven (9,1%) other pool members had Grade 1 or 2 enamel changes. There were no children with Grade 3 changes. All enamel changes noted were on the labial, not lingual surfaces, and involved predominantly the frontal teeth. Changes in Clark pool children involved between one and 30 teeth each, median 6. Grade 2 changes were seen only in four Clark pool members, involving between two and six teeth each. Three of these four children were from a single family. The one child from the other pool with an abnormal exam, had involvement of only one tooth with a Grade 1 change.

Symptoms associated with swimming for the three groups are shown in Table 1. Skin burning and rashes, and teeth pain, sensitivity, and chalkiness were reported only by Clark pool members. Twenty-seven of 37 members of the Clark pool noted the unusual symptoms of teeth pain or sensitivity. It was temporally associated with swimming in the pool and often described as sensitivity to air, hot and cold, or teeth pain when trying to eat. Most of those who complained of teeth pain or sensitivity, also noted a chalky taste in their mouth. Others described a slimey sensation, and/or black or green staining of enamel. Brushing the teeth was reported to get rid of the chalkiness, sliminess, and staining.

No team members from either pool were given citrus fruits or instructed in the use of any special diet as part of training. Dry jello was the only unusual food item used and was often consumed prior to competition for "quick energy." This was eaten by 11 of 27 Clark team members and 6 of 11 other team members.

Case control study 1 - Clark members with enamel changes (n=13) versus those without (n=24) - Changes in enamel were seen in both swim team members and their siblings. There were significant associations (Pearson's correlation coefficients) between enamel changes and hours/week spent in the pool (0.35, p=.03),(Table 2) having complaints of eye irritation (0.38, p=.02), teeth pain (0.32, p=.05)(Table 3) , and the use of a soft rather than a medium bristle tooth brush (0.34,p=.04). Enamel changes were also correlated with increasing age (0.30, p=.06) and increasing number of glasses of fruit juice / drink consumed per week (0.29,p=.08). (Table 4). These last two associations were statistically significant when members were grouped. Erosion was greater in members more that 10 years of age (p=.003, Fisher's Exact Test), and in members consuming more than 20 fruit juices/drinks per week (p=.01, Fisher's Exact Test). A stepwise regression analysis with dental grade as the dependent variable, indicated that increasing hours / week swimming,use of a soft rather than medium brustle tooth brush, increasing average juices consumed, and increasing age, were all independently associated with enamel changes. There were no statistically significant association seen for time of day swimming, swimming with the head under water, getting water in the mouth when swimming, chewing on toothpicks, erasers, pens, or other items, consumption of fruits or carbonated beverages, the number or times/day teeth were brushed or a history of wearing dental braces.

Case control study 2 - Clark team members (n=27) versus other team members (n=11) Clark team members spent more hours/week in the pool than other team members (.47,p=.002). There were no other statistically signigicant correlations measured including chewing on various items, dietary habits, and dental care. An abnormal dental exam was positively correlated with membership on the Clark team (0.27,p=09). Involvement of 4 or more teeth was significantly associated (p=.03, Fisher' Exact Test) with membership on the Clark team.

Case control study 3 - Clark swim members (team and siblings, n=37) versus other team members (n=11)- Significant positive correlations were found between membership in the Clark pool and hours/week spent in the pool (0.4, p=.004), and between membership in the other pool and average number of grapefruit eaten/week (0.33, p=.02). There was also a positive correlation (0.24,p=.09) between abnormal dental grade and membership in the Clark pool. Changes seen in four or more teeth were significantly associated (p=.03, Fisher's Exact Test) with membership in the Clark pool.

DISCUSSION

The term enamel erosion generally implies the loss of tooth substance because of a chemical process, whereas attrition or abrasion connotes a mechanical process. However, it is reasonable to expect that chemical and mechanical factors may interact. The most frequent type of erosion involves localized loss of enamel in the bucco-cervical region, usually of unknown origin (2). The less common generalized loss, similar to what was seen in this study, is usually ascribed to some known acid, such as citrus fruits or juices, acid fumes in industry, or gastric acid from repeated vomiting. Except for the latter, the pattern of lost tooth tissue is in keeping with the external origin of the acid and mainly involves the labial surfaces of incisor teeth (2). Other endogenous factors such as salivary citrate and mucin levels, and pH may also play some role (3).

