MARKED DECREASE IN TRABECULAR BONE QUALITY AFTER FIVE YEARS OF SODIUM FLUORIDE THERAPY - ASSESSED BY BIOMECHANICAL TESTING OF ILIAC CREST BONE BIOPSIES IN OSTEOPOROTIC PATIENTS

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Abstract from Bone 15 (4) 393-399 1994

Sodium fluoride has for more than 2 decades been a commonly used therapeutic agent for established osteoporosis because of a repeatedly documented anabolic effect on trabecular bone mass. Recently, however, three controlled trials have failed to demonstrate any therapeutic advantage of NaF over placebo with respect to vertebral fracture rate. Also, there have been several reports of an increased incidence of nonvertebral fractures during fluoride administration. Thus, the efficacy of fluoride therapy remains a controversial issue. The aim of this longitudinal study was to investigate the effect of sodium fluoride (40-60 mg per day), calcium (45 mmol), and vitamin D-2 (18,000 IU) on trabecular bone strength, assessed before and after 1 or 5 years of treatment for osteoporosis. Iliac crest biopsies were taken before and after 1 year of treatment in 12 patients, and before and after 5 years of treatment in 14 patients. Measurements were made of biomechanical competence, ash content, and bone fluoride content, and bone strength parameters were normalized for ash content, thereby obtaining a measure of trabecular bone quality. Bone fluoride content was significantly increased after both 1 and 5 years of treatment, indicating that the administered fluoride had been ingested. After 1 year of treatment, no difference was observed in iliac crest trabecular bone ash content. A general trend for decreased bone strength and bone quality was observed, but this was insignificant. After 5 years of fluoride treatment, an insignificant decrease in iliac crest trabecular bone ash content was observed. A significant reduction of 45% was found in trabecular bone strength (p < 0.05), and an even more pronounced reduction of 58% was found in trabecular bone quality (p < 0.01). The results of this study indicate that long-term administration of sodium fluoride may be detrimental to bone quality, at least as measured in non-loaded iliac crest trabecular bone.

Key words: Biomechanical competence; Bone fluoride content; Fluoride therapy; Iliac crest biopsies; Osteoporosis.
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COMPRESSIVE PROPERTIES OF CORTICAL BONE: MINERAL ORGANIC INTERFACIAL BONDING

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Abstract from Biomaterials 15 (2) 137-145 1994

Bone tissue is an anisotropic non-homogeneous composite material composed of inorganic, bone mineral fibres (hydroxyapatite) embedded in an organic matrix (type I collagen and non-collagenous proteins). Factors contributing to the overall mechanical behaviour include constituent volume fraction, mechanical properties,
orientation and interfacial bonding interactions. Interfacial bonding between the mineral and organic constituents is based, in part, on electrostatic interactions between negatively charged organic domains and the positively charged mineral surface. Phosphate and fluoride ions have been demonstrated to alter mineral-organic interactions, thereby influencing the mechanical properties of bone in tension. The present study explores the effects of phosphate and fluoride ions on the compressive properties of cortical bone.

Key words: Bone; Interfacial bonding; Mechanical properties; Mineral.

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EFFECTS OF FLUORIDE ON HUMAN BONE CELLS IN VITRO - DIFFERENCES IN RESPONSIVENESS BETWEEN STROMAL OSTEOBLAST PRECURSORS AND MATURE OSTEOBLASTS

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Abstract from European Journal of Endocrinology 130 (4) 381-386 1994

The cellular effects of sodium fluoride (NaF) on human bone cells in vitro have been variable and dependent on the culture system used. Variability could be attributed to differences in responsiveness to NaF among different populations of cells at various stages of differentiation in the osteoblastic lineage. In this study we compared the effects of NaF in serum-free medium on cultures of more differentiated human osteoblast-like (hOB) cells derived from trabecular bone explants and on osteoblast committed precursors derived from human bone marrow, i.e. human marrow stromal osteoblast-like (hMS(OB)) cells. Sodium fluoride (10^{-5} mol/L) increased proliferation of hMS(OB) cells (p < 0.05, N = 10) but was not mitogenic to hOB cells (p > 0.05, N = 10). Alkaline phosphatase (AP) production increased in both hMS(OB) (p < 0.05, N = 9) and hOB cells (p < 0.05, N = 9). No significant effects on procollagen type I propeptide production were obtained in either culture. In the presence of 1,2 5-dihydroxycholecalciferol (10^{-9} mol/L), NaF enhanced alkaline phosphatase (p < 0.05, N = 8), procollagen type I propeptide (p < 0.05, N = 7) and osteocalcin (p < 0.05, N = 7) production by hMS(OB) cells but not by hOB cells. Our results suggest that osteoblast precursors are more sensitive to NaF action than mature osteoblasts and that the in vivo effects of NaF on bone formation may be mediated by stimulating proliferation and differentiation of committed osteoblast precursors in bone marrow.

