A review of the literature to determine the relationship of diet and nutrition to dental caries.

Kumin, Sidney
Boston University

http://hdl.handle.net/2144/16415
Boston University
BOSTON UNIVERSITY
SCHOOL OF EDUCATION

Thesis

A REVIEW OF THE LITERATURE TO DETERMINE THE RELATIONSHIP
OF DIET AND NUTRITION TO DENTAL CARIES

Submitted by

Sidney Kumin
(B.S., Boston University, 1951)

In Partial Fulfillment of Requirements for
the Degree of Master of Education
1951
First Reader: Leslie W. Irwin
Professor of Education

Second Reader: James A. Wylie
Associate Professor of Education
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CHAPTER I
THE SELECTION OF THE PROBLEM

Purpose.-- It was the purpose of this study to determine the trends in research conclusions concerning the relation of diet and nutrition to the problem of dental caries for presentation to health educators.

Scope.-- This study provides evidence of some of the statistics which emphasize caries as the big dental problem in America today. The words diet, nutrition, and dental caries have been defined, to establish the relationship of each to the other. The subject of tooth development has been covered to show findings that:

1. Either the nutrition and/or the diet of the mother may have an effect on tooth development in the intrauterine life of the fetus.
2. This effect may lead to or aid in later deleterious action on the teeth.
3. Either diet and/or nutrition may have effect on teeth during teeth formation.
4. Diet and not nutrition may have appreciable effect upon the structure of the tooth enamel once the permanent teeth are calcified.

-1-
In keeping with the above, the paper considers nutrition as the utilization of food by the body, and diet as the food we eat. Foods are considered as proteins, carbohydrates, fats, vitamins, and minerals. Foods which have been found conclusively to be related to the problem are discussed. In this analysis attention is given to the relation to caries of fluorides in waters and foods. The factor of malnutrition is reviewed also to provide more inclusive and conclusive evidence of the relation of diet and nutrition to caries.

The research studies and other materials reviewed cover both sexes of all ages, including intra-uterine life. The information is useful to all. It might be helpful especially to teachers and health educators who have any cause to educate concerning tooth hygiene and/or the problem of dental caries.

Justification.—In the readings of the writer his attention has been attracted to the number of contradictions in the literature which have proclaimed the merits of various treatments and products marketed for the prevention of dental caries. These contradictions have indicated a need for a review and digest of the literature to determine the trends in research conclusions. It was felt that such conclusions would help to provide a more valid reference for health educators, and others, who attempt to motivate good concepts and practices concerning factors which are related to dental caries.
A very high percentage of the American population suffer from dental caries. This destruction of the teeth can interfere with proper mastication and subsequent digestion of food. Moreover, dental caries may be the cause of infections which seriously affect various parts of the body.

There is much contradiction in the literature concerning dental caries. A careful review of such literature provides a general trend of research conclusions concerning the relation of diet and nutrition to dental caries. An analysis of this type may help to correct concepts and to provide a valid reference for educational use.

In reviewing the various material available this study provides the coverage necessary to establish an understanding of the problem as well as to furnish the teacher and the health educator with information which should be helpful in any educational discussion which concerns good hygiene for teeth, generally for all people and especially for pregnant women and for pre-school and school children.

According to most authorities diet and nutrition are considered to be primary factors contributing to sound teeth. Therefore attention is given to determine what relation, if any, diet and nutrition have in the problem of dental caries.

Review of the Research.-- Most discussion by reviewers of research in this problem area is directed primarily toward the relation of diet to dental caries. It is most commonly
thought today that dental caries is initiated by the local environmental substances which are found in the mouth. Because of this theory, efforts in research today are bent towards altering the local environment so that it is unfavorable to caries. The writer arrived at his conclusions by reviewing the literature, weighing the evidence, and establishing his conclusions along the lines of research.

Definitions.-- The following medical and dental terms are defined in order for the reader to understand this study more completely:

- acidity--quality of being acid; excess of acid
- alveolar pyorrhea--a purulent discharge from the alveoli of the teeth
- bacterium (plural, bacteria)--any of a very large group of unicellular, vegetable microorganisms existing morphologically as cocci (oval or spherical cells), bacilli (rods), spirilla (spirals), and vibrios (comma shaped), etc.
- calcification of teeth--deposition of lime salts within the organic matrix during the development of a tooth
- caries--decay of the teeth in which cavities are formed in them by the gradual destruction of enamel and dentine
- caries of the teeth--a localized, progressive, molecular disintegration of the teeth, beginning with the solution of the enamel by lactic and pyruvic acids. The acids are the product of enzymic action of oral bacteria upon carbohydrates \([C_6H_{12}O_6] \rightarrow \text{bacterial enzymes} = 2C_3H_6O_3 \text{ (lactic acid)}\). The initial process is followed by bacterial invasion of the dentinal tubuli. The acids formed break down and remove the inorganic constituents of the enamel and dentine, and the unsupported organic matrix is gradually removed, leaving the so-called cavity of decay.
coenzymes--substances associated with and activating enzymes

cuspid--a long, single-rooted tooth, the crown consisting of one cusp or point

DMF--Decayed, Missing, Filled (teeth)

deciduous tooth--one of the twenty temporary or milk teeth; those replaced by succedaneous permanent teeth

dentine--the calcified tissue which forms a major part of a tooth. Dentine is related to bone but differs from it in the absence of included cells. It is covered by the enamel over the crown of the tooth, by the cementum over the roots, and itself surrounds the pulp chamber and root canals which contain the dental pulp.

disaccharide--a carbohydrate formed by the condensation of two monosaccharide molecules

enamel--the vitreous substance of the crowns of the teeth

enzyme--a catalytic substance formed by living cells and having a specific action in promoting a chemical change

epithelium--a tissue composed of contiguous cells with a minimum of intercellular substance. It forms the epidermis, etc.

