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DIET TO INCREASE

TOOTH RESISTANCE TO DENTAL CARIES

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SUMMARY

Diet is a neglected science in Taiwan, as well as in many other countries. By the year 2000, the goals of the World Health Organization and the International Dental Federation are to reach 65 per cent caries free for 5 to 6 year old children and 3.0 DMFT per 12 year old child. Diet is one of the preventive measures that can be utilized to reach these goals.

The thesis places emphasis on diet to increase tooth resistance and demonstrates individual nutritional requirements for stronger tooth structure. The writer also provides a recommended daily diet to increase tooth resistance.

In general, nutrients which are good for systemic health are likely to be good for dental health. Nutrients include calcium, phosphorus, vitamin A, vitamin D, magnesium, fluoride and protein. These nutrients are essential in the formation of dental enamel, dentine, and cementum.

While the tooth is developing and before the crowns of the teeth are fully formed, calcium and phosphorus have an important role in enamel composition. The best food sources of calcium and phosphorus are milk and milk products, such as whole dry milk (calcium 9mg/gm, phosphorus 8mg/gm).

Vitamin A ensures proper formation of tooth enamel and dentine. The best food source of vitamin A is liver, whether beef, pork, lamb, goose, or any other animal liver (Beef liver 349 IU/gm).

Vitamin D has remineralization and recrystallization action to

increase tooth resistance. The food which is the richest in vitamin D is herring (3.3 IU/gm).

Magnesium acts as a cofactor in the transfer of phosphate and the mobilization of calcium. Kelp abounds with magnesium at a level of 7.3 mg/gm.

Concerning fluoride, the dental profession should continue to strive for water fluoridation of every community with a central supply. For residents in fluoridated water communities the dental incidence should be reduced by 50 to 60 percent. Fluoride is the most important and practical nutrient to increase tooth resistance. The mechanisms of fluoride are: increased tooth enamel resistance; increased rate of maturation; remineralization of incipient lesions; reduction of demineralization; improved tooth morphology; and cariostatic and antibacterial actions. Dietary sources of fluoride other than fluoridated water include fish meal (80-250 ppm). Sea food is a very good source of fluoride (Sardine 8-40 ppm; shrimp shell 18-48 ppm; and shrimp meat 0.4 ppm).

Protein ensures normal tooth eruption. The best food sources of protein are meat and sea food (Pork bacon, canadian style 0.2 mg/gm, salmon 0.22 mg/gm).

While many of the functions of those nutrients found in a healthy diet must still be scientifically established for their effectiveness in increasing tooth resistance, the writer has utilized current available information to compile Nutrient Allowance Charts for specific groups in the population, and tables containing foods and food composition believed to be more likely to increase tooth resistance to dental caries.

The writer has shown how data from the Nutrient Allowance Charts and Tables of Foods and Food Composition can be utilized to compile daily food servings which are recommended to increase tooth resistance to dental caries.

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1 INTRODUCTION

The relevance of food, nutrient, and diet to both oral and general health is interrelated between the three.

Food is defined by Sinclair et al (1987) to be what people and animals eat and without which living things can not grow.

According to Humphrey et al (1974) "food" is defined as any substance other than water that can be taken into the body of an organism for its maintenance, growth, and reproduction or provide energy for other activities.

The authors pointed out that "nutrient" is a substance that is absorbed into a plant or into the body of an animal and that helps it to grow, whereas "diet" is the food that a person or animal eats regularly.

Humphrey et al (1974) stated that nutrition is the process of taking food or nutrients into the body and absorbing them. All living things need nutrition in order to grow and stay healthy. Nutrition deals with the relation of food substances to body function and health.

A general definition of nutrition according to McDonald (1974) is " that science which deals with food nutrients and their role in attaining and maintaining health."

The recognition of nutrition, the evaluation of diet, and the design of appropriate recommendations for nutritional improvement to increase teeth resistance are important phases of preventive dental care.

1.1 DIET IN GENERAL

Kirschmann and Dunne(1984) have stated that nutrition is the relationship of diet to the health of the human body. Proper nutrition means that all the essential nutrients from diet are supplied and utilized in an adequate balance to maintain optimal health and well-being. Nutritional deficiencies result whenever inadequate amounts of essential nutrients are provided to tissues that must function normally over a long period of time. Good nutrition is essential for: normal organ development and functioning, for normal reproduction, growth, and maintenance; for optimum activity level and working efficiency; for resistance to infection and disease; for the ability to repair bodily damage or injury; and for increased tooth resistance.

Kirschmann and Dunne (1984) have emphasized that no single substance will maintain vibrant health. Although specific nutrients are known to be more important in the functions of certain parts of the body, even these nutrients are totally dependent upon the presence of other nutrients for their best effects. Every effort should therefore be made to attain and maintain an adequate, balanced daily intake of all the necessary nutrients throughout life.

In Taiwan there is a need to justify the importance of choosing the right nutrients and adequate daily amounts for specific groups of the population. For most people living in Taiwan today, there is no problem getting enough to eat. All kinds of food are available and people have access to whatever food they

want. However they do not know how to control their diet, so that there is a high prevalence of diet related diseases such as: high fat in the blood, renal function disorder or uremia and cardiac infarct. The most prevalent disease in Taiwan is dental caries.

Taiwan has become a rich country with overseas trade balance second in the world, after Japan and followed by West Germany. Because Taiwan is a prosperous commercial and industrial country, people entertain and tend to eat too much. Too much money is spent on eating, without knowing what is good to eat. Yet, with a marvellous range of foods to choose from, many Taiwanese are not eating healthy diets or correct dietary amounts.

In fact, researchers regularly uncover new evidence that many health problems are related to what people eat and drink. There are undoubtedly many reasons for this, but one step in the right direction is to seek out correct information on diet and apply it to eating habits.

Nowadays the role of the diet has become part of medicine. There are consultant natural therapists or dietitians working and serving in modern hospitals, both public or private. They prescribe diets for special groups of people or patients, such as diet in pregnancy, lactation, and children's meals; diet for adolescents; diet for elderly patients; diet for people who undertake strenuous physical exercise or training; diet for overweight or under weight; diet for postoperative care patients; for uremia; for hypertension; for cardiac disease; and

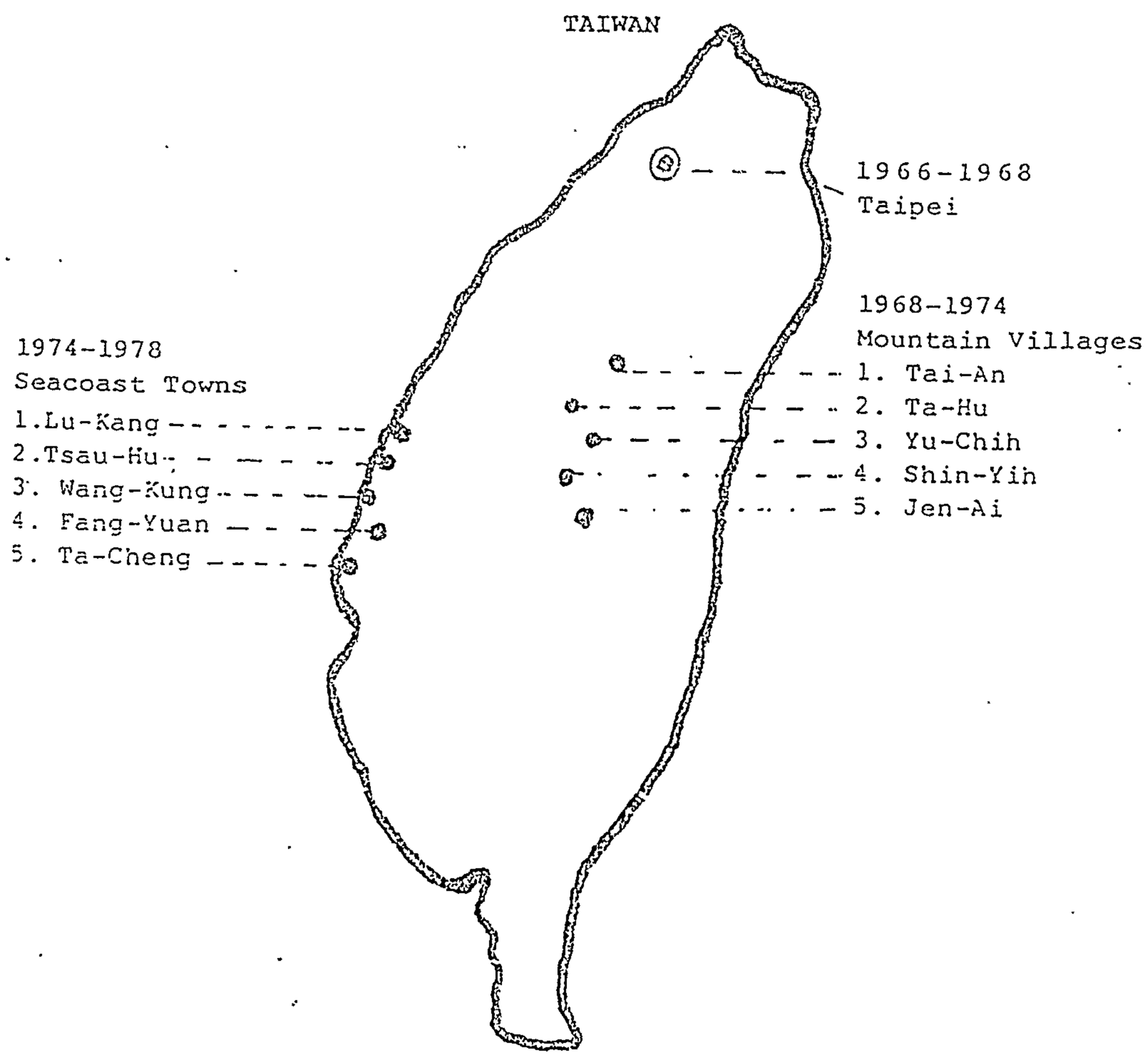
diabetes and so on.

Diet takes on a very important role in preventive medicine and practical medicine for the health of the population.

1.2 DIET IN CARIES

The clinical experience of the writer as a dentist in Taiwan has suggested the importance of choosing a nutritious and healthy diet to increase tooth resistance to dental caries.

The writer has been practising dentistry for more than twenty three years and when serving in Chang Hwa Christian Hospital as chief of the Dental Department, used to go out treating poor people. This was charity treatment, and involved screening school children for several years between 1966 and 1978. Each time the team, with residents and nurses, spent three days to one week in a certain suburb or village.



During this work in Taipei, between 1966 and 1968, the writer noticed a low incidence of caries among FU-SHING primary school children in a high socioeconomic area. These children had a wide variety of foods and a highly nutritious diet. Between 1968 and 1974, visits were made in the mountain villages and specifically in Tai-An, Ta-Hu, Yu-Chih, Shin-Yin and Jen-Ai. These people have a simple diet with a lot of vegetables and little meat as their main diet and their sugar consumption is low. They had a high incidence of caries and poor oral hygiene with halitosis. Between 1974 and 1978, several towns near the seacoast were visited; Lu-Kang, Tsau-Hu, Wang-Kong, Fang-Yuan, and Ta-Cheng. These people live on fish. It was noticed that the people have a high incidence of mottled enamel and low incidence of dental caries. After studying their diet it was found that their main diet was fish.

After studying all these results from these three groups the writer was convinced that there is a strong link between diet and teeth resistance and the prevalence of dental caries.

1.3 AIMS OF THE THESIS

In order to reduce dental caries by "increased tooth resistance," dental educators need to place a much greater emphasis on education and research. Community participation should be encouraged, by way of lectures and distribution of written material such as manuals and brochures.

Diet should be carefully studied as it is the most important

intake in daily life both maintaining, and sustaining good teeth and well-being of the individual.

The aims of this thesis are to:

Investigate the link between diet and tooth resistance so that the public could be informed of a healthy diet that would be of benefit to their oral health.

Investigate those diets that could increase tooth resistance during the development of the tooth and maintain the tooth in a healthy state once erupted.

Emphasize the importance of diet during the developmental period of the tooth, especially before eruption and during formation and maturation.

Review the literature and to select all the information concerning diet to increase tooth resistance.

The final aim is to compile a table of dietary intake that would be appropriate for increasing tooth resistance in specific groups of the populaton.

2 BIOLOGY OF THE TEETH

Adams(1981) has stated that teeth are generally considered to have evolved from epidermal scales which were situated around the mouth in primitive animals. In man the teeth are less specialised than in many other animals. There is some degree of variation in that the anterior teeth are adapted for incising and the posterior teeth are adapted for crushing and mixing. Another change is that man in common with most mammals now has only two sets of teeth, deciduous and permanent. The first dentition lasts for a comparatively short time until the jaws are large enough to accommodate the permanent teeth.

There are thirty-two teeth in the permanent dentition and these are symmetrically arranged with eight teeth in each of four quadrants, right and left, upper and lower. The deciduous dentition contains twenty teeth as there are no premolars and only two molars in each quadrant.

2.1 THE ERUPTION OF THE TEETH

Melfi (1988) has defined tooth eruption as the combination of bodily movements of the tooth, both before and after the emergence of its crown into the oral cavity. The process serves to bring the tooth into position and maintain it in occlusion with the teeth of the opposing arch. Tooth eruption begins at the time the crown is completed and the root starts to form and continues throughout the life of the tooth.