Key words: Human bone cells; In vitro; Osteoblasts.

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EXPOSURE TO HIGH FLUORIDE CONCENTRATIONS IN DRINKING WATER IS ASSOCIATED WITH DECREASED BIRTH RATES

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Abstract from *Journal of Toxicology and Environmental Health* 42 109-121 1994

A review of fluoride toxicity showed decreased fertility in most animal species studied. The current study was to see whether fluoride would also affect human birth rates. A U.S. database of drinking water systems was used to identify index counties with water systems reporting fluoride levels of at least 3 ppm. These and adjacent counties were grouped in 30 regions spread over 9 states. For each county, two conceptionally different exposure measures were defined, and the annual total fertility rate (TFR) for women in the age range 10-49 yr was calculated for the period 1970-1988. For each region separately, the annual TFR was regressed on the fluoride measure and sociodemographic covariables. Most regions showed an association of decreasing TFR with increasing fluoride levels. Meta-analysis of the region-specific results confirmed that the combined result was a negative TFR/fluoride association with a consensus combined p value of .0002-.0004, depending an the analytical scenario. There is no evidence that this outcome resulted from selection bias, inaccurate data, or improper analytical methods. However, the study is one that used population means rather than data on individual women. Whether or not the fluoride effect on the fertility rate found at the county level also applies to individual women remains to be investigated.

Key words: Birth rates; High fluoride exposure.

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*IN VITRO* FLUORIDE TOXICITY IN HUMAN SPERMATOZOA

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Abstract from *Reproductive Toxicology* 8 (2) 155-159 1994

Effects of sodium fluoride (NaF) on washed, ejaculated human spermatozoa at doses of 25, 50, and 250 mM were investigated *in vitro* at intervals of 5, 10, and 20 min. Sodium fluoride (NaF) did not affect the extracellular pH of sperm, except that a slight acidification was caused by the 250 mM dose only. The treatment caused a significant enhancement in acid phosphatase (ACPase) and hyaluronidase activities after 5 and 10 min. However, the decrease in the lysosomal enzyme activity after 20 min treatment could have been due to the gradual increase in
fluoride accumulation by spermatozoa leading to membrane damage. Silver nitrate staining of sperm revealed elongated heads, deflagellation, and loss of the acrosome together with coiling of the tail. Sperm glutathione levels also showed a time-dependent decrease with complete depletion after 20 min, indicating rapid glutathione oxidation in detoxification of the NaF. The altered lysosomal enzyme activity and glutathione levels together with morphologic anomalies resulted in a significant decline in sperm motility with an effective dose of 250 mM.

Key words: ACPase; Forward progression; GSH; Human sperm; Hyaluronidase; In vitro; Morphology; NaF; pH.
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CHRONIC ALUMINUM FLUORIDE ADMINISTRATION.
1. BEHAVIORAL OBSERVATIONS

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Abstract from Behavioral and Neural Biology 61 (3) 233-241 1994

This study examined the behavioral effects of chronic ingestion of various monofluoroaluminum complexes in drinking water. Forty young adult male Long-Evans rats were divided into four groups of 10 rats each. The groups received different concentrations of AlF₃ in the drinking water from three sample solutions having a total Al concentration of 0.5, 5.0, and 50 ppm, respectively, or double-distilled deionized water on an ad lib. basis for 45 weeks. General decline of bodily appearance was observed in the lowest concentration AlF₃ group, and animals in this group succumbed in greater numbers during the course of the study than those in any other group. Examinations of performance in an open field, an analysis of walking patterns, and a balance beam test did not find any difficulties indicative of motor disorder. Indeed, on the initial trial on the balance beam, the AlF₃-treated animals exhibited superior performance. No group differences were found in behavior assessed by spontaneous alternation or by a modified Morris water maze test. When retested in the Morris maze after a low dose of scopolamine (0.4 mg/kg), the control animals took longer to reach the platform while the AlF₃-treated rats were not affected. In an olfactory preference test, the AlF₃-treated animals failed to show preferences exhibited by the controls, indicating a possible olfactory impairment. The level of Al in the brains of the AlF₃-exposed rats, as determined by direct current plasma analysis, was almost double that of the control animals. There was a similar trend for the Al content found in the kidneys.