fluorosis--poisoning by absorption of toxic amounts of fluorine

chronic dental fluorosis--hypoplasia and discoloration of the teeth resulting from the continued use during the formative period of the tooth, of water containing toxic amounts of fluorine

gingiva--that part of the gum which surrounds the tooth and lies incisal or occlusal to the crest of the alveolar ridge

gingival--as above; also called marginal

glucose--the crystalline monosaccharide, dextrose; a product obtained by the incomplete hydrolysis of starch

hypoplasia--underdeveloped or defective enamel
irradiate—treat with x-rays or radium rays
lactic—pertaining to milk or its derivatives
lactic acid—a bacterial by-product in dental caries
lactobacillus acidolphus—a species of large bacilli producing acid but no gas from glucose, lactose, maltose, and sucrose
lesion—an alteration of structure or of functional capacity due to injury or disease
mandible—the lower jaw bone
mandibular—pertaining to or affecting the mandible
maxillae—the bones of the upper jaw taken as a unit
maxillary—pertaining to or affecting the maxilla (plural, ae)
microbe—any single microorganism whether animal or vegetable
microbial—pertaining to, resembling, or of the nature of a microbe
molar—a grinding tooth with multicuspid crown (In man there are twelve molars: three right and left in both the maxillary and mandibular arches, the molar distal to the second bicuspid being called first molar; the next, second molar; and the last, third molar. The popular names for these teeth in the same order: sixth year molar, twelfth year molar, and wisdom tooth)
morphology—the branch of biology which deals with structure and form
mottled enamel—a dappled condition of the teeth caused by hypoplasia, with a later extraneous staining; chronic dental fluorosis
mucin—a mixture of glycoproteins that forms the basis of mucus. It is soluble in water and precipitated by alcohol or acids.
pellagra—a deficiency disease occurring endemically in Italy, southern France, Spain, and in the southern United States. Also seen sporadically in other areas.
permanent tooth—one of the thirty-two teeth of the second dentition: eight incisors, four canines, eight premolars, and twelve molars

pH—symbol used in expressing hydrogen-ion concentration. A pH above seven represents alkalinity in an aqueous medium; below seven, acidity.

phosphoric acid—a 50 per cent solution of absolute acid in water, obtained from bones or the oxidation of phosphorus

pyorrhea—a flow of pus

rickets—a deficiency disease of children, marked by disordered ossification (conversion of tissue into bone), disordered nervous system, and delayed dentition

saccharose—a disaccharide composed of one molecule of glucose and one molecule of fructose

scurvy—a nutritional disorder caused by deficiency of vitamin C, characterized by extreme weakness, spongy gums, and a tendency to develop hemorrhages under the skin, etc.

succedaneous tooth—one of the permanent teeth which takes the place of a deciduous tooth

sucrose—a cane sugar, saccharose

symbiosis—the intimate and harmonious association of two dissimilar and unrelated organisms to their mutual advantage

symbiotic—pertaining to symbiosis

temporary teeth—teeth of the first dentition; milk teeth; deciduous teeth

tooth—one of the calcified organs supported by the alveolar processes and gums of both jaws, serving to masticate food, aid speech, and influence facial contour. Each tooth consists of: (1) a main mass of dentine surrounding a pulp cavity which contains the dental pulp with its nerves and vessels; (2) a coronal portion (crown) covered by enamel; (3) a radicular portion (root) which may be single, bifid (divided into two parts), or trifid (divided into three parts),
covered by bone called cementum; (4) a cervical portion (neck), the junction of crown and root.

ulcer--an open sore in the soft tissue of the body which discharges pus or serum

ulcerative--pertaining to ulcer

Recapitulation and implications.-- The writer in this study has presented the trends in research conclusions concerning the relation of diet and nutrition to the problem of dental caries. It is believed that this information will be helpful to health educators and others in explaining preventive measures, especially for mothers, mothers-to-be, and children.
CHAPTER II
PROCEDURES

The attention of the writer was attracted to the number of contradictions in the literature proclaiming the merits of various treatments and products marketed for the prevention of dental caries. These contradictions indicated a need for a review and digest of the literature to determine the trends in research conclusions and to establish concepts which would provide a reference for the writer as well as for others who were attempting to motivate good concepts and practices.

From the beginning the writer found that the source material for his thesis could be obtained only at dental and medical libraries. With a rough outline in mind, the writer first went to the Boston Medical Library and surveyed the resources available there. Some material was helpful but the writer was not satisfied with this material. Accordingly, he made arrangements with the head librarian at one of the leading dental schools to use the combined facilities of that school's dental and medical library.

Two bibliography sources were basic aids. From them a tentative bibliography of over 200 items was prepared. These items were scanned to obtain an overview of the problem and
some concepts concerning caries factors. Early in the research readings there was an indication to the writer that diet and nutrition were considered to be primary factors contributing to the development of sound teeth. Also, that one of the basic factors of caries was considered to be diet.

The writer discussed this viewpoint with several dentists and found that although there was no unanimity of opinion, diet was the only element it was thought generally to be one of the basic factors. With this in mind, a defined outline was shaped. Further scanning of the research material was accomplished. Although many variables were found to be inclusive elements diet, especially the raw and refined sugars, was found to be an imposing factor.