Melfi (1988) explained that in its simplest form tooth

eruption may be pictured as the occlusal movement of the tooth brought about, partly, by the lengthening of the root and the development of additional bone beneath the root.

2.1.1 THE DECIDUOUS TEETH

Bhaskar(1986) has described the eruption phase as physiological tooth movement, when significant developmental changes occur, including the formation of the roots, periodontal ligament, and dentinogingival junction of the tooth.

Mjor and Fejerskov (1986) in describing the eruption of teeth have stated that before a tooth can take up its functional position in the dental arch, it must move from the site of its development in the body of the jaw to the occlusal plane. The chief movement is in an incisal or occlusal direction, but the teeth may also rotate, drift mesially or undergo a tipping movement. To reach the occlusal plane the teeth must move successively through the overlying bone, lamina propria and epithelium.

The rate at which a tooth erupts is different at different stages of eruption. First there is a relatively slow period at the start of eruption. This is followed by a faster period as the tooth moves through the overlying tissues. Finally, there is a period during which the tooth approaches the occlusal plane, when the rate of eruption slows.

Mjor and Fejerskov (1986) have suggested that the forces responsible for eruption could be provided by: firstly,

development and consequent elongation of the root; secondly, apposition of bone between the end of the developing root and the pre-existing bone; thirdly contraction by the gubernacular cord; fourthly, contraction of the obliquely inclined cells of the periodontal ligament could pull the tooth out of its socket; and finally, blood pressure or the pressure of interstitial tissue fluids could provide a force for eruption.

Mjor and Fejerskov (1986) have found from current evidence that: firstly, the force or forces responsible for moving the tooth in a coronal direction remain to be defined.

Secondly, more than one force may be responsible and different forces may be implicated at different stages of eruption.

Thirdly, by a process of elimination but in the absence of direct evidence, it is reasonable to hypothesize that blood pressure or interstitial pressure is responsible for the initiation and the movement of the tooth during at least the early part of the eruptive process, but that contraction of the cells of the periodontal ligament could contribute a force afterwards.

Finally, the dental follicle regulates resorption of bone lying in the path of the erupting crown.

2.1.2 THE PERMANENT TEETH

Mjor and Fejerskov (1986) have stated that a pre-requisite for normal eruption of permanent incisors, canines, and premolars, is resorption of the roots of the primary teeth. Resorption of the primary teeth is a physiological phenomenon, and results in shedding of these teeth. During the initial stages of ruption of the permanent successor the bone between the rimary and the permanent tooth is resorbed. After the bone all is lost, resorption of the hard tissues of the primary ooth takes place. Resorption of the primary tooth may start before all the bone between the primary tooth and its permanent successor is resorbed.

Jenkins (1978) has also emphasized that resorption is brought about by the activity of osteoclasts (odontoclasts). Usually, resorption begins on that part of the root adjacent to the permanent crown. The pressure of the growing and erupting permanent successor provides an important stimulus to the resorption process.

Melfi (1988) has described the process of shedding and stated that when the odontoclast resorbs cementum it may be called a cementoclast, and when it resorbs dentin it may be called a dentinoclast. Cementoclasts and dentinoclasts are found along the root of a primary tooth undergoing shedding.

2.1.3 CHRONOLOGY OF THE HUMAN DENTITION

Chronology of the human dentition is based on the work of Logen and Kronfeld (slightly modified by McCall and Schour)

Table 1 Chronology of the human dentition

(Bhaskar 1986 p372)

Tooth	Formation of enamel matrix and dentin begins	Amount of enamel matrix formed at birth	Enamel completed	Emergence into oral cavity	Root completed
Primary dentition					
Maxillary					
Central incisor	4 mo. in utero	Five sixths	1½ mo	7½ mo.	1½ yr.
Lateral incisor	4½ mo. in utero	Two thirds	2½ mo	9 mo.	2 yr.
Canine	5 mo. in utero	One third	9 mo	18 mo.	3¼ yr.
First molar	5 mo. in utero	Cusps united	6 mo	14 mo.	2½ yr.
Second molar	6 mo. in utero	Cusp tips still isolated	11mo.	24 mo.	3 yr.
Mandibular					
Central incisor	4½ mo. in utero	Three fifths	2½ mo	6 mo	1½ yr.
Lateral incisor	4½ mo. in utero	Three fifths	3 mo.	7 mo.	1½ yr
Canine	5 mo. in utero	One third	9 mo.	16 mo.	3¼ yr.
First molar	5 mo. in utero	Cusps united	5½ mo.	12 mo	2¼ yr
Second molar	6 mo. in utero	Cusp tips still isolated	10 mo	20 mo	3 yr.
Permanent dentition					
Maxillary					
Central incisor	3-4 mo.			7-8 yr.	10 yr.
Lateral incisor	10-12 mo.			8-9 yr	11 yr.
Canine	4-5 mo.			11-12 yr.	13-15 yr.
First premolar	1½-1¾ yr.			10-12 yr.	12-13 yr.
Second premolar	2-2¼ yr.			10-12 yr.	12-14 yr.
First molar	At birth	Sometimes a trace		6-7 yr	9-10 yr
Second molar	2½-3 yr.			12-13 yr.	14-16 yr.
Third molar	7-9 yr.			17-21 yr.	18-25 yr.
Mandibular					
Central incisor	3-4 mo.		4-5 yr	6-7 yr.	9 yr.
Lateral incisor	3-4 mo.		4-5 yr	7-8 yr.	10 yr.
Canine	4-5 mo.		6-7 yr.	9-10 yr.	12-14 yr.
First premolar	1¾-2 yr.		5-6 yr	10-12 yr.	12-13 yr.
Second premolar	2¼-2½ yr.		6-7 yr.	11-12 yr.	13-14 yr.
First molar	At birth	Sometimes a trace	2½-3 yr.	6-7 yr.	9-10 yr.
Second molar	2½-3 yr.		7-8 yr.	11-13 yr.	14-15 yr.
Third molar	8-10 yr.		12-16 yr.	17-21 yr.	18-25 yr.

*From Logan, W.H.G., and Kronfeld, R.: J. Am. Dent. Assoc. 20:379 1933, slightly modified by McCall and Schour.

2.2 TOOTH STRUCTURE AND COMPOSITION

The tissues which make up a tooth are the enamel, the dentin, the cementum, and the pulp. Figures (1) and (2) are diagrams of teeth which have been cut approximately through the middle in a faciolingual direction.

Figure 1 Diagrammatic drawing of a longitudinal faciolingual section of a maxiliary first premolar.

(Permar 1982 p18)

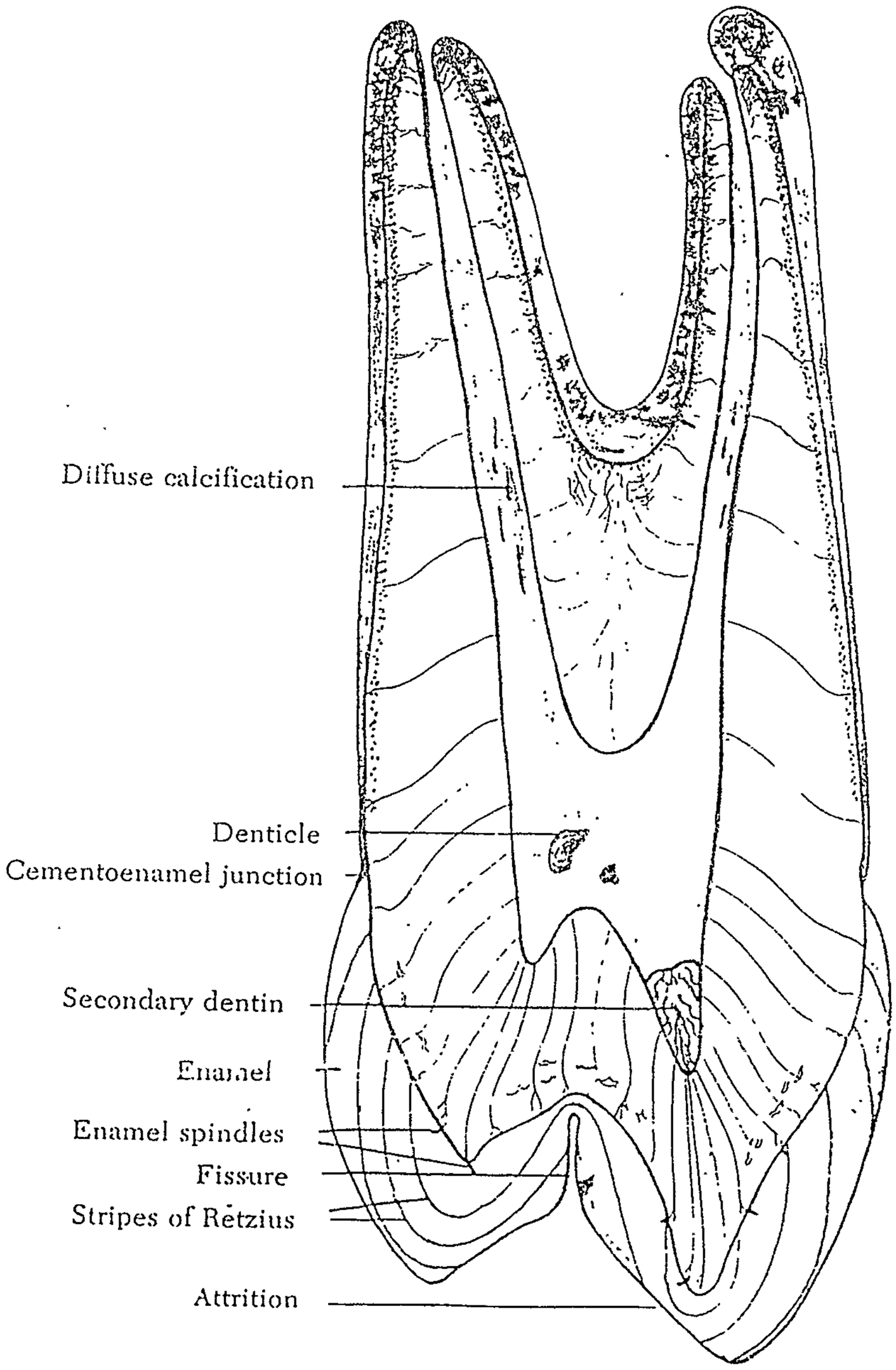
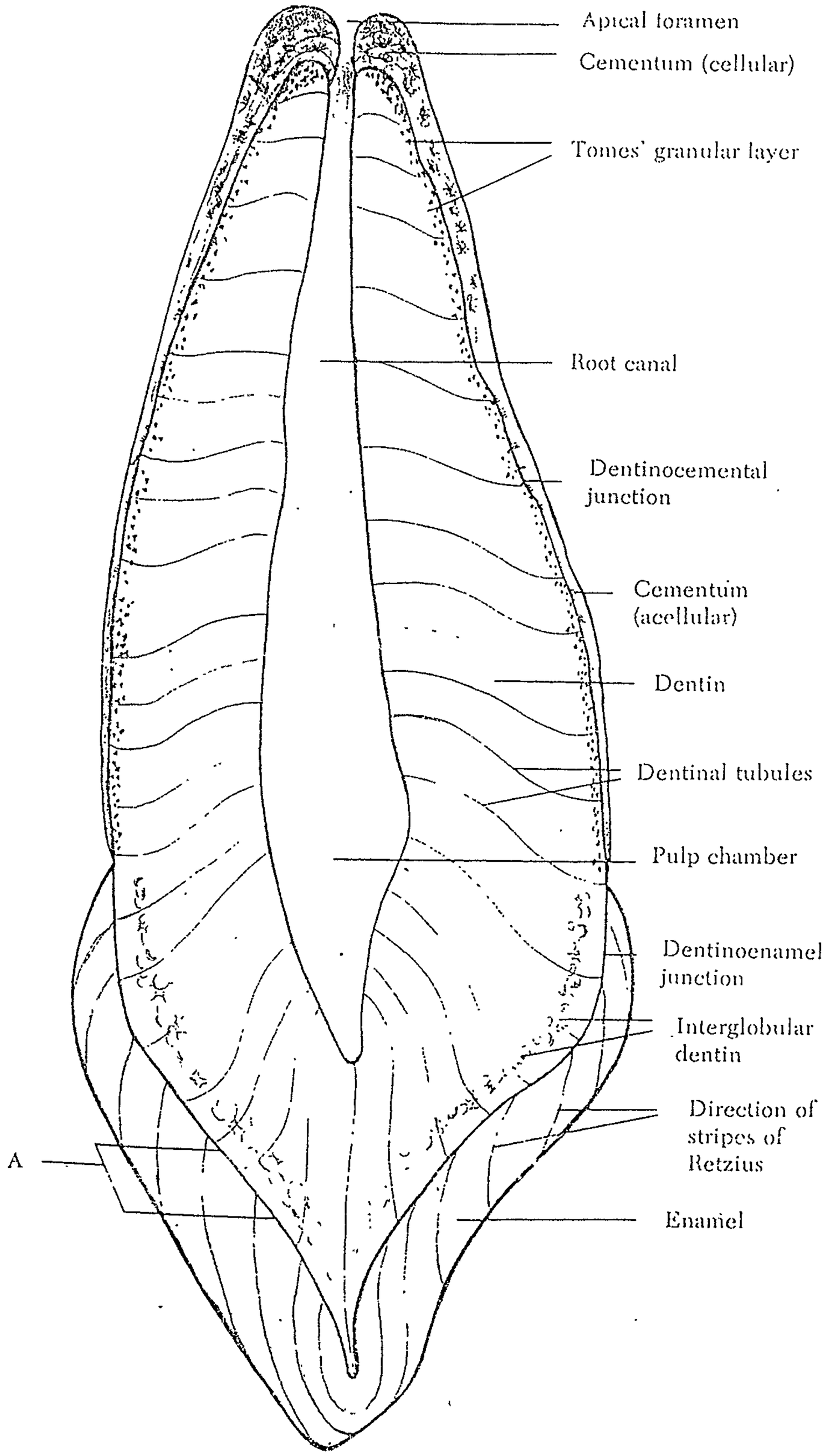


Figure 2 Diagrammatic drawing of a longitudinal faciolingual section of a canine

(Permar 1982 p17)



Tooth enamel comprises the surface of the crown of the tooth and cementum comprises the surface of the root. Dentine, which lies beneath the enamel of the crown and beneath the cementum of the root, makes up the bulk of the hard tissue of the tooth. The tooth pulp is the only noncalcified tissue of the tooth. It occupies the pulp chamber in the crown of the tooth and the root canals to the apical foramen.