Key words: Aluminum fluoride; Behavior.
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COMPARISON OF THE EFFECTS OF FLUORIDE ON THE CALCIUM PUMPS OF CARDIAC AND FAST SKELETAL MUSCLE SARCOPLASMIC RETICULUM
Evidence for tissue-specific qualitative difference in calcium-induced pump conformation
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Abstract from Biochimica et Biophysica Acta - Biomembranes 1191 (2) 231-243 1994

Comparison of the effects of fluoride (NaF, 1-10 mM) on the catalytic and ion transport functions of the Ca$^{2+}$-ATPase in sarcoplasmic reticulum (SR) vesicles isolated from rabbit cardiac and fast-twitch skeletal muscles revealed similarities as well as striking tissue-specific differences depending on the experimental conditions employed. Short preincubation (3 min at 37 degrees C) of cardiac or fast muscle SR with fluoride in the absence of Ca$^{2+}$ and ATP prior to initiating enzyme turnover by simultaneous addition of Ca$^{2+}$ and ATP to the assay medium resulted in a strong inhibitory effect of fluoride on ATP-energized (oxalate-facilitated) Ca$^{2+}$ uptake and Ca$^{2+}$-ATPase activity. On the other hand, when turnover was initiated by the addition of ATP to SR preincubated with fluoride in the presence of Ca$^{2+}$ but in the absence of ATP, fluoride caused concentration-dependent stimulation of active Ca$^{2+}$ uptake by fast muscle SR with no appreciable change in Ca$^{2+}$-dependent phosphoenzyme (EP) formation (from ATP) or Ca$^{2+}$-ATPase activity but inhibition of active Ca$^{2+}$ uptake by cardiac SR with concomitant inhibition of EP formation and Ca$^{2+}$-ATPase activity. Exposure of cardiac or fast muscle SR to fluoride in the presence of both Ca$^{2+}$ and ATP resulted in concentration-dependent stimulatory effect of fluoride on Ca$^{2+}$ uptake with no change in EP formation or Ca$^{2+}$-ATPase activity; this effect diminished substantially at saturating oxalate concentration in the assay. Assessment of the effects of deferroxamine (1 mM) and exogenous aluminum (10 µM) did not indicate a requirement for aluminum in the inhibitory or stimulatory effect of fluoride. These results suggest that (a) the Ca$^{2+}$ and ATP-deprived (E$^1$/E$^2$) but not the Ca$^{2+}$ plus ATP-ligated (CaE$^1$ATP) conformation of the SR Ca$^{2+}$-ATPase is susceptible to inhibition by fluoride in both cardiac and fast muscle; (b) the Ca$^{2+}$-bound conformation (CaE$^1$) of the SR Ca$^{2+}$-ATPase is susceptible to inhibition in cardiac muscle but is refractory to fluoride in fast muscle; and (c) the stimulatory effect of fluoride is largely secondary to its ability to mimic the action of oxalate in intravesicular Ca$^{2+}$ trapping when the fluoride-resistant enzyme is turning over normally. Fluoride inhibited phosphorylation of the Ca$^{2+}$-free enzyme by P-i in cardiac and fast muscle SR indicating that fluoride sensitivity of the phosphorylation site of the SR Ca$^{2+}$-ATPase is similar in cardiac and fast muscle. In cardiac SR, disruption of the functional interaction between Ca$^{2+}$-ATPase and its regulatory protein phospholamban, through phosphorylation of the latter (by cAMP kinase) did not alter the fluoride sensitivity of the Ca$^{2+}$-bound enzyme (CaE$^1$). These results, coupled with the refractoriness of CaE$^1$ATP to fluoride in cardiac and fast muscle SR, suggest that a tissue-specific difference in the accessibility (reactivity) of the nucleotide binding site to fluoride upon Ca$^{2+}$ binding to the enzyme may account for the observed difference in fluoride sensitivity of the cardiac versus fast muscle enzyme - i.e., when the ATPase is in CaE$^1$ conformation, its ATP binding site is "fluoride-reactive" in the cardiac enzyme but is "fluoride-resistant" in the fast muscle enzyme.