Continued surveying and searching of the literature further emphasized the trend in research thinking. Accordingly, the assumptions and conclusions of the writer were based upon this trend.
CHAPTER III
THE NATURE OF THE PROBLEM

Incidence of caries:-- During the year ending June 30, 1945, there were 2,970,280 children born in the United States. Half will require dental services between their second and third birthdays. Klein and Palmer point out that "...by age 15 years more than 95 per cent of the boys and girls have had one or more permanent teeth attacked by caries. Practically the whole population becomes 'baptized,' so to speak, with caries experience by the time the early adolescent years are reached." At the Guggenheim Dental Clinic in New York almost 50 per cent of the two-year-olds examined had one or more decayed teeth. Three out of ten toddling patients had seven or more cavities. Nearly 25 per cent required at least one extraction. It is evident that tooth decay attacks its victims young as well as old.


2 per cent of the population escapes the ravages of some oral breakdown. A very high percentage are victims of caries: 92 per cent, according to F. J. Ford \(^1\) and the American Dental Association. Bond \(^2\) states that in special investigations 60 per cent of a group of five-year-olds were found to have seven or more cavities and that by age five, 90 per cent had some dental decay.

**Reflection of caries experience:**-- As the child grows older, his probabilities of acquiring caries become greater; the caries experience during childhood will be reflected in the caries experience and dental defects of the young adult. During World War II, dental defects caused rejection of 20.9 per cent of the male draftees in the United States. From this evidence it can be safely assumed that caries is the big dental problem in America today. The problem becomes increasingly more important when we realize that destruction of the teeth can interfere with proper mastication and the subsequent digestion of foods. The spread of infections or

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3/ Loc. cit.

toxins to distant parts of the body may result in secondary infections involving the heart, kidneys, or nervous system. Frequently it may give rise to the rheumatic pains of children and it may be a cause of anemia. Dr. Anna Mintz, president of the Massachusetts Division of the American Society of Dentistry for Children, has been quoted by Bond as saying that if decay is neglected it becomes progressive and may infect the whole body. Decay interferes with mastication, and the child becomes malnourished. The crowns may be broken down and become smaller than nature intended. Spaces are created in the jawbone, and the teeth then shift unnaturally. Since the jaw is still growing, even the child's facial contour may be changed.

Diet, nutrition, and dental caries defined.-- The relationship of diet and nutrition to dental caries is the subject of extensive and controversial literature. Because dental caries is most commonly thought to be initiated by the local environmental substances found in the mouth, discussion at present seems to be directed primarily towards the relation of diet to the problem. For the purpose of this paper, discussion considers diet to mean the food that we eat; nutrition is defined as the utilization of food by the

2/Loc. cit.
body. At the University of Michigan Workshop, conducted to evaluate dental caries' control techniques, the following definition of dental caries was accepted:

"Dental caries is a disease of the calcified tissues of the teeth. It is caused by acids resulting from the action of micro-organisms on carbohydrates, is characterized by a decalcification of the inorganic portion and is accompanied or followed by a disintegration of the organic substance of the teeth. The lesions of the disease occur predominantly in particular regions of the teeth, and their type is determined by the morphologic nature of the tissue in which they appear."\(^1\)

\(^2-4\) It is most widely believed that the dental decay process is a balance of forces. The initiating force is thought to be the action of bacteria, normally present in the mouth, on sugars and starches, resulting in the production of acids. Instead of the formation of acids directly on the tooth enamel, there is an intermediary called a bacterial plaque. This plaque is a sticky film consisting of saliva, food particles, debris, and bacteria.


There may be one or a number of local factors which aid the initiation of decay by promoting food retention and subsequent conversion to acid.

In this activity the insoluble calcium salts of the hard structures of the teeth are transformed into soluble salts by chemical action. The soluble salts are washed away, and a cavity is formed. Dental caries does not attack the surfaces of the teeth indiscriminately. Most cavities develop in sheltered areas or on surfaces of the enamel which harbor mucinous plaques and thus favor the lodgment of food residues. It is in these areas that the formation of acids resulting from bacterial activity attacks the tooth surface. Dr. P. Pincus reports that the initial carious attack on collagen in dentine is due to a gram-negative bacillus constantly present in caries. This attack releases sulfuric acid, which attacks the dentine. Any crack in the enamel armor is an avenue for the bacteria to the dentine. In this respect, cavity formation and the resistance of teeth to destruction may depend in part on the ability of the saliva to neutralize or buffer the acid production and retention.

Additional findings have been made by Drs. Reidar F. Sognnaes and George B. Wislocki. At the meeting of the

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\[1\] P. Pincus, "Caries," British Dental Journal (December 5, 1947), 83:239.
American Association for the Advancement of Science they reported that the disappearance of a newly discovered jelly-like chemical in teeth may be the first step toward tooth decay. Found to be a constituent of both the dentine and enamel of normal teeth, the jelly-like chemical is a sugar-contained protein and belongs to the general class of mucin. Under the influence of certain bacteria and enzymes, it can change from its jelly-like state to a liquid. Apparently the beginning step of decay takes place in the destruction of this chemical and its disappearance from the little tubes in the dentine. This precedes the invasion of bacteria which have been believed generally to be the primary step in tooth decay.

1. Tooth Development

Importance.-- It has long been an accepted fact that an optimal diet with good nutrition is of great importance during pregnancy, both for the mother and the fetus.

2/ Ford in the Medical Press has stated that tooth development begins early in intra-uterine life and that


there is a possibility for abnormalities to develop in pregnancy. Sprawson and King signified that ideal development and growth of the jaws and teeth will be coincident with ideal development of the body as a whole. This in turn will depend on maternal diet. Severe deficiencies of building materials in the mother before birth can interfere with the formation of dental tissues so that even if dietary perfection is attained later, the dental formative cells may not then be able to perform in perfection.

The requirements leading to a healthy mouth actually begin before birth, and the expectant mother should adhere to a definite plan for the development of sound teeth. She can apply hygienic measures and be assured that her diet contains milk, butter, cheese, eggs, and green vegetables—the rich sources of calcium and calcifying vitamins essential for the formation of teeth and bones. However, it has been shown that it is quite unnecessary to feed large quantities of calcium.