2.2.1 TOOTH ENAMEL

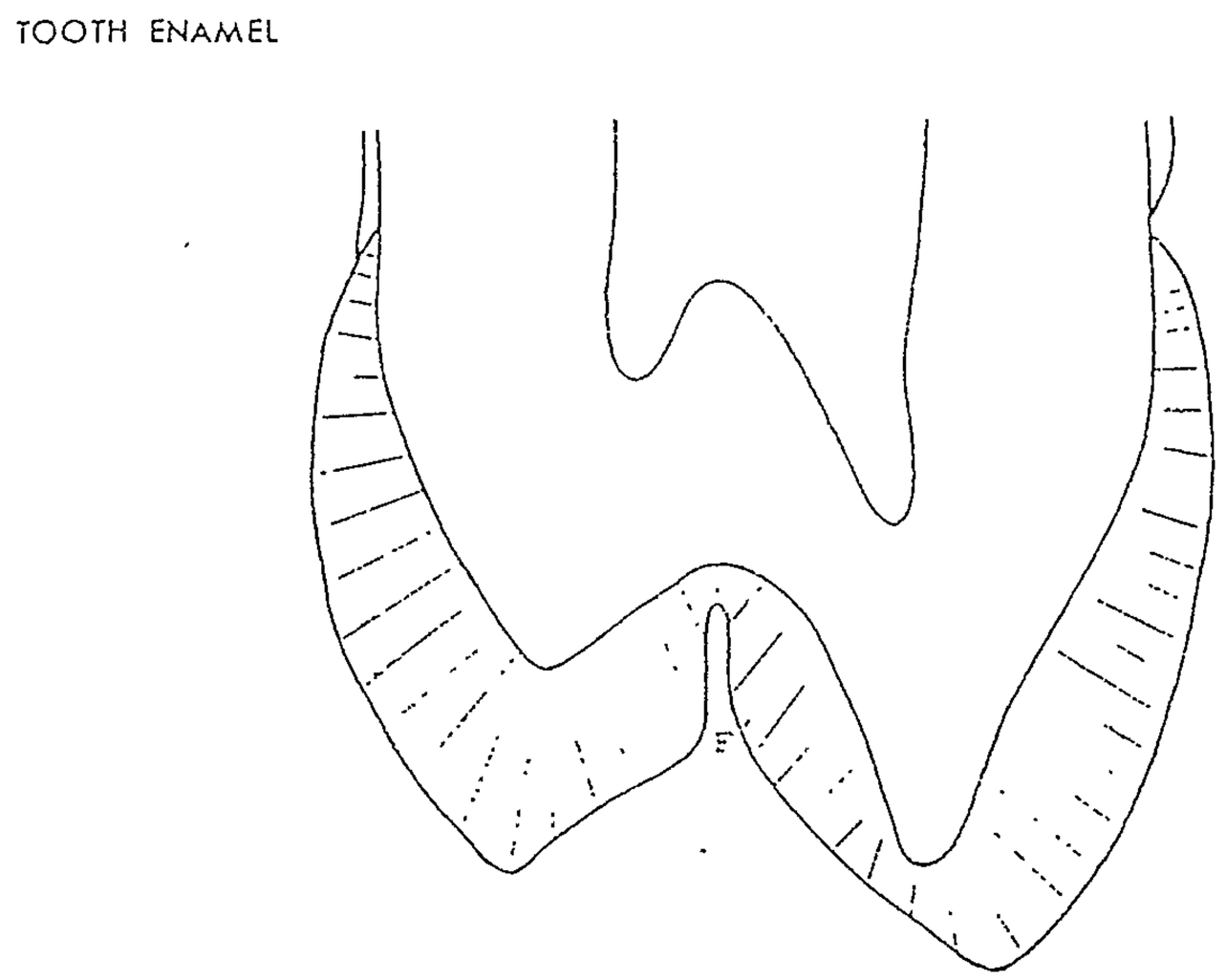
Enamel is the hardest tissue of the body and is composed of both inorganic and organic substances. Mature human enamel is about 96% inorganic. The remaining 4 per cent of its substance is an organic matrix and water.

MACROSCOPIC STRUCTURE OF ENAMEL

The crown surfaces are composed of hard, shiny enamel. In young individuals who are free from dental caries, no other tooth tissues are exposed in the oral cavity. On the labial surfaces of the maxillary central incisors of a young person there are to be seen a number of fine horizontal lines on the enamel. In the cervical part of the crown these lines are close together; incisally on the crown they are further apart. These lines are called " Perikymata". On the newly emerged incisor teeth of a six - or seven-year-old child, three prominences, or scallops are observed along the incisal edge. These prominences are called "mamelons".

Figure 3 Diagrammatic drawing of a longitudinal faciolingual section of the crown of a maxillary first premolar tooth

(Permar 1982 p40).



In an adult mouth the posterior teeth have grooves, fissures, and pits marking the occlusal surface.

In thickness the enamel varies in different parts of the tooth crown. At its thickest parts it may be 2 or 2.5 mm thick, while at the cervical line it thins to a knife edge.

Enveloping the crown of the tooth, and adhering firmly to its surface, is the enamel cuticle, a covering which has been the subject of many studies since it was first described by Alexander Nasmyth in 1942. Enamel cuticle is actually two cuticles :

(1) Primary enamel cuticle

(2) Secondary enamel cuticle / dental cuticle /basal lamina The primary enamel cuticle which is the last product of the enamel-forming cells/ameloblasts, becomes mineralized. The secondary enamel cuticle is a product of the reduced enamel epithelum, and it does not become mineralized. The secondary enamel cuticle is the outermost layer and it probably wears away after a period of tooth use. The dental cuticle is structurally described as a basal lamina.

MICROSCOPIC STRUCTURE OF ENAMEL

Tooth enamel is made up of minute rods which extend from the dentinoenamel junction toward the outer surface of the enamel. They are arranged roughly perpendicularly to the dentinoenamel junction. Seldom are the rods perfectly straight; In some parts of the tooth they have multiple curvatures. It has been estimated that a human maxillary central incisor contains 8,586,000 enamel rods, and that a maxillary first molar contains 12,297,000 rods. The average diameter of a rod is about 4 micrometers. Each enamel rod seems to be composed of a series of small units that fit together in a row somewhat like a string of beads. This segmented construction is a result of the manner of formation of the rods.

Each enamel rod appears to be encased in a rod sheath, and the sheathed rods seem to be cemented together by an interrod substance. However, all three are extremely hard. This frame work of rods, rod sheaths, and interrod substance is the organic matrix of the enamel.

The entire organic substance of enamel is only about 4% of its composition. The other 96% of enamel is mineral substance which exists in the form of tightly packed submicroscopic crystals. Chemically, the organic matrix of enamel has not been fully determined. There is some agreement that it is a lacy network of proteins known as enamelins.

The chemical nature of the inorganic part has been extensively studied. It is generally agreed to be a crystalline calcium phosphate known as hydoxyapatite.

Examination with an ordinary microscope of a thin ground tooth section reveals other formations in enamel :

(1) Bands of Hunter-Schreger

(2) Striae of Retzius

(3) Enamel lamellae

(4) Enamel tufts

(5) Enamel spindles

Some of these formations are of little known clinical importance, while others are of great importance.

Bands of Hunter-Schreger are seen when a longitudinal ground section of a tooth crown is examined by reflected light under the low power of the microscope.

The striae of Retzius are a different kind of bands, or lines, in the enamel. For most of the crown the striae of Retzius end on the crown surface, and their termination on the surface is marked by a series of shallow depressions. The ridges between the depression are called the perikymata.

Enamel lamillae (little layers) have been described by some histologists as faults in enamel matrix formation and by others as cracks in the enamel due to injury. Enamel tufts also are visible in ground tooth section. Histologically they are hypomineralized or unmineralized inner ends of some groups of enamel rods, with their rod sheaths and surrounding interrod substance.

Enamel spindles are peripheral ends of cytoplasmic processes of certain pulp cells (odontoblasts) that extend across the dentinoenamel junction a short distance into the enamel.

The dentinoenamel junction in many teeth is not a straight line, but rather a scalloped line in which small curved projections of enamel fit into small concavities of the dentin.

Enamel contains no cells; it is a product of specialized epithelial cells (ameloblast). It has no circulation in the form of blood vessels or other structures, but that it is permeable to some substances has been demonstrated in studies using dyes and solutions of radioactive substances.

PERMANENCE OF ENAMEL

Once tooth enamel is formed the mineralizaton is never decreased by any physiological process within the tooth. Enamel has no possibility of anatomical self-repair following damage by injury or by caries.

2.2.2 DENTINE

COMPOSITION

Dentine is a calcified tissue, composing of both organic and inorganic substances. Although not nearly so hard as tooth enamel, dentine is harder than bone. Mature dentine is about 70 per cent inorganic substance and about 30 per cent organic material and water.

STRUCTURE OF DENTINE

The organic part of dentine, known as the organic matrix, is composed of very small fibrils and a surrounding structureless cementing substance. In dentine development the organic matrix is formed first; then minerals in solution, similar to the minerals of enamels and cementum, are deposited in the cementing substance. Dentine becomes a hard tissue when these minerals crystallize out of solution, the crystals forming on and around the fibrils.

Dentine is perforated by innumerable holes called dentinal tubules which contain dentinal fibers.

A dentinal fiber / Tomes' fiber occupies each dentinal tubule. It is the cytoplasm of the pulp cell.

CLINICAL IMPORTANCE OF STRUCTURE OF DENTINE

The structure of dentine influences both the pattern of caries lesion and the speed with which dental caries destroys a tooth; and it accounts for the sensitivity frequently experienced by patients during the performance of an oral

prophylaxis or during the eating of hot or cold foods.

2.2.3 CEMENTUM

Cementum is the layer of calcified tissue that makes up the surface of the root of a tooth. It overlies and is attached to the root dentine. Around the cervical part of the root, cementum is about 0.05 mm. thick; on the apical part of the root of a functioning tooth it is usually considerably thicker.

COMPOSITION

Like enamel and dentine, cementum is made up of organic matrix which contains crystallized mineral substances. Cementum may have cells, called cementocytes, irregularly scattered through it. It does not contain blood vessels or nerves.

Cementum is not quite so hard as dentine, being about 50 per cent inorganic (mineral) material and about 50 per cent organic substance and water. It has the same hardness as bone.

STRUCTURE OF CEMENTUM

Compared to dentine, cementum has more similarities and some differences in structure. As in dentine, the organic matrix is composed of a framework of fine fibrils held together by an amorphous cementing substance which becomes calcified. Unlike dentine, cementum, may contain whole cells.

Cementum is a product of the periodontal ligament, certain cells of the periodontal ligament lying close to the tooth

root become surrounded by forming cementum and thus are converted into cells of the cementum (cementocytes).

CLINICAL IMPORTANCE OF CEMENTUM

Melfi (1988) has stated that the cementum is part of the mechanism by which a tooth is attached in the tooth socket. It probably continues to be produced intermittently by the periodontal ligament throughout the life of the tooth. Additions of cementum at the root apex are believed to cause a slow occlusal movement of the tooth that partially compensates for the loss of crown length which results from attrition during years of used. Cementum also repairs damage to the tooth roots which have been resorbed following injury.

2.2.4 TOOTH PULP

COMPOSITION

Tooth pulp is the only noncalcified tissue of a tooth. It is a soft connective tissue, and like other connective tissue it is made up of cells, intercellular substance, and tissue fluid.

While the cells of young pulp tissue are chiefly fibroblasts, specialized types of cells also are present such as histiocytes, undifferentiated mesenchymal cells, and odontoblasts. The intercellular substance of the pulp consists of two kinds of material, the amorphous substance and the fibrous substance. Tooth pulp contains blood vessels and nerves. In many teeth there are also calcifed structures called denticles and diffuse

calcifications.