The first sign of industrial erosion has been described as an etching of the inciso-labial surfaces; the appearance has been likened to that of ground glass. This type of change has been noted after as little as five weeks of exposure to industrial acid fumes. If erosion progresses the dentine, secondary dentine, and pulp may eventually become exposed (1). Similar changes have been ascribed to excessive ingestion of acidic fruit juices, with the classical picture involving loss of tooth substance, hypersensitivity, and amalgams standing up from the general tooth surface because of loss of tooth substance surrounding them (4). Others have described pitting of enamel and the formation of a gingival ridge (a small ledge of unaffected enamel next to the gum line) (5). A case of widespread erosion has been described after excessive ingestion of fruit drinks and juices for a period of three to four months (6).

We should note here that although the enamel loss noted in this study mimics that caused by exogenous acids, most of the children had only grade 1 changes. For the most part, this consisted of a dull, glazed appearance, and is something that could be easily overlooked in a routine dental examination. Whether or not this represents a distinctly unusual finding would require examination of a much larger control group.

The findings reported here must be interpreted with caution because of the small number of individuals involved in the study, the incomplete involvement of both teams (which could have resulted in selection bias), and possible reporting bias by cases dissatisfied with the pool or those who knew of their dental changes prior to enrollment in this study. However, the lack of significant differences in most of the variables tested between the Clark pool members and the other team, and between those with and without enamel erosions lend credence to the results.

The data indicate an association between enamel changes and both membership in the Clark pool and, for members, the average number of hours/weeks spent in the pool. Two case control studies involved comparison of Clark pool team members alone, and then combined with their siblings with the other pool swim team members. In addition to statistically significant differences in dental grade, Clark team members generally spent more average hours/week in their pool than other team members. However, unless swimming in pools in general has some previously unreported deleterious affects on enamel, this difference should not have influenced the results. Despite numerous other variables tested, there were no other significant differences found between the two teams. In comparing Clark team members and siblings with other team members, other team members consumed on an average more grapefruit/week than Clark pool members. This, if anything, would contribute to rather than detract from enamel changes.

The other case control study involved Clark Pool members with abnormal dental grades versus those with grade 0. Several other variables beside hours spent in the pool were associated with abnormal enamel. Consumption of fruit juices or drinks has long been associated with enamel erosion (4-9). It is interesting that, among Clark pool members, increasing consumption of fruit juices/drinks had an independent effect on enamel changes. The association of abnormal enamel with use of a soft rather than a medium bristle toothbrush is puzzling. Whether this represents cause (failure to brush away some noxious substance) or effect (switch to a soft brush because of symptoms attributed to erosion or reporting bias of those known to have dental erosion) is unknown. No other dental care practices were found to be associated with erosion, including number of times/day teeth were brushed, brushing back and forth as compared with up and down, the use of braces, or chewing on a variety of objects. Brushing patterns have been associated with enamel damage (2), but the changes described involved the buccal surfaces of the teeth, and are different from those noted in these children. Chewing on hard objects, such as bobby pins, pipes, etc., can result in localized damage (2), again different from the changes seen in this study.

Age was also found to be an independent variable in enamel erosion and may reflect differences between primary and secondary dentition, though again this is purely speculative.

An association between swimming in the Clark pool and enamel changes can be hypothesized as causal only if it has biologic plausability. Maintenance of a pool requires chlorination to inhibit bacterial growth. An alkali such as soda ash which was used at the Clark Pool will neutralize acid. Hydrochloric acid has long been associated with enamel erosion--in industry (1), when used diluted for the treatment of achlorhydria (7), and when marketed commerically for the cleaning and whitening of teeth (10). In this last instance, a four percent HCl solution with a pH of about 0.07 was used by dentists to remove plaque. This product was shown to cause enamel dissolution in vitro after a five second application (10).

Solubility studies of enamel, hydroxy apatite, and fluorapatite (contituents of teeth) in saliva and in synthetic solution over the pH range 4 to 8 show that precipitation takes place above pH of six and dissolution below about pH 5.5 These affects are overcome when sufficient fluoride is present (11).