2/J. D. King, "Nutritional Factors in Dental Caries and Parodontal Disease," British Medical Bulletin (1944), 2:222-225.

3/Elmer V. McCollum, op. cit., p. 46.

amounts of calcium and phosphorus to mothers during pregnancy in order to bring about deposition of calcium in
the teeth of the fetus. Sherman and Lanford, using M. Mellanby's investigations, indicate that "the body resources
of the mother may serve to a limited extent as a factor of safety, so that the poor diet of the mother before birth is
somewhat less disastrous in its effects on her child's teeth than is correspondingly poor diet of the infant after birth."

According to the Medical Press, it is generally regarded that the ingestion of a pint of milk daily with a mixed diet will supply insufficient calcium to maintain a positive balance. This is further substantiated by the findings of the Michigan Workshop that there is no evidence to indicate that well-nourished pregnant young women need more calcium than is supplied by a diet adequate to meet total nutritional requirements. Moreover, there is a plentiful supply of calcium and phosphorus substances in the bony skeleton. In addition to this observation, it is conceived that calcification of the teeth must be regarded


as important only after birth,\(^1\) since 85 per cent of the total calcification of teeth takes place after birth.

**Sequence.**—At birth the infant has twenty primary teeth deep in his jawbones, and the first permanent teeth are in the formative stage. Except for unusual circumstances, every child has all his deciduous teeth by the time he is two and one-half years old. Drs. Rhoads, Rapoport, \textit{et al.},\(^3\) give the mean age as between 27.2 and 28.9 months. Eruption of the permanent teeth to replace the deciduous, temporary ones, begins about the fifth year.\(^4\) Calcification of the permanent teeth begins at birth, and the enamel is formed before the tooth erupts.

Once the enamel is completely formed, it has no blood

\(^1\)M. E. Breckenridge and E. L. Vincent, \textit{op. cit.}, p. 273.

\(^2\)Evelyn C. Sprawson, \textit{loc. cit.}


\(^6\)M. E. Breckenridge and E. L. Vincent, \textit{loc. cit.}


supply and therefore cannot receive an appreciable amount of
nourishment from the rest of the body. Moreover, the
completed enamel is no longer subject to systemic nutritional
disturbances. Similarly, the crowns of all permanent teeth,
with the exception of the third molars, are calcified at the
average age of eight, and the crowns of the first permanent
molars are calcified at the age of three. The writer
found no conclusive evidence that nutrition can improve
enamel, once the cells which laid it down are lost.
Nutrition can have an appreciable effect upon the structure
of the enamel only during tooth formation. Since the
teeth undergo calcification throughout childhood, it is
advisable to provide the child with calcifying factors
throughout this span, rather than to limit efforts to the
period of infancy.

2. Nutrition

Role of vitamins and minerals.-- What about the role of

2/I. Schour and M. Massler, "The Effects of Dietary
Deficiencies upon the Oral Structures," Journal of the
American Dental Association (July, 1945), 32:871 ff.
5/Philip Jay, "Nutrition and Dental Caries," Journal of the
New Jersey Dental Society (January, 1944), 15:20 ff.
vitamins and minerals during tooth development? Dr. 
Hamilton Robinson, at the American Dental Association 
meeting in Chicago, stated that "certain minerals are 
important for the formation of sound teeth, but there is no 
clear-cut scientific evidence that those minerals are 
necessary to prevent disease in mature teeth." He stated 
further that "vitamins as a weapon against dental disease is 
a case of firing blind. It is of value in deficiency 
diseases such as scurvy and rickets."

Findings of the Michigan Workshop.-- The following 2/ 
conclusions were agreed upon at the Michigan Workshop: 
(1) Chronic mild deficiencies of vitamin A have no 
significant effect on the structure of the hard tissues or 
the shape of the teeth. However, chronic severe 
deficiencies of vitamin A produced characteristic 
abnormalities in the structure and form of the enamel and 
dentine of developing teeth of animals. Furthermore, a 
vitamin A deficiency does not cause an increase in the caries 
attack rate. (2) There is no evidence in the literature that 
a deficiency of vitamins B and C has an effect upon the

1/Hamilton B. G. Robinson, "The Metabolism of Minerals and 
Vitamins and the Effect of Systemic Conditions on Dental 
Caries," Journal of the American Dental Association (July, 
1949), 39:58.


The vitamin B complex is concerned primarily with the soft tissues. (3) It has been demonstrated that vitamin D is of value in the formation of the hard dental structures, including the teeth themselves, and there is evidence to suggest the possibility of increased susceptibility to caries in teeth which have been formed during a condition of vitamin D deficiency. However, evidence that this vitamin aids in the prevention or retardation of dental caries at any stage of its progress is not supported by observations which have passed beyond the controversial stage. Furthermore, there is no conclusive evidence to indicate that there is any significant difference in the caries attack rates of patients who receive vitamin D from sunshine, cod liver oil, or irradiated ergosterol. (4) In regard to the intake of minerals, there is sufficient evidence in the literature to justify the view

1/See also A. L. Knieser, A. W. Mann, and T. D. Spies, "Relationship of Dental Caries to Deficiencies of the Vitamin B Group," Journal of Dental Research (June, 1942), 21:259-262.