COMPONENTS OF THE PULP

Fibroblast cells are more numerous than any other kind of cell in the pulp.

Histiocytes and undifferentiated mesenchymal cells are located throughout the pulp near the capillaries.

The odontoblasts are specialized connective tissue cells located next to the dentine.

Korff's fibers are minute rope-like, corkscrew-shaped structures that lie among the odontoblasts during early dentin formation.

Blood vessels are plentiful in young pulp, and lymphatic vessels also have been demonstrated in the pulp.

Along with the blood vessels, nerves enter the tooth through the apical foramen, giving the pulp a good nerve supply.

Denticles are bodies of an irregularly rounded shape frequently found in tooth pulp.

Diffuse calcifications are small, thin scatterings of calcified material frequently found in the pulps of older teeth, usually in the root canals.

CLINICAL IMPORTANCE OF THE PULP

Tooth pulp has the following functions: Formative; Sensory; Defensive.

Melfi (1988) has stated that a fully developed tooth may function for many years after its pulp has been removed and the pulp canal filled. Although the enamel of the tooth becomes more brittle its function is not affected by the loss of the pulp. The cementum is not affected, nor is the process of continued cementum formation. A tooth without pulp can not produce reparative dentine or sclerotic dentine. Pulp loss usually comes about as a result of caries or of tooth fracture or trauma, with accompanying pulp infection.

Careful treatment by the dentist is essential in either case to prevent the infection from travelling through the root canal and apical foramen into the tissues surrounding the tooth, with possibly a consequent loss of the tooth.

2.3 THE IDEAL TEETH

Nizel (1972) has stated that human dental caries does not have a single cause: rather it is a complex ecological disease. He considers dental caries in humans to be the result of an interaction of the resistance of the tooth with the demineralizating effects of organic acids produced by fermentative action of bacteria on sugar.

The ideal teeth are teeth whose qualities and structures have been improved so that the resistance to dental caries of the enamel surface has been increased by means of improved diet during pre-eruptive and post-eruptive stages.

3 DIETARY REQUIREMENTS FOR TEETH DEVELOPMENT

Donsback (1983) had stated that there should be no need to justify the importance of diet in any area of the health sciences,since the proper intake of all nutrients each day for persons of all ages is vital to the preservation and maintenance of life.

The study of diets involves the relationship of foods and food factors to the health of the human body. In general, the discrepancies in health we are concerned with are due to deficiencies of one or more of the food factors. These food factors can be generally considered to be " Proteins" "Fats", "Carbohydrates", " Minerals ", and " Vitamins".

McDonald (1974) has emphasized the role of proper diet selection and intake in increasing tooth resistance. He has pointed out that the importance of diet is not only to the oral cavity but to the health and happiness of the individual, family, community, and nation.

3.1 PROTEINS, FATS, AND CARBOHYDRATES

PROTEINS

Nizel (1981) has stated that proteins are nutrients "of first importance" because they are the indispensable constituents of the cytoplasm and nuclei of all cells. They not only serve as building blocks for cellular membrane and tissue structure but they also are precursors of antibody and are the essential component of the enzymes and hormones that catalyze metabolism. When intake dietary carbohydrates and fats is inadequate, proteins can serve as a source of energy.

Human dental enamel is made up of 0.2 to 0.4 per cent organic matter which contains an insoluble protein. The protein found in the developing enamel of unerupted teeth differs from mature enamel in that it contains exceptionally large amounts of protein, glutamic acid and histidine. Proteins always consists of a nitrogen atom plus carbon, hydrogen, and oxygen; some may also have sulfur, iodine, phosphorus, copper, manganese, zinc, or iron atoms.

According to Armstrong (1964) normal human dentine, which is 21 to 22 per cent organic matter, is primarily protein in nature (only 1 or 2 per cent is not protein). The principal amino acids in dentin are glycine, alanine, proline, and hydroxyproline, which makes it chemically similar to collagen. Carious human dentin has less arginine, proline and hydroxyproline than sound dentine, which may be due to a contamination of the matrix by noncollagenous protein or peptide material as well as to some proteolytic degradation of

the matrix.

FATS

The importance of fat in the diet is the result of a number of interrelated factors. Fat is not only an excellent dietary source of energy, supplying 9 calories per gram, but it also has a number of other desirable characteristics. Under normal conditions, the ingestion of fat soluble vitamins is also associated with an adequate fat intake. Most of the ingested fat is oxidized to provide energy, if needed, or is stored in adipose tissue. Hess (1956) has stated that a very small amount of lipids, primarily phospholipid and cholesterol, has been found in the organic portion of enamel and dentine. Dirksen (1963, 1964) has applied special techniques for the qualitative and quantitative analysis of the lipid content of dentine. In general, he was able to demonstrate the presence of cholesterol esters, cholesterol, triglycerides, diglycerides, monoglycerides, fatty acids and various phospholipids. Sound dentine was found to contain inositol phosphatide, sphingomyelin, lecithin, phosphatidyl, ethanolamine, lysocephalin and three unidentified phosphatides.

Irving (1958, 1963) has stated that the functions of lipids in teeth has been investigated with the aid of a Sudan dye. Sudanophilic inclusions which are interpreted to be lipid granules have been found in ameloblasts and adontoblasts, and it is felt that these lipids may be sites for cacification of the teeth.

CARBOHYDRATES

Nizel (1966) has stated that carbohydrates have occupied a significant place in the diet from early times when man became a cultivator rather than a hunter of food. Today carbohydrates still supply a major portion of the energy of the diet of man (ranging from 50% to 90%).

Carbohydrates are principally a source of dietary energy, but these compounds have additional functions which should be recognized. They play a role as part of the structure of other biologically important materials, such as glycolipids, glycoproteins, nucleic acids and heparin. It is important, therefore, not to lose sight of these additional functions and to consider the carbohydrates only as an energy source. Burges et al (1960) stated that six aldose sugars, galactose, glucose, mannose, fructose, rhamnose, and xylose, have been recovered from the hydrolysates of the organic matter of bovine and human tooth enamel. Stack (1956) has found that 10 times as much carbohydrate is found in the outermost layer of enamel as in the inner. Furthermore, in pooled " chalky " enamel, which has 3 to 4 times as much organic matter as normal enamel, he has recovered 12 times as much carbohydrate as in normal enamel.

In sound dentine Armstrong (1960) found 0.4 per cent "glucose " units of unrefined carbohydrate material and 10 times this amount in carious dentine. Furthermore, the fractions of carious dentine resistant to collagenase fractions action or autoclaving contain 30 times as much

cabohydrate material as sound dentine.

As a general approximation, Donsbach (1983) has shown that the following can be used as physiologic food values:

Protein ———————————— 4 calories per gram.

Fat ———————————— 9 calories per gram

Carbohydrate ———————————— 4 calories per gram

It is important to remember that the above table relates to grams of pure food source.

3.2 MINERALS AND TRACE ELEMENTS

According to Donsbach (1983) minerals can be referred to as the " unsung heroes " of life because they do not receive the attention that vitamins do in most literature. He pointed out that our need for minerals is as essential as our need for oxygen. The body can tolerate a deficiency of vitamins for a longer period of time than it can a deficiency of minerals.

Inorganic minerals or elements are chemicals, they can be quantitated by gravimetric methods;

1). MARCROMINERALS: calcium, phosphorus, magnesium, sodium, potassium, sulfur, iron and chloride.

2). MICROMIENRALS (or trace elements): copper, manganese, zinc, iodine, cobalt, molybdenum, selenium and fluoride, lithium, vanadium, strontium

CALCIUM

Calcium is the most abundant mineral in the body. It is estimated that 99 per cent of the calcium in the body is deposited in the bones and teeth and the remainder is in the soft tissue.

PHOSPHORUS

Phosphorus has more functions than other minerals in the body. About 80 per cent of the phosphorus in the body is found in the bones and teeth and about 20 per cent is found in the soft tissue cells.

MAGNESIUM

Magnesium is present in calcified tissues and ranks after calcium and phosphorus in the abundance of mineral elements in teeth. The magnesium content of teeth is approximately 0.4 per cent (enamel) and 0.4 per cent (dentine), expressed on a fresh tooth basis.

SODIUM

Sodium in the body is found in the extracellular fluid. The major function of sodium is working with chloride to regulate the pH of the body fluids.

POTASSIUM

Potassium is found mostly in the cells as compared to sodium which found in extracellular fluids.

SULFUR

Sulfur is involved in collagen formation, it is not considered possible that a deficiency could occur.

IRON

Iron is a part of hemoglobin which carries oxygen throughout the body. Small amounts of iron are found in every tissue cell and in the components of each cell. It is estimated that 25 per cent of the population in USA is deficient in this mineral.

CHLORIDE

Chloride is very rarely deficient, since populations consume

seasoning salts in the form of sodium chloride. The major function of chloride is as a part of hydrochloric acid.

MANGANESE

Manganese is an important catalyst and a co-factor or component of many enzymes in the body.

ZINC

Zinc is the second largest quantity trace mineral in the body. It is necessary for absorption and activity of vitamins.

IODINE

Iodine is a part of the thyroid hormones thyroxine and triiodothyronine.

COBALT

Cobalt is considered an essential mineral and is an integral part of vitamin B-12 (Cobalamine).

MOLYBDENUM

Molybdenum is a component of several essential enzymes.

The major function of Selenium is that of an antitoxidant.

FLUORIDE

Fluoride can increase deposition of calcium to make stronger teeth and bones. It is added to the drinking water as a dental caries preventive.

COPPER

Copper is an essential trace mineral and is found in all body tissue.

Afseth et al (1980) stated that significant reductions in acid production in plaque have been shown by $CuSO_4$. More importantly, recent research has indicated a strong plaque and anti-bacterial effect of copper.

LITHIUM

Lithium in 1978 has been associated with low caries prevalence. These findings are worth further investigation.

MOLYBDENUM

Jenkins (1983) stated that molybdenum and dental caries has been excellently reviewed. If molybdenum does reduce caries the mechanism is still unknown.

SELENIUM

Selenium has already been demonstrated as essential by its uptake into the glutathione peroxidase enzymes. Curzon and Crocker (1978) stated that adequate levels of selenium would promote good enamel formation and a negative relation of the element in enamel to dental caries has been shown.

STRONTIUM

Dedhiya et al (1974) studied the incoporation of strontium and/or fluoride in synthetic apatites. When used in combination, the effect of the strontium and fluoride in

reducing dissolution was far greater than fluoride alone. A recent finding is that there is a reduction in carbonate content of apatite by incorporation of strontium (Featherstone et al 1980). Furthermore, strontium appears to play a role in the remineralization process (Featherstone and Shariati 1983) where optimum concentrations of strontium are necessary for rapid remineralization.

VANADIUM

Vanadium is another trace element associated with low caries prevalence based on early epidemiologic studies of Tank and Storvick (1960). These authors reported that the relationship they found between the metal and dental caries was also affected by the fluoride levels in some water supplies. The mechanism is unclear with both reductions and increases being reported

Minimum daily amounts that should be present in a good diet supplement.

Table 2 Minimum daily amounts of mineral elements

(Donsbach 1983 p339)

Calcium	1000 mg
Magnesium	400 mg
Potassium	99 mg
Phosphorus	150 mg
Iron	20 mg
Iodine	225 mg
Copper	2 mg

Zinc ..... 20 mg

Chromium ..... 5 mg

Manganese ..... 20 mg

Selenium ..... 20 mg

Fluoride ..... drinking 1ppm of fluoridated water

Nizel (1981) has stated that essentially there are two phases in the growth of bone and tooth, First, there is the formation of calcificable matrix,or collagen, which is produced by osteoblasts (or odontoblasts of tooth). Second, there is the calcification phase, which begins as a precipitate of calcium phosphate from supersaturated serum.

The initial precipitate appears to be octacalcium phosphate, which has an amorphous appearance. Then there is a laying down of amorphous calcium phosphate within spaces or compartments in the collagen fibrils known as seeding or nucleation. The amorphous mass is converted into hydroxyapatite by free lysyl and hydroxylysyl amino acid groups and a fat soluble inductor substance. The apatite grows in ribbons within the fibril to form crystallites. The crystallites grow and coalesce to form crystals. As the bone matures, the crystals grow to such a size that they displace the water between them. The mineralization of cementum, is probably similar to that of bone because of its histological resemblance. The theories for cartilage and bone calcification seem to apply equally well to dentine mineralization. The calcification pattern of enamel is quite different from that of bone, cementum, and dentine. Mineralization and matrix formation occur simultaneously from

the start and, as the maturation proceeds, the mineral content of enamel rises to a final value of 95 to 97 per cent, while the organic matrix falls to a mere trace (0.2 to 0.8 per cent). The apatite crystals of enamel may be 200 times larger in volume than those of bone or dentine.

The calcification mechanism for the enamel is obscure when contrasted to that of bone, dentine, and cementum. According to Irving (1978) the most feasible theory on the mineralization mechanism of enamel is that there is an initial apatite nucleation on mantle dentin crystals, followed by growth across the tissue.

3.3 VITAMINS

Bernier and Muhler (1966) stated that the diet should be similarly considered with respect to the adequacy with which it supplies vitamins in abundant amounts.