Key words: Calcium pump; Cardiac muscle; Fast skeletal muscle; Fluoride; Sarcoplasmic reticulum.

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EFFECTS OF PLASMA FLUORIDE AND DIETARY CALCIUM CONCENTRATIONS ON GI ABSORPTION AND SECRETION OF FLUORIDE IN THE RAT

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Abstract from Calcified Tissue International 54 (5) 421-425 1994)

This 30-day balance study with weanling rats was designed to determine the effects of plasma fluoride and dietary calcium concentration and their interaction on the absorption, balance, and tissue concentrations of fluoride. The three major groups differed according to the total exposure and plasma concentrations of fluoride. One group received fluoride only in the diet and the other two received additional fluoride by continuous infusion from miniosmotic pumps implanted S.C. Each group was divided into two subgroups with dietary calcium concentrations of 0.4% or 1.4%. Fluoride intake with the diet did not differ among the groups. Fecal fluoride excretion was directly related to plasma fluoride concentration. The absorption and balance of dietary fluoride were inversely related to plasma fluoride concentration. These effects were greatest in the groups fed the 1.4% calcium diet. The interactions of plasma fluoride and dietary calcium on these variables were highly significant (P < 0.0001). The balance of dietary fluoride was negative in the four groups that received additional fluoride by infusion. In the two groups that received fluoride only in the diet, the plasma and bone fluoride concentrations were 41% and 59% lower, respectively, in the 1.4% dietary calcium group. The findings indicate that net fluoride secretion into the GI tract can occur when plasma fluoride concentrations and calcium intake are elevated. They suggest that elevated plasma fluoride levels and calcium intake are factors that may diminish the effect of oral fluoride treatment in osteoporotic patients.

Key words: Balance; Dietary calcium; Metabolism; Osteoporosis; Secretion.
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EFFECT OF A COMBINED CHLORHEXIDINE AND NaF MOUTHRINSE - AN IN VIVO HUMAN CARIES MODEL STUDY

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Abstract from Scandinavian Journal of Dental Research 102 (2) 109-112 1994

Chlorhexidine (CHX) is probably the most widely used and the most potent chemical plaque inhibitory agent, whereas fluoride (F−) is the only truly accepted anticaries agent available at present. As they have discrete mechanisms of action, a combination effect of these agents on human dental caries may exist. The inhibitory effect of CHX on the formation of, and acid production in, plaque may reduce
a relatively extreme cariogenic challenge sufficiently for it to be overcome by the local F⁻ concentrations achieved by brushing or rinses. The aim of this study was to evaluate the possible caries inhibitory effect of combining 2.2 mM CHX mouthrinses used twice daily with daily 11.9 mM NaF rinses in an *in vivo* human caries model using plaque-retaining bands on premolars scheduled for extraction. Nine subjects (a total of 28 teeth) were fitted with the bands for 4 wk. Saliva and plaque samples were collected before and after the study period for bacterial cultures, and the tooth surfaces were analyzed by microradiography after careful tooth extractions. The combination of CHX and F⁻ rinses resulted in enamel mineral loss only slightly higher than that observed in “sound” enamel and clearly less than with F⁻ rinses alone. Both total plaque bacteria and *Streptococcus mutans* were reduced by CHX rinses, confirming the discrete mechanisms of action.

Key words: Chlorhexidine; Dental caries; Dental plaque; Fluorides; Mutans streptococci; NaF.

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**FLUORIDE UPTAKE IN HUMAN DENTINE FROM GLASS-IONOMER CEMENT *IN VIVO***

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Abstract from *Archives of Oral Biology* 38 (12) 1093-1098 1993

The purpose was to examine F uptake and distribution in dentine from a F⁻-containing glass-ionomer cement *in vivo*. Nine volunteers were selected from dental students who were scheduled for extraction of their third molars. Two cavities were prepared on the same occlusal surface of the third molars for each subject; one was restored-with glass-ionomer cement (Virtabond), the other with zinc phosphate cement as a control. After 3 months the teeth were extracted. F profiles in the dentine from the cavity floor to the pulpal surface were determined in tissue immediately adjacent to the restorations. An abrasive micro-sampling technique was used. The F concentration of the dentine was highest immediately beneath glass-ionomer cement filling, decreasing towards the pulpal surface. Overall F concentrations were greater in the dentine beneath the glass-ionomer cement than in that beneath the zinc phosphate cement. It was concluded that the glass-ionomer cement markedly enhanced fluoride uptake by underlying dentine *in vivo*.