5/See also C. D. M. Day, "Nutritional Deficiencies and Dental Caries in Northern India," British Dental Journal (March 3, 1944), 76:115 ff. and (March 17, 1944), 76:143 ff.
that the ingestion of calcium and phosphorus in amounts sufficient to prevent skeletal defects will be adequate for the formation of teeth with normal composition and structure in the average well child. There is no conclusive evidence that the caries attack rate for fully formed erupted teeth is affected by the addition of calcium and phosphorus, even to a low normal diet. Further, there is no evidence to indicate that normal children require more calcium than is supplied by a diet adequate to meet the total nutritional requirements. Such a diet will contain approximately one quart of milk per day. There is ample evidence to support the conclusion that calcium of milk is absorbed better than calcium present in any other form.

Studies concerning vitamin D.-- In the studies of 233 children observed through age two, 153 through age four, and 53 through age 5, Rhoads and Rapoport, et al., found that there was some tendency for higher incidence of caries for those receiving cod liver oil over those receiving irradiated evaporated milk. The study indicated the importance of a continuous source of vitamin D as a factor in reducing the incidence of caries between the ages of four and one-half and six.

King, in the British Medical Bulletin, stated that

1/op. cit., p. 449.

2/op. cit., p. 223.
"...clinical investigations of M. Mellanby and her colleagues have shown clearly that nutritional factors such as vitamin D are of real significance in determining dental health, not only during the period of tooth development but even after calcification is complete. No claim is made that increased consumption of foodstuffs rich in vitamin D, calcium, and phosphorus will do more than reduce the ravages of caries."

East and Kaiser, in studies reported by McBeath and Verlin in the Journal of the American Dental Association, found that the caries records of communities is a reflection of the vitamin D produced in the body by sunlight. That is, the more adequate the available sunlight of a given region, the lower the caries rate. This report signified the use of vitamin D in any form. It was stated that cod liver oil "showed unmistakable improvement in the caries situation according to the dose given."

There is evidence to contradict the sunshine theory. For example, with sunshine there are good teeth in the U. S. South, and bad teeth in South Africa. And where there is a lack of sun, you find good teeth where Eskimos live, and bad teeth in England. The numerous variable factors are ever at work.


2/Elmer V. McCollum, op. cit., p. 53.

Summary of value of vitamins A, B, C, D, and nicotinic acid.-- Although various other studies point out the value of vitamins A, B, C, D, and nicotinic acid to development of gingival epithelium, ulcerative lesions of gums, and rickets, there is very little clear-cut evidence in relation to their effect on dental caries. This is in accord with the findings of the Michigan Workshop. One bit of possible evidence is advanced in the Journal of Pediatrics for October, 1947. In a study of "Dental Caries Experience in Postwar Italy among Teen-Age Children in Naples," it was noted that the vitamin B deficiency may have inhibited caries, inasmuch as both nicotinic acid and thiamin are necessary for the complete degradation of carbohydrates to their acid end-products in the mouth.

Relation of fluorides to caries.-- Attention should be

1/Hamilton B. G. Robinson, op. cit., p. 54 ff.
given to the relation of fluorides to caries. Studies show that people born and raised in communities where there are one or more parts per million of fluorine in the drinking water have less decay than those who live where there is no fluorine in the water. Although there is no complete agreement as to how fluorine acts, it is indicated that the effectiveness is derived in part from its ability to render the tooth substance less soluble in acid. Experiments have shown that the acid solubility of tooth enamel is reduced.


after exposure to fluoride solutions. The best results come from continuous use of water containing fluorine during the first twelve to fifteen years of life, when the teeth are developing. In tests made by Knutson and Armstrong over a three-year period, the application of sodium fluoride directly to teeth was found to have reduced the caries' incidence as much as 36 to 41 per cent.* However, the application of sodium fluoride has not as yet been determined a panacea. Some react well, and others not at all. Dr. Henry Klein, the United States Dental Health Administrator, has studied this issue and has found that children who get the most benefit from fluorine have had parents with better-than-average teeth. Moreover, Massler and Schour, in their studies of 162 Naples (Italy) children, found that fluorides were of no influence: there was no significant amount of fluorine in the Naples water supply. Massler and Schour have stated also that:

"The ingestion of water containing more than five


4/"Dental Caries Experience in Postwar Italy among Teen-Age Children in Naples," op. cit., p. 438.
pants per million of fluoride during a protracted period of enamel (crown) formation and calcification results in a characteristic mottling of the enamel in 90 per cent of children. In 35 per cent, the enamel may be subject to hypoplasia, and is permeable by oral stains, often appearing brown. The ingestion of water containing about two parts per million of fluoride results in mild mottling in approximately 50 per cent of children. The ingestion of water containing one part per million of fluoride results in a mild mottling of the enamel (chalky white spots) in about 10 per cent of exposed persons.1

Evidence is inconclusive concerning the experiments in several cities where fluorine has been added to the drinking water supply. Nevertheless, some help is anticipated.

Recent reports on a carefully controlled community experiment with the fluoridation of drinking water at Newburgh and Kingston, New York, reveal a 30 per cent reduction in dental caries in those communities. The greatest reduction was found in the younger children, since their permanent teeth had the greatest exposure to the fluoride during tooth formation.

Regardless of instances of contrary findings, it is believed generally at this time that fluorides found in waters and foods have shown the most promise as a means whereby the ingestion of an element during tooth development may serve in turn as a partial protection against the caries process. The American Dental Association and the United

States Public Health Service both have recommended the controlled fluoridation of the community water supply as a safe and practical means of cutting down dental decay.

**Malnutrition.--** There is sufficient evidence to suggest that the incidence of caries is not increased in areas of lowered nutrition or malnutrition. A number of studies have been conducted in various famine-stricken countries. There had been extreme shortages of foodstuffs in these countries, and malnutrition was countrywide. From England, Norway, and Italy, where nutritional standards were lowered during the war years, reports point out that the incidence of caries was lowered. Nearly all reports stress the factor of a lowered sugar intake.