Kirschmann and Dunne (1984) explained that all natural vitamins are organic food substances found only in living things, that is, plants and animals. Vitamins function with chemicals called enzymes, which have numerous essential functions within the body. Enzymes are made up of two parts: one is a protein molecule and the other is a coenzyme. This coenzyme is often a vitamin, or it may contain a vitamin, or it may be a molecule that had been manufactured from a vitamin. Much work has been done to determine requirements of vitamins of various age groups and in cirumstances of additional needs, such as pregnancy and lactation.

Vitamins are essential for growth and reproduction:

(1) the formation of antibodies.

(2) coagulation of the blood.

(3) resistance to infection.

(4) formation of intercellular substances and integrity of bones, teeth, skin, blood and nervous tissue.

Donsbach (1983) is of the opinion that disease does not exist in the well nourished body. Vitamins are one of the important nutrients necessary for vital function to proceed normally in the body.

The fat soluble vitamins, as the term implies, are those

four vitamins (A,D,E,K,) which are found in nature generally associated with fatty food such as butter, cream,vegetables oils, and the fats of meat and fish. The general characteristics of the fat-soluble vitamins are:

(1) They are more stable to heat than the water soluble vitamins and are less likely to be lost in the cooking and processing of foods.

(2) Fat-soluble vitamins are absorbed from the intestine along with fats and lipids in foods.

(3) They are stored in the body, chiefly in the liver.

Vitamin A is the most important of all vitamins. The chief functions of vitamin A are to maintain the health of epithelial tissues and to get proper formation and maintainance of tooth enamel and health of gums.

Table 3 FOOD SOURCES OF VITAMIN A

(Donsbach 1983 p301)

100 gm Beef liver	43,900 IU
100 gm Apricots, dried	10,900 IU
100 gm Sweet potatoes	8,800 IU
100 gm Collards	7,800 IU
100 gm Dandelion greens	11,700 IU
100 gm Swiss chard	5,400 IU
100 gm Spinach	8,100 IU
100 gm Pumpkin	6,400 IU
100 gm Liver wurst	6,350 IU
100 gm Papaya	1,750 IU
100 gm Persimmon	2,700 IU

1200 gm Cantalous	3,400 IU
100 gm Carrots	11,000 IU
100 gm Nectarine	1,480 IU
100 gm Swordfish	2,100 IU
100 gm Oat flakes	5,000 IU
100 gm Raisin Bran	4,675 IU
100 gm Cheddar cheese	1,300 IU
100 gm Butter	3,300 IU
100 gm Egg, whole	1,180 IU

Vitamin K is the well known "coagulating factor". It is found in some foods such as alfalfa, cosein, soybean oil, most green leafy vegetables. It is stored in the liver. Vitamin D promotes growth and proper mineralization of the bones and teeth. This is accompanied by the proper utilization of calcium and phosphorus. Vitamin E has a beneficial effect on the organs of reproduction. The most important function of vitamin E is its ability to prevent peroxide formation.

The water soluble vitamins consist of the B complex and vitamin C. Vitamin C (ascorbic Acid) is probably the least stable of the vitamins and is very sensitive to oxygen, its potency can be lost through exposure to light, heat, and air.

One of the functions of vitamin C is formation and maintainance of collagen protein. (Collagen protein is tissue " cement" for skin, cartilage, tendon, bone and tooth)

All B complex vitamins are water-soluble substances. They are active in providing the body with energy, basically by converting carbohydrates into glucose, which the body burns to

produce energy.

According to Kirschmann and Dunne (1984) the known B-complex vitamins are B1 (thiamin) B2 (Riboflavin), B3 (Niacin), B5(Pantothenic acid), B6(Pyridoxine), B12(Cyanocobalamin), B15(Pangamic acid, biotin, choline, folic acid, inositol, and PABA(Para-aminobenzoic acid).

FUNCTIONS OF VITAMIN B1(THIAMINE)

1) Assists in conversion of carbohydrates to glucose,

2) Stabilizes the appetite,

3) Maintains gastrointestinal tonus,

4) Necessary for normal function of nervous system.

FUNCTIONS OF VITAMIN B2(RIBOFLAVIN)

1) Assists the eye in light adaptation,

2) Assists the conversion of tryptophan to niacin,

3) Assists in the metabolism of carbohydrates, proteins and fats

FUNCTIONS OF VITAMIN B_3 (NIACIN)

The chief function of vitamin B3 (Niacin or Niacinamide) in the body is to form the active portion of coenzymes that play an essential role in tissue oxidations.

FUNCTIONS OF VITAMIN B_5 (PANTOTHENIC ACID)

Donsbach (1983) has pointed out that pantothenic acid (vitamin B5) stimulates the adrenal glands and increases hormone formation important for healthy skin and nerves, the synthesis of cholesterol, steroids and fatty acids.

FUNCTIONS OF VITAMIN B6 (PYRIDOXIN):

1) Essential for the complete metabolism of many of the amino acids.
2) Essential for the metabolism of fats, particularly the essential unsaturated fatty acids.
3) Involved in antibody production.
4) Helps maintain sodium-potassium balance.
5) Involved in proper DNA and RNA action.
6) Facilitates glycogen conversion to glucose.

FUNCTIONS OF VITAMIN B12 (CYANOCOBALAMIN):

1) Essential for normal functioning of all cells, particularly bone marrow, nervous system, and the gastrointestinal tract.
2) Very important in formation of nucleic acids.
3) It is required by the body for red blood cell formation by the bone marrow.

FUNCTIONS OF VITAMIN B15 (PANGAMIC ACID, BIOTIN, CHLORINE, FOLIC ACID, INOSITOL, AND PABA (PARA-AMINOBENZOIC ACID)).

Pangamic acid

1) Keeps fat from infiltrating the liver.
2) Serves as a detoxification agent.
3) Increases the body's efficiency in using oxygen.
4) Regulates blood levels of steroids.
5) Extends cell lifespan.

Biotin

1) Essential in the formation of nucleic acids,

2) Essential in the formation of glycogen,

3) Required in the synthesis of several of the non-essential amino acids,

Choline

1) Aids in metabolism of fats.

2) As a constituent of acetylcholine, it assists normal nerve function.

3) Assists in the synthesis of certain hormones such as epinephrine (adrenalin).

Folic acid (Folacin)

1) Necessary for synthesis of nucleic acids.

2) Necessary for synthesis of certain amino acids.

3) Prevention of macrocytic anemia.

4) Utilization of amino acids.

Inositol

1) Aids in metabolism of fats

2) Growth factor

PABA (Para-aminobenzoic acid)

1) Helps to prevent eczema and loss of pigmentation, referred to as vitiligo.

2) High amounts are effective in burn pain control.

3) Facilitates the body's production of folic acid.

4) Acts as a part of the coenzyme system.

The mineral amounts needed each day for optimum health are shown in the following table :

Table 4 The mineral amounts needed each day for optimum health

(Donsbach 1983 p318)

Vitamin A	25,000 mg.
Vitamin D	1,000 mg.
Vitamin E	400 mg.
Vitamin B-1	60 mg.
Vitamin B-2	60 mg.
Vitamin B-3	60 mg.
Vitamin B-6	60 mg.
Vitamin B-12	100 mcg.
Vitamin C	1,200 mg.
Pantothemicacid	120 mg.
PABA	60 mg.
Chlorine	60 mg.
Inositol	60 mg.
Folic Acid	400 mcg.
Biotin	100 mcg.

4 DIET TO INCREASE TOOTH RESISTANCE

Murray (1983) has pointed out that diet can affect the tooth stucture and morphology in two ways, first, while the tooth is developing before eruption and, second, a local oral effect after the tooth has erupted into the mouth.

Chapter three is an overall literature review on dietary requirements for tooth growth. Proteins, fats, carbohydrates, minerals, and vitamins are very important elements in the formation of a stronger tooth. This chapter concentrates on the most important dietary factors which have a direct or indirect effect on increased tooth resistance.

The discussion in this chapter puts much greater emphasis on more important tooth-resistance diets, consisting of calcium, phosphorus, magnesium, fluoride, vitamin A and vitamin D.

4.1 CALCIUM

Kirschmann and Dunne (1984) have explained that although all vitamins and minerals are essential for the proper formation and continual health of the teeth, an adequate calcium intake is especially helpful for maturation.

Donsbach (1983) stated that calcium is the most abundant mineral in the body. It is estimated that 99 per cent of the calcium in the body is deposited in the teeth and bones and the remainder is in the soft tissue.

Calcium is accompanied by magnesium, phosphorus and vitamin A, vitamin C and vitamin D. Nizel (1981) has stated that the major function of calcium is to provide crystalline rigidity and strength to the teeth and bones. The bones and teeth contain the 99 per cent of body calcium in the form of hydrated tricalcium phosphate and hydroxapatite [$Ca_{10}(PO_4)_6(OH)_2$].

Kirschmann and Dunne (1984) have mentioned that the major function of calcium is to act in coorporation with phosphorus to build and maintain teeth and bones.
If the diet is very high in protein, more calcium is needed to prevent a loss of calcium from bones.

According to Department of Health N.S.W. (1987) records many older men and women in Australia suffer from osteoporosis, a disorder in which the bones become less dense and break easily.This may be due in part to an insufficient intake of calcium.

4.1.1 FOOD SOURCES OF CALCIUM

In the USA, milk and milk products provide 85 per cent of the calcium in the diet. Therefore, without the use of milk and/or milk products, it would be very difficult to meet the recommended levels of intake.

In ordinary diet, the best sources of calcium are hard cheeses, milk and dark green leafy vegetables (the darker the green, the more the calcium) such as dandelion greens , mustard greens, turnip greens, collards, and kale. Although spinach, beet greens,and chard are high in calcium, it is in the oxalate form, which is relatively insoluble and therefore non-utilizable. Good sources of calcium are ice cream (140mg), black trap molasses, broccoli, baked beans, dried legumes, and dried figs. Fair sources of calcium are cottage cheese (52 mg per two rounded tablespoons). string beans, parsnips, lima beans, salad greens, eggs, and bread. A combination of foods that will furnish 800 mg of calcium per day is suggested in table 5.

Table 5 Calcium content of selected foods

(Nizel 1981 p200).

FOOD	CALCIUM.(mg) PER AVERAGE SERVING	PER 100 GM
Sesame seeds, whole, ¼ c	348	1160
Milk, 8 oz glass, ½ pt	285	118
Salmon, red canned with bones, ⅖ c	259	259
Sardines, canned in oil, 2 fish, drained	174	435
Cheese, American cheddar, 1 oz	225	750
°Leafy vegetables, avg. ½ c, cooked	140	167
Ice cream, plain, avg. ¾ c	123	123
†Molasses, medium, 2 tbsp	116	290
Artichokes	102	51
Broccoli, ⅔ c	88	88
Baked beans, canned with molasses, ½ c	82	56
tomato sauce ½ c	70	49
Cream, light; 7 tbsp	74	97
Orange, 1 medium	62	40
‡Cottage cheese, 2 round tbsp	52	96
String beans, ⅔ c, cooked	50	50
Parsnips, ½ c, cooked	44	57
Lima beans, ½ c, cooked	38	47
Salad greens, raw, avg. 2 large or 4–5 small leaves	34	68
Sesame seeds, hulled, ¼ c	33	110
Egg, 1 large	26	54
Figs, dried, 1 large	25	125
canned, 3, with juice	13	13
Bread, whole-wheat, 1 slice	23	96
white, 1 slice (4% milk solids)	19	79
Peanut butter, 2 scant tbsp	22	74
Peas, canned. ½ c	20	25
Apricots, dried, cooked, 4 halves	20	22
Orange juice, 6 oz	20	25
Dates, 3–4 pitted, 1 oz	22	72
Prunes, 4–5 medium, cooked	17	25
Grapefruit, ½ medium	16	16
Cereal, whole grain, avg. ⅔–¾ c; cooked	8–15	9

Recommended dietary intakes according to the Department of Health NSW (1987) and indicated in table 6.

Table 6 Foods as sources of calcium

(The Department of Health NSW 1987 p20).

Food	Amount edible portion	Calcium average content milligram
Milk	600 mL	670
Milk. 1 cup	250 mL	280
Skim milk. 1 cup	250 mL	290
Modified milk (Hi-Lo). 1 cup	250 mL	340
Low fat. modified milk (Shape) 1 cup	250 mL	390
Powdered full cream milk. 2 tablespoons	18 g	200
Powdered skim milk. 2 tablespoons	22 g	240
Yoghurt. plain	200 g	380
Cheese. cheddar type	20 g	150
Cottage cheese	20 g	20–25
Ice cream	150 mL	100
Cream. 1 tablespoon	20 g	12
Butter. 1 tablespoon	20 g	2
Fish. cooked	100 g	25
Salmon. canned. with bones	100 g	95
Sardines. canned	100 g	500
Egg. one	55 g	25
Haricot or lima beans. cooked. ½ cup	100 g	50
Tahini. 1 tablespoon	20 g	180
Bread. wholemeal. white or brown 1 slice	30 g	10
Oatmeal cooked. 1 cup	250 g	15
Cornflakes. 1 cup	30 g	1
Wheat breakfast biscuits. 2	30 g	10
Vegetables. cooked. average	100 g	25
Broccoli	100 g	75
Parsley	10 g	30
Fruit. average. raw 1 piece	100 g	10
Figs dried	50 g	140
Molasses. 1 tablespoon	25 g	125
Sugar	—	0

4.1.2 METABOLISM OF CALCIUM

Nizel(1981) has stated that calcium is absorbed from the intestine,mainly in the proximal portion of the duodenum, by an active process which requires energy. Vitamin D and a vitamin D induced calcium-binding protein play a role in the active absorption of calcium. Calcium is also absorbed by

passive ionic diffusion in the remainder of the small intestine.