Key words: Cement; Dentine; Fluoride; Glass-ionomer; *In vivo*.

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DENTAL TISSUE EFFECTS OF FLUORIDE
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Abstract from Advances in Dental Research 8 (1) 15-31 1994

It is now well-established that a linear relationship exists between fluoride dose and enamel fluorosis in human populations. With increasing severity, the subsurface enamel all along the tooth becomes increasingly porous (hypomineralized), and the lesion extends toward the inner enamel. In dentin, hypomineralization results in an enhancement of the incremental lines. After eruption, the more severe forms are subject to extensive mechanical breakdown of the surface. The continuum of fluoride-induced changes can best be classified by the TF index, which reflects, on an ordinal scale, the histopathological features and increases in enamel fluoride concentrations. Human and animal studies have shown that it is possible to develop dental fluorosis by exposure during enamel maturation alone. It is less apparent whether an effect of fluoride on the stage of enamel matrix secretion, alone, is able to produce changes in enamel similar to those described as dental fluorosis in man. The clinical concept of post-eruptive maturation of erupting sound human enamel, resulting in fluoride uptake, most likely reflects subclinical caries. Incorporation of fluoride into enamel is principally possible only as a result of concomitant enamel dissolution (caries lesion development). At higher fluoride concentrations, calcium-fluoride-like material may form, although the formation, identification, and dissolution of this compound are far from resolved.

It is concluded that dental fluorosis is a sensitive way of recording past fluoride exposure because, so far, no other agent or condition in man is known to create changes within the dentition similar to those induced by fluoride. Since the predominant cariostatic effect of fluoride is not due to its uptake by the enamel during tooth development, it is possible to obtain extensive caries reductions without a concomitant risk of dental fluorosis.

Key words: Dental caries; Dental fluorosis; Dose-response relationship; Enamel; Post-eruptive effects; Pre-eruptive effects; TF index.

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ERUPTION OF DECIDUOUS TEETH: INFLUENCE OF UNDERRUTRITION AND ENVIRONMENTAL FLUORIDE
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Abstract from Ecology of Food and Nutrition 30 (2) 89-97 1993

A house to house survey in six rural villages in South India was conducted to assess the influence of undernutrition and environmental fluoride on deciduous dental eruption. Three villages surveyed were from the endemic fluorosis area where the estimated fluoride concentration was 5 ± 1.2 ppm. Oral cavities of all the children in the age group 5-48 months were examined and a tooth was marked erupted when it was visible emerging through the gingiva. Undernutrition, as classified by Gomez classification, was widely prevalent among preschool children in the surveyed area (n = 708; normal: 5.1%; grade-I: 29.1%; grade-II: 53.1% and grade-III: 12.7%). Children in the severe grade of malnutrition possessed fewer teeth at a given age. Analysis of variance revealed that fluoride has significant (P < 0.005) detrimental effects on dental eruption among children in the 18-30 month age group. The efficacy of Bailey’s formula (age in months = number of teeth erupted + 6) in indica-
ting the chronological age was evaluated in the 5-24 month aged children (n = 347).
Bailey's formula failed to assess the age correctly in 87%, with underassessment in
58% and overassessment in 29%. Its efficacy did not differ between the endemic and
non-endemic areas. We conclude that i) undernutrition is a prevalent problem in
rural areas in South India, ii) age calculation by Bailey's formula did not indicate
the chronological age in the majority of children and hence is not useful in under-
nourished populations, and iii) undernutrition compounded by high water fluoride
may delay the eruption of teeth.
Key words: deciduous dentition; dental health surveys; fluoride; India; nutritional
status; nutrition surveys; preschool child; tooth eruption.
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WATER FLUORIDATION, TOOTH DECAY, AND CANCER

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Abstracted from a paper presented at the XXth Conference of the International
Society for Fluoride Research, Beijing, China, September 1994

It has become widely accepted among dental and public health professionals that
fluoridation reduces tooth decay by one-half to two-thirds. However, recent large-
scale studies in New Zealand, Canada, and the United States have reported similar
or lower tooth decay rates in nonfluoridated areas as compared to fluoridated areas.
Moreover, findings in the United States and worldwide show that, over the last 25
years, reductions in tooth decay rates in nonfluoridated areas are comparable to
those in fluoridated areas.