Gas chlorination systems tend to lower pH due to the chlorine reacting with water to form hypochlorous acid and hydrochloric acid. Although the pH levels recorded at the Clark pool for the month of July (6.6 - 7.2) were lower than that recommend (7.2 - 8.2), there are no records indicating levels below 6.6. Residual chlorine levels were on the whole below what is generally recommended (12). Readings were not recorded between 9:00 a.m.and 11:00 a,m.,so we do not know what they were during that time. Also, there is no indication of where in the pool the readings were taken, so we do not know if they would have been uniform throughout. Resolution of the problem of pH regulation, evident throughout July, coincident with repair of the pump in early August, suggests that the problem with the pump may have affected the normal operating condition of the entire filtration, recirculation system. This conceivably could have resulted in uneven distribution of chlorine through the pool with pockets of lower pH - though there is no evidence to support this, and it seems likely that the presence of swimmers in the pool would have assured adequate mixing. We also have no assurance of the accuracy of the readings or records, and cannot rule out the presence of some other chemical not found at the pool site or listed in the inventory. While pH and chlorine levels were

monitored by pool personnel, tests were not conducted for total alkalinity and calcium hardness which play an important role in maintaining properly balanced pool water.

The limitations of this small study as outlined earlier, and the lack of documented exposure to pH levels known to be associated with enamel dissolution raise serious doubts about a causal relationship between exposure to the Clark pool and abnormal enamel. However, the symptoms of teeth pain, sensitivity, and chalkiness, the enamel changes found which were consistent with those reported from exogenous acids, the documented pH problem at the Clark pool, the lack of a fluoridated water supply which may have provided a protective effect, and the data from these three small case control studies is certainly difficult to dismiss.

It is difficult to reconstruct in retrospect exactly what caused all the problems at the Clark pool in the summer of 1980. There are well documented complaints of teeth pain and sensitivity, and skin rashes during that summer, prior to any reports of enamel erosion. Interviews with many pool members suggest that complaints were widespread, that the summer of 1980 was distinctly different from other summers at the same pool in terms of symptoms experienced, and that the pool management appeared to many members to be unresponsive to complaints.

The pool records we examined were incomplete and did not indicate for the most part the amount or name of chemicals added, the time added, or the identification of the person adding them as would have been appropriate. The extant records do indicate that there were problems with maintaining desired pH and chlorine levels which persisted through the month of July.

There is certainly evidence that the operation of the pool in 1980 would not have met the standards of the Swimming Pool Code of New Jersey. Recommendations from the Department for future use of the pool include close monitoring for the 1981 season, sampling prior to opening the pool to patrons for pH, free chlorine residual, total alkalinity, calcium hardness, and level of dissolved solids, training for the pool manager in pool chemistry and maintenance, and detailed and accurate record keeping.

Table 1

Symptoms Associated with Swimming in Pool

Symptom	Clark Swim Team (n=27)		Clark Team Sibs (n=10)		Other Pool team (n=1	
	No.	%	No.	%	No.	%
skin burning	15	(55.6)	4	(40)	0	(0)
skin rash	20	(74.1)	6	(60)	0	(0)
eye irritation	23	(85.2)	5	(50)	9	(81.8)
teeth pain/sensitivity	22	(81.5)	5	(50)	0	(0)
teeth chalkiness	21	(77.8)	4	(40)	0	(0)
stomach upset	2	(7.4)	0	(0)	1	(9.1)
vomiting	1	(3.7)	0	(0)	0	(0)

Table 2

Hours/Week Spent in Pool by Clark Swim
Team Members and Siblings by Dental Grade

	Number of Hours								
Dental Grade	<6	6-<12	12-<18	18-<24	24-<30	30-<36	36-<42	42-49	Total
0	2	1	4	3	4	8	1	1	24
1	0	2	0	0	1	4	0	2	9
2	0	0	0	1	0	0	0	3	4

Table 3

Teeth Pain Sensitivity in Clark Swim Team Members and Siblings by Dental Grade

Dental Grade	Teeth Pain/Sensitivity	
	Present	Absent
0	15	9
1	8	1
2	4	0

Table 4

Average Fruit Juices/Drinks Consumed per Week by Clark Team Members and Siblings by Dental Grade

Dental Grade	Number of Glasses				
	0-3	4-7	10-13	14-20	21-42
0	4	4	7	8	1
1	2	2	1	2	2
2	0	1	0	0	3

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