Donsbach (1983) has pointed out that calcium is rather poorly absorbed, with possibly only 30 per cent or less of the ingested amount actually being taken up by the body.

THE FACTORS WHICH INFLUENCE CALCIUM ABSORPTION ARE:

(1) Acid media in stomach, adequate amounts of vitamins A, vitamin D, and vitamin C.

(2) Adequate protein and fat in the diet.

(3) Absorption takes place primarily in the duodenum which is only from 10 to 12 inches in length, and time plays a very important role.

Nizel (1981) has stated that calcium is held in reserve in the trabeculae of the long bones and can be drawn out of the trabeculae when needed. The body tends to maintain a continuous dynamic equilibrium between those minerals that are stored in the bone and those that are found in the blood serum. The blood and tissue fluid calcium act as a pool that is contributed to by diet or bone resorption and is drawn upon for bone and tooth formation in the child and for lactation in the nursing mother.

The degree of development of the bone trabeculae, where osteoid tissue is formed, and the amount of calcium salts deposited is directly related to the amount of calcium available from the diet.

Nizel (1981) has pointed out that of a dietary intake of

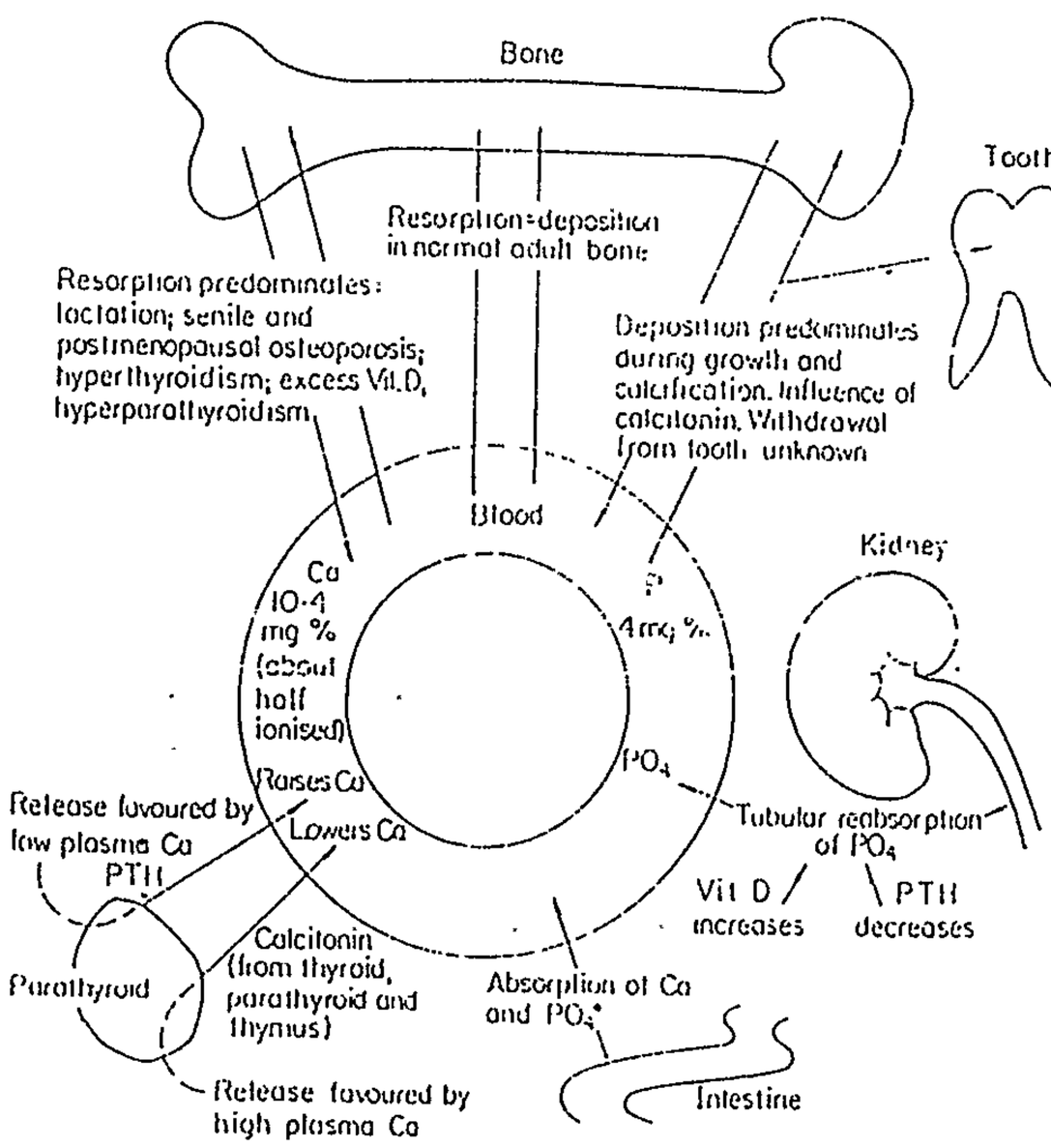
1000 mg of calcium, 700 to 800 mg can be expected to be excreted in the faeces. Calcium excreted in the stool is mostly unabsorbed calcium from food.

When the serum calcium is depressed or the dietary intake is low, absorption of calcium is more efficient and thus excretion is less.

After the bones and soft tissues have taken up all the calcium that they can hold, the excess will be excreted in the urine. There is a relatively insignificant daily loss of 15 mg of calcium via perspiration. Calcium can also be lost via bile and digestive secretions.

According to Jenkins(1978) the main factors in the general metabolism of calcium and phosphorus are shown in figure 4.

Figure 4 Diagram of the main factors in the general metabolism of calcium and phosphorus (Jenkins 1978 p48).



4.1.3 MECHANISM OF CALCIUM

Nizel (1981) has stated that calcium salts are constantly being deposited and resorbed in dynamic tissues such as bone trabeculae and as a consequence are readily mobilized to respond to increasing body demands during the active growth years as well as during pregnancy and lactation. On the other hand, the calcium in the enamel and dentine of teeth is more stable, which in the author's opinion negates the theory that for every baby, the mother loses a tooth.

Calcium is required with prothrombin and thromboplastin to form thrombin.

4.2 PHOSPHORUS

McDonald (1974) has stated that there is general agreement that diets that supply adequate amounts of calcium also contain sufficient amounts of phosphorus.

Donsbach (1983) has explained that phosphorus is extremely vital to health because of its role in all body processes. Although the body uses up phosphorus at a rate one and a one-half times that of calcium, most of our diets are quite high in the phosphorus element from the protein foods (meat,fish, and poultry) and the cereals. About 80 per cent of the phosphorus in the body is found in the bones and teeth and about 20 per cent is found in the soft tissue cell - where it is initially concerned with normal function.

PHOSPHORUS IN THE BODY HAS THE FOLLOWING FUNCTIONS:

(1) Formation of strong teeth and bones.

(2) Acts as blood buffer to maintain pH.

(3) Essential constituent of nucleoproteins.

(4) Essential fat metabolite, factor-phospholipids.

(5) Part of enzyme system which activates the oxidation of carbohydrates-glucose and glycogen.

(6) A constituent of myelin sheath of nerves.

Donsbach(1983) has emphasized that a calcium phosphorus balance exists in the body and is very important to maintain normal body function.

Harris (1970) has stated that a significant cariostatic action has been demonstrated by inorganic phosphates when added to

cariogenic diets of rats, and organic phosphates also reduce caries. Newbrun (1978) pointed out that the exact mechanism of action of phosphates in caries reduction is a local effect in the mouth rather than a systemic influence through ingestion.

4.2.1 FOOD SOURCES OF PHOSPHORUS

Our diet is quite high in the phosphorus element. Nizel (1981) stated that an intake of 800 to 1200 mg of phosphorus daily is recommended.

Nizel (1981) has stated that in animals it has been shown that excess dietary phosphorus will increase bone loss and bone porosity and significantly decrease bone mineral and also will cause calcification of kidney, tendon, heart and thoracic aorta. However,the author has pointed out that in humans there are conflicting opinions as to whether reasonably high intakes of phosphorus are detrimental to health.

Animal foods, such as meat, fish, poultry, eggs and milk, rich in protein are also rich in phosphorus. Nuts, legumes, and whole grain cereals are also good food sources of phosphorus. According to Nizel(1981)the phosphorus content of selected foods is shown in table 7.

Table 7 Phosphorus content of selected foods

(Nizel 1981 p204)

FOOD	*PHOSPHORUS (mg)* PER AVERAGE SERVING	PER 100 GM
Liver, fried, 2 slices, 75 gm	311	358
Milk, 8 oz glass, ½ pt	227	93
Cod steak or sole, 100 gm	220	220
Lamb, leg, roast, 2 slices, 100 gm	208	208
Beef, rib roast, 1 slice, 100 gm	186	186
hamburger, ¼ lb, 85 gm	165	194
Baked beans, canned, ½ c	120	92
Cheese, American cheddar, 1 oz	140	478
Peanut butter, 2 scant tbsp	118	393
Shredded wheat, 1 biscuit	102	360
Whole-wheat cereal, ½ c, cooked	113	83
Oatmeal, ⅔–¾ c, cooked	105	57
Cottage cheese, 2 round tbsp	108	189
Egg, 1 large	101	210
Ice cream, plain, avg., ¾ c	99	99
Cream, light, 7 tbsp	77	77
Broccoli, ⅔ c	76	76
Nuts, mixed, 1–12 nuts, ½ oz	67	446
Parsnips, ½ c, cooked	62	80
Lima beans, ½ c, cooked	97	121
Peas, canned, ½ c	62	77
Corn, canned, ½ c	43	52
Cauliflower, ¾ c, cooked	42	72
Leafy vegetables, ½ c. cooked, avg.	45	45
Bread, whole-wheat, 1 slice	60	263
white 1 slice (4% milk solids)	21	92
Apricots, dried, cooked, 3 halves	34	34
Figs, dried, 1 large	33	111
canned, 3, with juice	21	35
Prunes, 4–5 medium, cooked	27	40
Dates, 3–4 pitted, 1 oz	18	60
Orange, 1 small	37	37
String, beans, ⅔ c, cooked	19	23
Grapefruit, ½ medium	16	16

In fact, Spencer et al (1975, 1978) found that absorption of calcium was unaffected by increasing phosphorus intake from 800 to 2000 mg per day at calcium intakes ranging from 200 to 2700 mg per day.

Nizel (1981) observed that high phosphorus intakes did not seem to affect calcium absorption when dietary calcium, was in the low to normal range. Hegsted et al (1979) showed that increasing the phosphorus intake from 1 gm to 2.5 gm and maintaining a 0.5 gm of calcium intake resulted in a

substantial increase in calcium retention and no change in apparent absorption of calcium when a high protein diet was consumed. The phosphorus supplement had no effect on calcium retention when a low protein diet was fed. The author considered that the dogma which states that the dietary calcium to phosphorus ratio must be 1:1 to be acceptable needs to be substantiated by further scientific evidence.

4.2.2 METABOLISM OF PHOSPHORUS

Phosphorus is absorbed rather efficiently as compared to calcium,so according to Donsbach (1983) care should be taken that calcium intake in supplemental form be at least twice that of phosphorus in order to be balanced.

Nizel (1981) has pointed out that the factors that influence calcium absorption also influence phosphorus absorption. Insolubie complexes with magnesium and iron will make phosphorus unavailable for absorption.

Similar to calcium, phosphorus is regulated by the metabolic and hormonal factors, vitamin D, calcitonin, and parathyroid hormone.

Like calcium, phosphorus is in dynamic equilibrium between fluids and cells and is constantly being released and rebuilt in bone structure.

Control of the amount of phosphorus in the body is exercised through excretion in the urine rather than by control of absorption.

4.2.3 MECHANISM OF PHOSPHORUS

McDonald (1974) has stated that phosphorus is an important bone and tooth mineral, and it also occupies a primary role in energy transformation. Phosphate compounds in the form of adenosine diphosphates and triphosphates(ADP and ATP) plus other compounds containing a high energy phosphate bond are essential to provide energy for biochemical reactions; many coenzymes have phosphate radicals.

McDonald (1974) has described the role of phosphorus in dental health, he pointed out that various soluble phosphates are effective in preventing dental caries in animals and humans. Although the primary mechanism of these phosphates posteruptively appears to be local, it is possible that a systemic effect does occur posteruptively.

These data show that an agent other than fluoride has been found that significantly protects the tooth against caries. Stookey and associates (1967) reported that significant reductions in dental caries were observed after the use of presweetened breakfast cereals to which 0.5% of $NaHPO_4$ and 0.5% Na_2HPO_4 had been added. The implications of this study are significant in that a practical method to fortify commonly used foodstuffs to prevent dental caries is demonstrated.