In the United States, studies made in or near


Birmingham, Alabama, indicate that the incidence of caries is lower in malnourished patients than in well-nourished persons. 1/

Day, in his studies of teeth in the Kangra district of northern India, noted that deficiency diets led to rickets and osteomalacia but that the caries incidence and experience was low. Day also noted that there was almost complete absence of sugar in the diet. He concluded that the physical nature of the diet is of greater importance in preventing and controlling dental caries than is the chemical and vitamin content.

In Norway during World War II. In Norway, Dr. Toverud reported that dental decay of Norwegian children had decreased 60 to 80 per cent during World War II. This decrease in decay resulted partly from the wartime diet which contained a low amount of refined carbohydrates, especially sugar and the sugar products. Norwegians also ate more of the natural foods such as fish, salted herring, potatoes, and carrots--foods high in calcium, phosphorus, iron, and vitamins A, B, C, and D. Since 1940 eight to nine thousand children aged seven to fourteen have been examined. An even greater reduction of caries during the war years was


2/Loc. cit.
noticed in children aged two and one-half to seven. The minerals present in the natural foods built up good resistance of the teeth to decay, while lack of carbohydrates in the diet lessened the amount of bacterial activity. Since 1945 dental decay in pre-school children has increased 30 to 40 per cent, Dr. Towerud found. It is to be noted that there was an increased ingestion of carbohydrates at this time.

In famine-ridden India.-- In famine-ridden India, where diet was poor and where severe malnutrition was exhibited, examination of over two hundred teen-age boys showed only $\frac{1}{1.56}$ cavities per boy. In contrast, children of the same age in Rochester, New York, had thirty-five times as many decayed teeth.

Studies of Dr. H. H. Neumann, a former medical officer of the New Zealand Health Department, demonstrated that caries was absent in cases of severe malnutrition and rickets.

In postwar Naples, Italy.-- Massler and Schour


4/"Dental Caries Experience in Postwar Italy among Teen-Age Children in Naples," op. cit., p. 431.
selected 162 teen-age children in postwar Naples (Italy) to show nutritional deficiencies. Food intake was low in quantity and deficient in quality, only about 50 per cent of the required proteins and calories being available. In spite of these factors, the caries experience was very much lower than in teen-age children in the United States. These findings seem to contradict the theory that good nutrition will arrest or prevent the progress of decay. Massler and Schour state that there is sufficient evidence to suggest that the incidence of caries is not increased in areas of lowered nutrition or even malnutrition. Similar age groups in the United States were compared to the Naples group. Prevalence of caries in the United States was more than twice that of Naples, in which group 35 per cent of the children surveyed were free of caries.

The relation between good nutrition and a protective influence against dental caries was not borne out by this study. The low refined sugar intake in Italy and the high refined sugar consumption in the United States may in part be the explanation. The role of the vitamin B deficiency may also be a factor.

Study of malnourished patients by Mann and others.---

In a study of 223 patients by Mann and others, it was

1/ A. W. Mann, et al., op. cit., p. 244.
found that the malnourished patients showed an incidence of dental caries only 30.5 per cent as great as that of the patients in the well-nourished group. Of the 223 patients, a per patient average of 2.07 tooth surfaces decayed was indicated, as compared to a per patient average of 3.21 tooth surfaces decayed in the 99 members of the control group.

According to Drs. Spies, Stone, Dreizen, and Greene of Northwestern University, Chicago, Illinois, and Hillman Hospital of Birmingham, Alabama, "...people on such poor diets that they get pellagra or other vitamin deficiency diseases, rarely have decayed teeth. But they are very susceptible to pyorrhea, and as a result may lose their teeth before they are forty years old."

3. Diet

Effects of sugar in diet.-- In the studies mentioned, it was noted that decreases in dental caries accompanied a restriction of the diet, notably a decline in the intake of sugar. The study of the dental records of children in Norway is of special interest. Here it was noted that after the war, when sugar was again available, an increase in sugar consumption was followed by a marked increase in dental caries.

When considering the relation of sugars in the diet, it

is necessary to recognize that a considerable number of 
people eat freely of some form of carbohydrates yet are 
caries immune, or nearly so. Some are immune during a 
period of years and then become susceptible. The most 
plausible reason given is that the offending organisms find 
the mouth environs unfavorable, due to some systemic 
condition.

Formation of acids.-- The concept that dental caries is 
caused by acids formed by carbohydrates, acted upon by 
enzymes produced by micro-organisms in the mouth, is not a 
new one, but the process is complex because of the many 
variables. According to Fosdick, the degradation of 
carbohydrates to lactic acid follows a series of reactions. 
It has been found that certain microbial enzymes cause the 
process to take place faster than others. Fosdick suggests 
that organisms such as the lactobacillus and yeast may have 
a symbiotic relationship in this respect. There must, however, 
be carbohydrates in the diet before the process of caries is 
possible. The fermentable sugars are most readily broken 
down to lactic acid, while an additional chain of reactions


2/L. S. Fosdick, "Carbohydrate Degradation by Mouth 
Organisms," Journal of the American Dental Association 
(March, 1939), 26:415.

3/L. S. Fosdick, "Degradation of Sugars in the Mouth and Use 
of Chewing Gum and Vitamin K in Control of Caries," Journal 
of Dental Research (April, 1948), 27:235.
is required for the starches. There must always be an adequate enzyme or coenzyme system present. The literature affords a number of articles to advance these theses and the indication that the restriction of sugar, either refined or natural, is effective in the control of dental caries. The Michigan Workshop further stated that "...the harmful effects of sugar, refined or natural, are not reduced by the addition of either vitamins or minerals." 