In 1977, epidemiological studies by Dr Dean Burk and me showing a link
between fluoridation and cancer were the subject of full-scale Congressional
Hearings. As a result, Congress mandated that the US Public Health Service
conduct animal studies to determine whether or not fluoride causes cancer under
laboratory conditions. The USPHS retained the Batelle Memorial Institute in
Columbus, Ohio, to perform two studies, one on mice and another on rats. The most
significant finding was the occurrence of an extremely rare form of liver cancer,
hepatoblastoma, in fluoride-treated male and female mice. In 1989
Batelle released the results of their rat study which showed a dose-dependent
relationship between oral squamous cell metaplasias and fluoride in both male and
female rats. Similar results regarding oral cell dysplasias were reported in a Proctor
and Gamble study. In addition, the Batelle rat study showed a dose-dependent
relationship between fluoride and the number of male rats with tumorous or
cancerous oral squamous cells - and also between oral squamous cell metaplasias
and tumors/cancers in female rats. In male rats it was found that osteosarcomas, a
rare form of cancer, were confined to rats in the two high fluoride groups.

Finally, using three different data bases, we found that, in humans, the bone
cancer incidence rate, mostly osteosarcoma, was around 50% higher in males living
in fluoridated areas (and many times higher in those under 20), and that the
incidence of oral and pharyngeal cancers was 30-50% higher in fluoridated areas.
Key words: Cancer; Dental caries; Fluoridation.
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AN ANALYSIS OF THE CAUSES OF TOOTH DECAY IN CHILDREN IN TUCSON, ARIZONA

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Abstracted from a paper presented at the Annual Meeting of the American Association for the Advancement of Science, San Francisco USA, February 22 1994

This revealing study by University of Arizona researchers adds to the growing list of comprehensive surveys which cast doubt on the validity of past claims for a dental benefit from low water fluoride levels. It is unique in its thorough assessment of a wide range of possible causative factors.

The genesis of the study was a 1992 report of a citizens' advisory committee, chaired by Emeritus Professor of Chemistry Cornelius Steelink, to study the benefits and risks of water fluoridation. The committee, from the evidence available, reported that there was no obvious relation of water fluoride content to the prevention of tooth decay in Tucson. In fact, a positive correlation seemed to be present. As Professor Steelink stated (Chemical and Engineering News, July 27 1992): "the more fluoride a child drank, the more cavities appeared in its teeth." Despite that finding, the City Council decided, on the advice of public health officials, to fluoridate the water supply.

After that decision, Steelink and others from the University of Arizona undertook a more thorough investigation of factors affecting tooth decay in children. His colleagues were an anthropologist and a public school nurse. Funds for the study came from the Departments of Anthropology and Chemistry.

Tucson had a unique data base for such an epidemiological study. There existed a compilation of dental records for all (26,000) elementary school children for the year 1987-1988. Detailed demographic statistics were accessible, in the Anthropology Department, for the city population of 500,000. Behavioral patterns had been recorded for this same population by the Garbage Project, a unique research division of the University of Arizona Anthropology Department. Finally, hydrologic data were available for different areas of the city, where fluoride content of the municipal water varies with the location of the wells.

They succeeded in gathering the following data on city households: income, ethnicity, children in school, education level of parents, fluoride content of neighborhood drinking water, mean DMFTs for children in school, sugar consumption, candy consumption, toothpaste usage, school fluoride mouthwash frequency, soda pop consumption, antibiotic usage, and a few other items. Many of the above factors are referred to in the literature as "dentally aware" practices. The garbage analysis of the households indicates that, contrary to popular dogma, poor people are not "dentally unaware". They practice the same types of dental prophylaxis as do middle class residents.

The goal was to find correlations between caries in children (DMFTs) and all of the above factors. The results indicate that fluoride in drinking water appears to play a variable role. If one plots the total population caries rate versus fluoride content, the relationship is direct, thus confirming Steelink's preliminary finding. In some subpopulations the relationship is inverse and in others (e.g., in this case, Hispanic) it is direct. Ethnicity seems to play the dominant role in Tucson. Household incomes and level of education are also strongly correlated.

Key words: Dental caries; Fluoridation; Garbage project; Tucson, Arizona.
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