Nizel (1981) has explained that since the great majority of the crystals are extracellular, they are in contact with body fluids, and thereby a dynamic equilibrium between the calcium and phosphorus in the blood and bone is possible. Parathyroid

hormone and vitamin D regulate this equilibrium. In general, however, most of the bone crystals in the mass of the skeleton are reasonably stable.

The mineralization of cementum is probably similar to that of bone because of its histological resemblence. The theories for cartilage and bone calcification seem to apply equally well to dentine mineralization.

The calcification pattern of enamel is quite different from that of bone, cementum and dentine. The author has stated that mineralization and matrix formation occur simultaneously from the start and, as the maturation proceeds, the mineral content raises to a final value of 95 to 97 per cent, while the organic matrix falls to a mere trace (0.2 to 0.8 per cent). The apatite crystals of enamel may be 200 times larger in volume than those of bone or dentine.

The calcification mechanism for the enamel is obscure when contrasted to that of bone,dentine, and cementum. According to Irving (1978) the most feasible theory to date on the mineralization mechanism of enamel is that there is an initial apatite nucleation on mantle dentine crystals, followed by growth across the tissue.

4.3 FLUORINE (FLUORIDE)

Fluorine is an essential trace mineral that is a halogen similar to chlorine, bromine, and iodine. It is a very reactive gas. Fluorine occurs in the body in compounds called fluorides.

Nizel (1981) has stated that fluoride is formed everywhere throught nature. The major source of ingested fluoride is water particularly from deep artesian wells. It is found in soils rich in fluorspar (calcium fluoride), cryolite (sodium aluminium fluoride) and other minerals such as fluorocarbonates, fluorophosphates and fluorosilicates. In the human fluoride is found mainly in the skeleton, the teeth, and the calcified structure.

Fluoride has unquestionally been shown to be a nutrient beneficial to dental health. According to Kirschmann and Dunne (1984) recent research indicates that fluoride increases the deposition of calcium, thereby strengthening the teeth, the bones and the calcified structures. Fluoride also helps to reduce the formation of acid in the mouth caused by carbohydrates, thereby reducing the likelihood of decayed tooth enamel. It is important to know that excessive amounts of fluoride are definitely harmful. Fluoride can destroy the enzyme phosphatase, which is initial to many body processes including the metabolism of vitamins. Fluoride inhibits the activities of other important enzymes and appears to be especially antagonistic toward brain tissues.

Systemic fluoride ingestion contributes to fluorapatite

formation within the body of the crystal. Local fluoride application will provide primarily a calcium fluoride coating to the enamel, and secondarily some fluorapatite formation in the surface of the crystal. Systemic fluoride intake is recommended from birth through the early teens in order to enrich the enamel with fluorapatite.

Messer and Singer (1976) concluded from the several lines of evidence dealing with fluoride's effect on growth rate, reproduction, hematopoiesis, and mineralization that the present evidence does not justify the inclusion of fluoride in the list of essential trace elements.
However, Specter and Curzon (1979) explained that the higher the level of fluoride in enamel, the less solubility is evidenced. However, enamel solubility still cannot be related to incidence of caries. Although studies showed that a high fluoridated water supply to the community presents lower enamel solubility and lower caries incidence, there is a question as to whether the major effect of lower incidence is by systemic or topical.

Malberg (1983) has stated that the beneficial effects of therapeutic levels of fluoride are accompanied by no known side effects to the general health of the population.
Fluoridated communities have a lower incidence of osteoporosis and dental caries than individuals who drink fluoridated deficient water.

4.3.1 FOOD SOURCES OF FLUORIDE

All foods contain at least traces of fluoride, while water

borne fluorides generally constitute the most important source for man. Modern diets are becoming increasingly important as a source of fluoride because of the increased use of fluoridated water in the preparation of processed foods and beverages.

Osis et al (1974) have stated that for temperate climates the optimal fluoride level in water supplies for reduction of dental caries without undesirable mottling is 1 ppm. Based on infant's and young children's usual and customary intake of between two and four glasses of water or its equivalent per day, this level of 1ppm would provide a total daily intake of 0.5 to 1 mg fluoride per day. For older children, adolescents, and adults, the intake from water would be equivalent to 1.5 to 2 mg of fluoride per day because they may drink between six and eight glasses of water or its equivalent per day.

Kramer et al (1974) emphasized that in the USA the intake of fluoride in foods by adults (exclusive of drinking water) averages approximately 1 mg per day in non-fluoridated communities and 2 to 3mg per day in fluoridated communities.

Hodge and Smith (1970) have stated that one mg of fluoride per liter of water equals 1 ppm fluoride. Therefore, if the consumption of 1500 ml of fluoridated drinking water (6 to 8 glasses /day) were added to the mg of fluoride in food, the total daily fluoride intake would average 1.2 mg for adults living in the non-fluoridated community compared with 3.5 to 4.5 mg for those living in the fluoridated (1ppm) community. The intake by children of fluoride from food and water would

be proportionatly less, depending on their calorie and water consumption needs. It is important to point out that the optimal recommendation of 1 ppm of fluoride was based on water intake only, even though the subjects must have ingested varying amounts of fluoride from their food also.

Dean in 1938 had reported that the fluoride level in food is not known to be a significant factor in producing mottled enamel. Only the ingestion of greater than optimal levels of fluoride in drinking water (2ppm) caused the fluorosis (mottled enamel).

According to Nizel (1981) fluoride concentration in fresh foods and beverages is shown in table 8.

Table 8 Fluoride concentration in fresh foods and beverages

(Nizel 1981 p269)

FOOD	*RANGE OF F IN PPM*
Beer	0.15–0.86
Cereals	0.18–2.8
Citrus fruits	0.07–0.17
Coca Cola	0.07
Coffee	0.2–1.6
Instant (powder)	1.7
Fish without bone or skin	1.0
Fish meal	80.0–250.0
Milk	0.04–0.55
Non-citrus fruits	0.03–0.84
Sardines	8.0–40.0
Shrimp meat	0.4
Shrimp shell	18.0–48.0
Tea	0.1–2.0
Instant (solution)	0.2
Vegetables and tubers	0.02–0.9
Wine	0.0–6.3

Adapted from Tables II and III in Hodge, H. C., and Smith, F. A.: Minerals: Fluorine and dental caries. *In* Advances in Chemistry, Series 94. Washington, D.C., American Chemical Society, 1970.

Meats, fruits, vegetables, and cereals contain very small amounts of fluoride. The rich sources of fluoride are seafoods, especially fish with small bones, such as sardines

and salmon, which tend to take up fluoride very readily. the amount of fluoride in fresh fish may be about 1.6 ppm, whereas in canned salmon, sardines, and mackerel it may be as high as to 7 to 12 ppm.

Nizel (1981) emphasized that it is important to realize that the average USA diet is low in fluoride content, and the best way to achieve optimal fluoride levels on a regular daily basis is via communal water supplies that contain 1 ppm fluoride.

4.3.2 METABOLISM OF FLUORIDE

During the pre-eruptive period when the enamel is mineralizing, systemic fluoride uptake by the tooth via the blood supply to the pulp takes place. For the most part, the fluoride ion becomes incorporated within the body of the enamel crystal. During the early posteruptive period the level of salivary fluoride is derived from systemic fluoride and plays the role of topical effect on the tooth.

The hydroxy ion in the hydroxypatite is substituted by the fluoride ion to produce fluorapatite which is firmly fixed and the reaction is irreversible.

$Ca_{10}(PO_4)_6(OH)_2 + 2F \rightarrow Ca_{10}(PO_4)_6F_2 + 2OH-$

Enamel Hydroxyapatite + Fluoride ---> Fluorapatite + Hydroxyl

Nizel (1972) has pointed out that the uptake of fluoride by enamel depends on the amount of fluoride ingested and the time of fluoride exposure: the higher fluoride level in the water, the greater is the initial rate of deposition during the

period of tooth mineralization . However, Silverstone (1982) concluded that after enamel is treated with fluoride, it becomes only a partially fluoridated hydroxyapatite.

Nizel(1981) has stated that it is important to understand how fluoride is absorbed, its distribution to the various tissues after absorption, and how the body through its excretion and storage mechanisms maintains a safe level.

The major site of absorption of fluoride in man appears to be the stomach and small intestine, primarily through the mucosal membranes. After ingestion, fluorides are absorbed in 30 to 90 minutes. The soluble fluoride in drinking water is almost completely absorbed, while appoximately 50 to 80 per cent of the fluoride that normally occurs in foods is absorbed. The more soluble the fluoride compound, the greater is the percentage of absorption.

The teeth, skeleton, and calcified structures store the highest concentrations of fluoride because of the affinity of fluoride for calcium. No soft tissue stores fluoride. The normal concentration of fluoride in saliva and milk is about 0.01 ppm. Nizel (1981) explained that the principle route of excretion of fluoride is the urine(90 to 95 per cent), the remainder (5 to 10 per cent) may be found in the faeces. The sweat also may be a route of excretion of a minute amount of fluoride.

The remarkable and impressive characteristic of fluoride excretion is its speed. Fluoride derived from communal water supplies is excreted in part via the urine of normal human

adults as early as three hours after ingestion. After 24 hours, as much as 50 to 60 per cent will have been excreted. In general, about half of the ingested fluoride is excreted in the urine each day. A steady state in which the fluoride excretion almost precisely equals the fluoride intake occurs within a relatively short period of time in adults ingesting 1 ppm of fluoride per day, as shown by the classic studies of Machele et al (1942).

4.3.3 MECHANISM OF FLUORIDE

Horowitz (1974) has stated that an agent used to prevent or treat a disease may be given systemically or topically. Systemic agents are taken into the body and circulate through the blood system to reach the sites where they produce benefits. The author has explained that the precise mechanisms by which fluorides protect teeth from dental caries are not completely understood; he considered that more than one mechanism is involved, and both topical and systemic exposures are important. Jenkins (1967) emphasized that until 1957, most dental experts believed that fluorides worked principally by increasing the resistance of enamel to acids produced in dental plaque by bacteria.

Brown and Konig (1977), Ericsson (1977) and Kleinberg (1978) stated that research clearly showed that other actions of fluoride, such as remineralization of initial or precarious lesions and a host of antimicrobial effects, are also important.

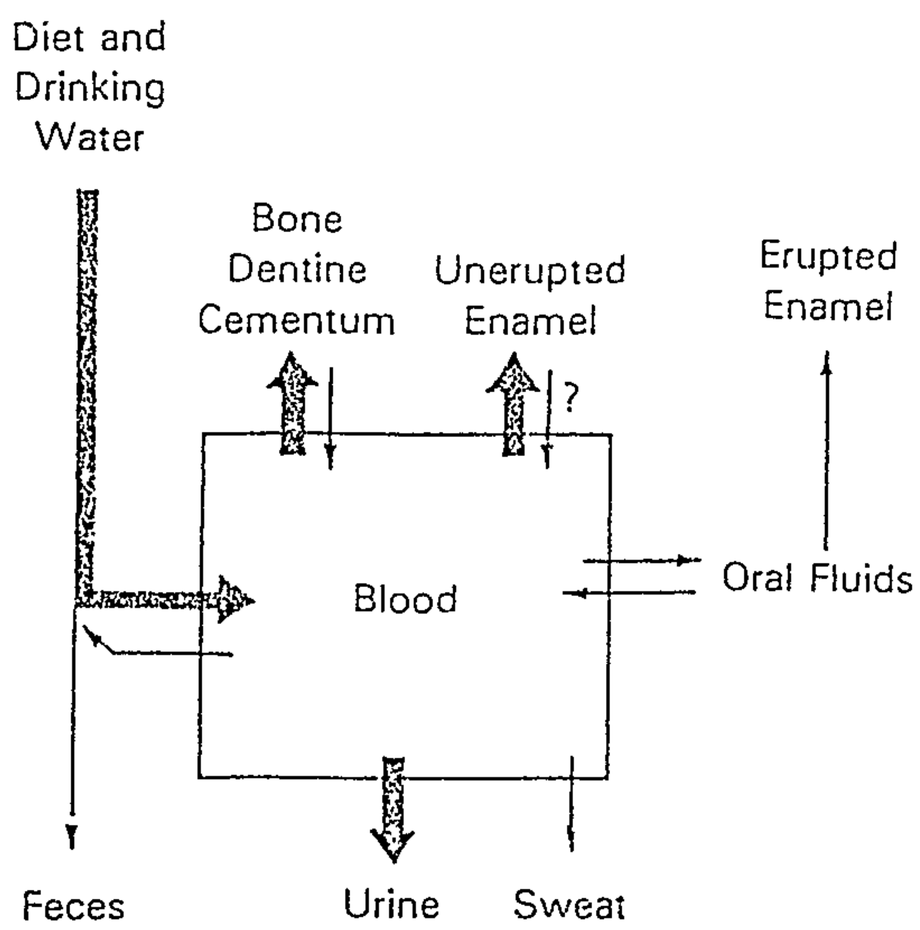
Armstrong and Singer (1970) and Weatherell (1977) stated that

fluoride is readily absorbed into the body, although the presence of ions that complex with fluoride, such as calcium and aluminum, may interfere with its absorption from the gastrointestinal tract. Usually, little fluoride is eliminated in the faeces. There is a temporary rise in the fluoride concentration of the blood shortly after its ingestion. The elevated fluoride level quickly subsides because fluoride is rapidly taken up by mineralizing tissue (bones and teeth) or excreted by the kidneys.