Effects of decreased sugar intake in Naples.—Concerning their study in Naples, Massler and Schour state that the most prominent common factor for the lowered prevalence of dental caries has been the marked decrease in the refined sugar intake. Massler and Schour's study also notes that people may eat freely of starchy foods and yet

1/L. S. Fosdick, "Degradation of Sugars in the Mouth and Use of Chewing Gum and Vitamin K in Control of Caries," loc. cit.


4/J. D. Boyd, op. cit., p. 211.


6/Loc. cit.

remain relatively free from caries, provided the intake of refined sugar is low.

Studies on starch foodstuffs.—Studies by Drs. H. W. Haggard and L. A. Greenberg, physiologists of Yale University, were reported in the Science Newsletter of December 10, 1949. They point out that trying to avoid tooth decay by avoiding sugar is impractical because almost all starch foodstuffs produce sugar in the mouth, and micro-organisms involved in tooth decay make no distinction as to the source of the sugar. Their studies were made at five-, ten-, twenty-, and forty-five-minute intervals after the following foods were eaten: a mixed meal; fresh orange juice; grapefruit juice; ice cream; crackers; chewing gum; caramel candy; and sweetened, bottled soft drinks. A caramel and orange juice each brought the sugar content of saliva almost to the same high concentration of 800 mg. per 100 c.c., and it took forty-five minutes before this concentration dropped to the point reached by the orange juice concentration after twenty minutes.

Additional evidence concerning sugars in diet.—From an analysis of the literature the writer believes that tooth decay can be reduced, in many cases, by cutting down on sugars. Sugars are shown to be especially dangerous because practically everyone can convert them to acid in the mouth, whereas only about 10 per cent of the people can reduce
starches all the way down to the acid state in the oral cavity. It is possible to do without carbohydrates to a greater extent, as demonstrated, for example, in the case of diabetics.

Everard C. Turner, in the British Dental Journal, adds more fuel to this concept. He explains that an average of 80 per cent of the rich people in Rome, eating mostly cooked foods and sugars, had caries; that 50 to 60 per cent of the poor people in Rome, eating mixed foods (cooked and crude), had caries; and that 20 to 30 per cent of the poor people in Rome Compaigne had caries after subsisting on uncooked food and hard bread. Turner indicates also that the Eskimos had no caries until they came in contact with the white man's food. The original Eskimo diet of fats, proteins, and about 10 per cent carbohydrates has been so modified that 50 per cent of their calories now come from carbohydrates. Steffanson, who has made many studies of the Eskimos, observes:

"...the only thing that matters greatly in regard to the health of the teeth is the chemical composition of the diet--the higher the percentage

1/Elmer V. McCollum, op. cit., p. 49.


of carbohydrates and the lower the percentage of animal proteins and fats, the greater the tooth decay."

1/ Sherman and Lanford indicate that high intakes of protective foods and a low consumption of sugar are both important. Sprawson presents the concept:

"...if proteins stagnate in the mouth but little decalcifying reaction can be produced, while alkaline products are produced in excess so that the general reaction is alkaline and cannot affect enamel; fats are practically unchanged in the mouth and so cannot directly affect it; water is neutral and therefore inert; and salts expressed mainly from vegetable foods are mainly neutral; but in any case the vegetable matter from which they are expressed acts as a toothbrush so that they cannot remain static. But carbohydrates are another question entirely. They are the one food that civilized man takes in an ultra-refined form and often to excess. Both chemically and physically he takes them...in such forms that they may stagnate, adhere to, or remain in prolonged contact with the enamel. In these forms they constitute the one food which may on fermentation produce an acid reaction—and in contact with the enamel."

Sprawson also claims that "...sugar has a strong chemical affinity for calcium, and in prolonged immersion and incubation of the crowns of the teeth in glucose solution, such as might occur in a confirmed sweet eater, the calcium is abstracted from the enamel." Dextrose in jams and sweets, he says, is a source of great potential dental harm. And, furthermore, "...in the United States of America a common

cola beverage which contains the disaccharide sucrose and phosphoric acid has a pH of 2.6. [This] cola causes a rapid and severe destruction of the enamel." Actually the pH below five is not a significant factor alone, because of other uncontrolled variable factors. However, when the pH of five or less continues for any length of time, the time factor does become important and emphasizes the pH.

**Effect of frequency of sugar intake.** -- Another important factor in the caries process is the frequency with which sugars are taken into the mouth. In an investigation conducted by Stephan and Miller, it was noted that when a 10 per cent glucose solution was used as a mouth rinse for two minutes, there was a rapid drop in pH and that the drop might remain for an hour or more. Thus a child who consumed refined sugars at intervals throughout the day would have more caries than the sporadic eater, if the other variables were similar. This suggests also that much damage is done during or shortly after meals.

Although there are differences of opinion as to the relation of diet to the caries problem, there seems to be a...
general concept that the restriction of sugar, either refined or natural, is effective in the control of dental caries. Listed among the undesirable elements in the diet are: too much sugar on cereal; heavily sweetened milk; rich pastries; sweet desserts; oversweetened carbonated beverages; ice cream; candy; maple syrup; jams; jellies; and cakes.

**Appetite for "sweets" and difficulty of control.**—On this subject *Hygeia* (August, 1947) presented the following information: that some soft drinks contain six teaspoons of sugar per bottle (*Hygeia* states that "...this is sugar in concentration"); that the average consumption of sugar has increased from 10 pounds per person per year in the 1800's to the present intake of 125 pounds per person annually; and that the United States Department of Commerce reported $520,000,000 wholesale was spent in ten months for candy to satisfy our national sweet tooth.

It is difficult to control the use of carbohydrates—especially sweets—because of the tremendous appetite for them. They are palatable, inexpensive, available, and certainly well advertised. The advertising of candy has even reached into a dental trade magazine with a circulation of 69,000 copies per month, which is received by most dentists.


in the United States. No mention was made either in the article or the magazine that refined sugar is used in the manufacture of candy and that candy usually runs from 75 to 85 per cent sugar. Popular candy bars are likely to weigh from one to two ounces and may contain five or more teaspoonfuls of sugar.

Dietary habits.—Since 1940 the per capita food supplies in the United States have been bountiful compared to other parts of the world, and the per capita volume has remained fairly constant during the last three decades. However, the relative importance of foods has shifted. There has been a rise in the consumption of sugar and citrus fruits and an upward trend in the use of dairy products. On the good side of the ledger has been the increase of dairy products, fresh fruits, and vegetables; on the bad side is the increase in consumption of refined sugar.

Genetic factors less important than character of diet.—Massler and Schour, in a comparison of 162 teen-age Naples children with 500 children thirteen years of age of Italian descent in Rochester, New York, concluded that genetic factors are less important in the caries problem than is the character of the diet. In this comparison it was evidenced


that the Rochester, New York, children showed the same prevalence of caries as other American children on the same diet with a high refined sugar intake.

Need for adequate diet.-- In relation to the adequacy of the diet, the Michigan Workshop Committee found no conclusive evidence that an adequate, optimal, or balanced diet as outlined by the Food and Nutrition Board, National Research Council, would influence the caries attack rate. However, a diet conducive to good general health was advocated. In addition, the Committee noted that there was no substantial evidence that fibrous foods, uncooked fruits or vegetables, or the so-called detergent foods reduce the caries attack rate.

1/Loc. cit.
CHAPTER IV
SUMMARY OF THE PROBLEM

Importance.-- The growth and development of children is aided or hindered by the development of their teeth. The mastication of food, speech, and the stimulation necessary for the proper growth of the gums, jaws, and face are all dependent upon the proper growth and development of the teeth. Loss of primary teeth too early may lead to the improper formation of the secondary teeth and malformation of the jaws and the face. In turn, further disturbances may manifest themselves through physical disorders or personality difficulties. It is necessary, therefore, that we direct our attention to certain factors which may hinder good tooth development. Caries is one of these.
CHAPTER V
INTERPRETATION OF THE FINDINGS

1. Ninety-two per cent of the population of the United States are victims of dental caries. By the age of fifteen years, more than 95 per cent of the boys and girls have had one or more permanent teeth attacked by caries.

2. As the child grows older, his probabilities of acquiring caries become greater.

3. The most common theory of dental caries considers that it is initiated by the action of bacteria, normally present in the mouth, on sugars and starches. In the process acids are produced. These acids form on the sticky surface film of the teeth. Unless the action of the acid is inhibited, the inorganic portions of the enamel dissolve and bacteria enter the teeth. Decay begins to accelerate after this.

4. Before and during pregnancy, an optimal diet with good nutrition is best for the well-being of both the mother and the fetus.

5. Well-nourished pregnant women do not need to ingest more calcium than is supplied by a diet adequate to meet total nutritional requirements.
6. It is advisable to provide the child with calcifying factors throughout childhood. Although calcium and phosphorus metabolism still are not completely understood, it is generally believed that the ingestion of these two substances in amounts sufficient to prevent skeletal defects will be adequate for the formation of normal teeth. The National Research Council recommends a daily allowance of 1.00 gm. of calcium for children to age twelve, and 1.00 gm. of phosphorus to age four. For ages four to twelve, an intake of 1.20 gm. of phosphorus is recommended.

7. There is no conclusive evidence in the literature that deficiencies of vitamins A, B, or C will have any significant effect on the caries attack rate.

8. Vitamin D is of value in the formation of the hard dental structures. There is also the possibility of increased susceptibility to caries in teeth formed during vitamin D deficiency.

9. Vitamin D may be taken in any form. There is no conclusive evidence that one form or another will provide significant differences in the caries attack rate.

10. Nutrition does not appear to have any significant bearing on the caries process. However, it is advisable to maintain good nutrition for general well-being.

11. Controlled fluoridation, with about one part fluorine per million parts of water, is anticipated as the most
effective method of mass prophylaxis found to date. The process is aimed primarily at children, so that the fluoride is incorporated into the tooth structure during the period of tooth formation. The use of fluorides in drinking water must be properly controlled by experts on a community basis, not as an individual measure.

12. Neither lowered nutrition, subnutrition, malnutrition, nor famine is in itself a cause of caries.

13. Studies have demonstrated that the reduction of sugar and refined cereal starches in the diet will cause marked reduction of tooth decay. It is advisable that sugar in the diet be kept low. This is especially important for children.

14. There is no agreement that diet plays the major role in dental caries. However, there is sufficient evidence to believe that the local environmental substances found in the mouth in connection with the diet do help to initiate the caries process.
CHAPTER VI
CONCLUSIONS

Evidence concerning the relation of diet and nutrition to the problem of dental caries is not now conclusive. There is much research yet to be done. The most widely held theory at this time is that the initiating force is believed to be the action of bacteria normally present in the mouth on sugars and refined starches which are parts of the diet.
CHAPTER VII
RECOMMENDATIONS

1. A diet should be selected which will provide adequate nutrition and which will promote the normal growth and development of the body, including the teeth.

2. The sugar intake should be restricted.

3. The teeth should be brushed immediately after each meal. The brushing should be thorough, to remove the sticky film which may be the bacterial plaque.

4. Fluorides should be utilized under the controlled techniques of experts. Fluorides are best utilized in at least the first twelve years of life, when the teeth are in the developmental and calcifying stages.

5. Regular visits should be made to the dentist for thorough, methodical checks of teeth and mouth. This preventive care probably is the best plan. It is undoubtedly the most satisfactory, and may well be the least expensive.
CHAPTER VIII

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