Figure 5 shows schematically what happens to fluoride when it is ingesed.

Figure 5 The kinetics of ingested fluoride

(Stallard 1982 p148)



Weatherell (1977) emphasized that fluoride concentrations in blood reach peak levels about 30 minutes after ingestion and, within a few hours, return to fasting levels. Fasting levels of fluoride in blood are low at about 0.02 to 0.03 parts per million (ppm).

Stallard (1982) has stated that while teeth are forming, small amounts of fluoride are incorporated into the enamel as hydroxyfluorapatite, which is more resistant to dissolution by acids than hydroxyapatite, the principal inorganic mineral of enamel. In the presence of high concentrations of plasma fluoride, the enamel surface continues to incorporate fluoride during the period of pre-eruptive maturation when the developing tooth is contained in its bony crypt within the jaws.

Because the enamel of newly erupted teeth is incompletely mineralized, appreciable diffusion of fluoride into enamel probably continues for an indefinite period of time following eruption. Of course, this type of uptake occurs only if fluorides are available at the enamel surface. Many researchers believe that the increasing concentration of fluoride in the enamel surface is crucial to establishing resistance to caries attack.

As figure 5 indicates, systemic fluoride is excreted in small amounts into the oral fluids through the salivary glands and crevicular fluid around the teeth. Some researchers believe that these continuous secretions of low concentrations of fluoride are responsible for a large part of the anticariogenic effects of fluoride. Although this may be so, fluoride must be ingested, circulated in the blood, and excreted into the mouth for this protective topical effect to be produced. An understanding of this process re-emphasizes the importance of systemic fluorides.

Mellberg (1977) stated that the mechanisms by which fluorides prevent decay, vary depending upon the agent used, its route of administration, the age at which it is administered, its concentration,its frequency of use, and the vehicle used to deliver it. Several mechanisms may operate simultaneously, with one or another pre-eminent at different times because of local conditions at the tooth surface.

4.4 MAGNESIUM

Donsbach (1983) has pointed out that magnesium has only recently been allocated the importance due to it as an important mineral nutrient in the body.

Nizel(1981) has stated that magnesium is present in both enamel and dentine, but its concentration in dentine is about twice that in enamel. According to Irving (1940) if a dietary deficiency in magnesium is induced in rats, the enamel and dentine of the incisor teeth will be hypoplastic because a deficiency in this mineral produces degenerative changes in ameloblasts and odontoblasts.

Nizel (1981) has pointed out that magnesium is a cofactor in the transfer of phosphate and the mobilization of calcium.

4.4.1 FOOD SOURCES OF MAGNESIUM

The following table of food composition indicates the main sources of magnesium. The information is computed from Kirshmann and Dunne (1984).

Table 9 Food sources of magnesium

(Modified from Kirschman and Dunne 1984 p242-280).

Bear	0.1 mg/gm
Mixed grain	0.49 mg/gm
Chocolate baking	2.92 mg/gm
Pear dried	0.33 mg/gm
Beef (chuck roast)	0.18 mg/gm
Lamb (leg)	0.13 mg/gm
Pork (ham)	0.19 mg/gm

Nuts and seeds	(almonds)	2.27 mg/gm
	(cashews)	2.68 mg/gm
	(peanuts)	1.75 mg/gm
Seafood	(crab)	0.34 mg/gm
	(snails)	2.5 mg/gm

4.4.2 METABOLISM OF MAGNESIUM

Magnesium is rather poorly absorbed, with less than 35% of the ingested amount being absorbed. The recommended daily allowance is from 400 mg to 500 mg and consequently over 1200 mg must be taken to ensure the minimal amount.

Magnesium is lost via both urine and faeces, significant amounts can be lost during prolonged episodes of vomiting or diarrhea.

4.4.3 MECHANISM OF MAGNESIUM

Nizel (1981) has stated that magnesium is a cofactor in the transfer of phosphate from adenosine triphosphate (ATP) to a phosphate receptor, or from a phosphorylated compound to adenosine diphosphate(ADP). This mineral is absolutely essential for the production of energy, the metabolism of carbohydrates and protein, and the utilization of fat.

Maintenance of a normal range of magnesium in the blood depends on a balance between absorption and renal excretion of sodium. There is no known hormonal regulating mechanism.

Small amounts of magnesium are present in the body fluids and take part in the transfer of enzymes by osmosis of water into

and out of the cells, they also take part in the regulation of the acid-base balance of the body.

4.5 VITAMIN A

Nizel (1981) has pointed out that the vitamin A found in animal foods has two slightly different forms, vitamin A1 and vitamin A2. Vitamin A1 is found chiefly in the liver and body fat of fish and also in other foods of animal origin such as liver, milk, butter, and egg yolk. Vitamin A2, which is of little importance in human nutrition, is found in fresh water fish.

Vitamin A is a pale yellow, almost colorless compound soluble in fat or fat solvents and insolubie in water. Because of its high degree of unsaturation, the vitamin A content of fats and oils can be destroyed by oxidation as they become rancid unless protected by antioxidants such as vitamin E or are stored in a cool, dark place.

Donsbach(1983) stated that the chief functions of vitamin A are to maintain the health of epithelial tissue and to ensure proper formation of tooth enamel, health of gums, and growth of bones.

4.5.1 FOOD SOURCES OF VITAMIN A

According to Nizel(1987) there are two general sources of vitamin A in the human diet:

(1) preformed vitamin A found in animal foods such as fish fat and fish liver.

(2) the precursor provitamin A carotenoids, found in plant foods that have a deep yellow or deep green pigment.

The major source of vitamin A in modern diet is the

provitamin A carotenoid found in plants. The deeper the yellow or the deeper the green of the fruits and vegetables, the more carotene.

According to Donsbach (1983) the food sources of vitamin A are shown in table 10.

Table 10 Food sources of vitamin A

(Modified from Kirschmann and Dunne p263-281)

LIVER:	
Lamb	505 IU/gm
Beef	439 IU/gm
Duck	399 IU/gm
Goose	310 IU/gm
Veal	225 IU/gm
Turkey	180 IU/gm
Butter	31 IU/gm
SEAFOOD:	
Nori	110 IU/gm
White fish	23 IU/gm
Crab	22 IU/gm
Eel	16 IU/gm
EGG:	
White dry	20 IU/gm
Yolk	18 IU/gm
Whole	5 IU/gm
CREAM:	
Sour cream	15 IU/gm
VEGETABLES AND FRUITS:	
Apricots dried	110 IU/gm
Sweet potatoes	88 IU/gm
Spinach	81 IU/gm
Pumpkin	64 IU/gm
Papaya	18 IU/gm

According to Department of Health, NSW (1987) vitamin A foods are shown in table 11.

Table 11 Food sources of vitamin A

(The Department of Health NSW 1987 p25).

Food	Amount edible portion	Average retinol equivalents microgram
Liver (average of lamb, chicken and calf livers), cooked	100 g	16.000
Kidney, cooked	100 g	200
Egg, 1	55 g	70
Milk	600 mL	240
Milk, 1 cup	250 mL	100
Modified milk (Hi-Lo), 1 cup	250 mL	45
Skim milk, 1 cup	250 mL	2
Modified milk (Shape), 1 cup	250 mL	2
Powdered full cream milk, 2 tablespoons	18 g	75
Powdered skim milk, 2 tablespoons	22 g	2
Cheese, cheddar type	20 g	70
Yoghurt, plain	200 g	70
Yoghurt, skim	200 g	4
Fresh cream 1 tablespoon	20 mL	75
Butter, 1 tablespoon	20 g	170
Table margarine, 1 tablespoon	20 g	200
Carrots	100 g	2.000
Yellow sweet potato	100 g	280–2.000
Silver beet or spinach, cooked	100 g	1.000
Broccoli or pumpkin	100 g	400
Parsley	10 g	100
Asparagus, canned green	100 g	50
Brussel sprouts or green peas	100 g	65
Beans or corn	100 g	45
Broad beans	100 g	40
Lettuce, 2 leaves	20 g	30
Sweet potato, white	100 g	5
Potato	100 g	1
Rockmelon, ½ small melon	100 g	350
Persimmon, 1 medium	120 g	325
Mango, 1 small	100 g	310
Apricots, 3 medium	100 g	250
Nectarines, yellow, 2 medium	100 g	160
Pawpaw, ¼ medium	100 g	130
Tomato, 1 medium	100 g	100
Peach, yellow, 1 medium	100 g	100
Mandarins, 2 small	100 g	45
Prunes, dessert, 6 medium	50 g	40
Plums, 3–4	100 g	35
Banana, 1 small	100 g	35
Blackcurrants, blackberries or cherries	100 g	20
Pineapple, 1 slice	100 g	10
Orange, 1 small	100 g	10
Apple, 1 small	100 g	5

4.5.2 METABOLISM OF VITAMIN A

Nizel (1981) has stated that preformed vitamin A is readily absorbed from the normal gastrointestinal tract. The various provitamin A carotenoids are absorbed more slowly than the preformed vitamin and are converted to vitamin A in the wall of the small intestine.

It is conservatively estimated that in humans about one-sixth of the provitamin A carotenoid intake may be expected to be transformed into vitamin A. This is determined on the basis that only about one-third of the provitamin A carotenoid is absorbed and that only about one-half of this has vitamin A activity for humans. Therefore, to arrive at the vitamin A equivalence, one must multiply the milligrams of carotenoid intake by a factor of 0.167. When an extraordinarily large amount of foods rich in beta carotene are ingested, some of the carotene may enter the circulation without having been converted into vitamin A, and in high concentrations may give a yellowish cast to the skin called hypercarotenemia. Hypercarotenemia may also be associated with certain diseases in which the conversion of carotene to vitamin A is impaired, such as diabetes mellitus and hypothyroidism. Any condition that impairs the normal flow of bile into the intestine will impair the absorption of the vitamin. Thus, a person with hepatic disease or biliary obstruction is likely do develop a deficiency of vitamin A even if the dietary intake is adequate.

Most of the total body content of vitamin A is stored in the

liver, and the depletion of these stores requires many months.

Thus, the signs and symptoms of vitamin A deficiency develop very slowly. If a patient is suffering from liver cirrhosis, the stores of vitamin A are markly reduced.

4.5.3 MECHANISM OF VITAMIN A

Nizel(1981) has described the provitamin A carotenoids, which are converted in the body to vitamin A. These are found in fruits and vegetables such as carrots, sweet potatoes, squash, apricots, peaches, corn, spinach, kale, and turnip greens. Three of these provitamins are known as alpha,beta,and gamma carotenes, and the fourth is cruyptoxanthin, the yellow pigment found in corn. For humans, beta carotene is the most important because it has the highest vitamin A activity and is the most plentiful. It is only after carotenes are absorbed and converted into vitamin A that they exert any vitamin activity. There are trans and cis forms of both carotene and vitamin A, the trans form having the greater potency.

4.6 VITAMIN D

According to Nizel (1981) there are three types of vitamin D but only two, vitamin D2 and vitamin D3, are of nutritional importance; vitamin D1 was found to be an impure mixture of sterols. These compounds are steroid alcohols (sterols) that are fat soluble and stable to cooking, processing, storage, and acids but sensitive to light.

Vitamin D2 is designated as ergocalciferol and is derived from the provitamin ergosterol,which is present in plants, especially in fungi and yeasts. Vitamin D3, the naturally occuring form of the vitamin in animal tissues, is produced in the skin and is designated as cholecalciferol.

Vitamin D functions both as a vitamin and as a hormone because, in the first instance, it is present in food and, in the second instance, it is formed in the skin and acts on distant target organs, specifically the intestine and bone. The principal action of vitamin D is to promote intestinal calcium and phosphorus proper utilization and mineralization of the teeth and bones.

4.6.1 FOOD SOURCES OF VITAMIN D

Nizel (1966) has pointed out that there are few good sources of vitamin D. Fish liver oils contain large variable amounts of the vitamin and have often been used as both vitamin A and D supplements. In many countries, including the United States, milk is routinely enriched with 400IU of vitamin D per quart. Ergosterol which on ultraviolet irradiation is

converted to vitamin D2 is found widely in the plant kingdom, being particularly concentrated in yeasts and fungi. Nevertheless, vitamin D is rarely found in vegetables.

Most animals acquire vitamin D by sunlight irradiation of 7-dehydrocholesterol, a precursor of vitamin D3 found in their skins. 7-dehydrocholesterol can be synthesized by animals from cholesterol, so a dietary source of the provitamin is not necessary.

Nizel (1981) has stated that vitamin D occurs naturally in such animal foods as fatty fish, eggs, liver, and butter but in small and insignificant amounts. Therefore, we have to rely on either fish liver oil or fortified milk as the major food sources for vitamin D.

Donsbach (1983) has provided the following information :

Food sources of vitamin D:

100 gm.Herring	330	IU
100 gm.Salmon	314	IU
100 gm. Tuna	260	IU

Note: 100 grams is equal to about three and one-half ounces.

4.6.2 METABOLISM OF VITAMIN D

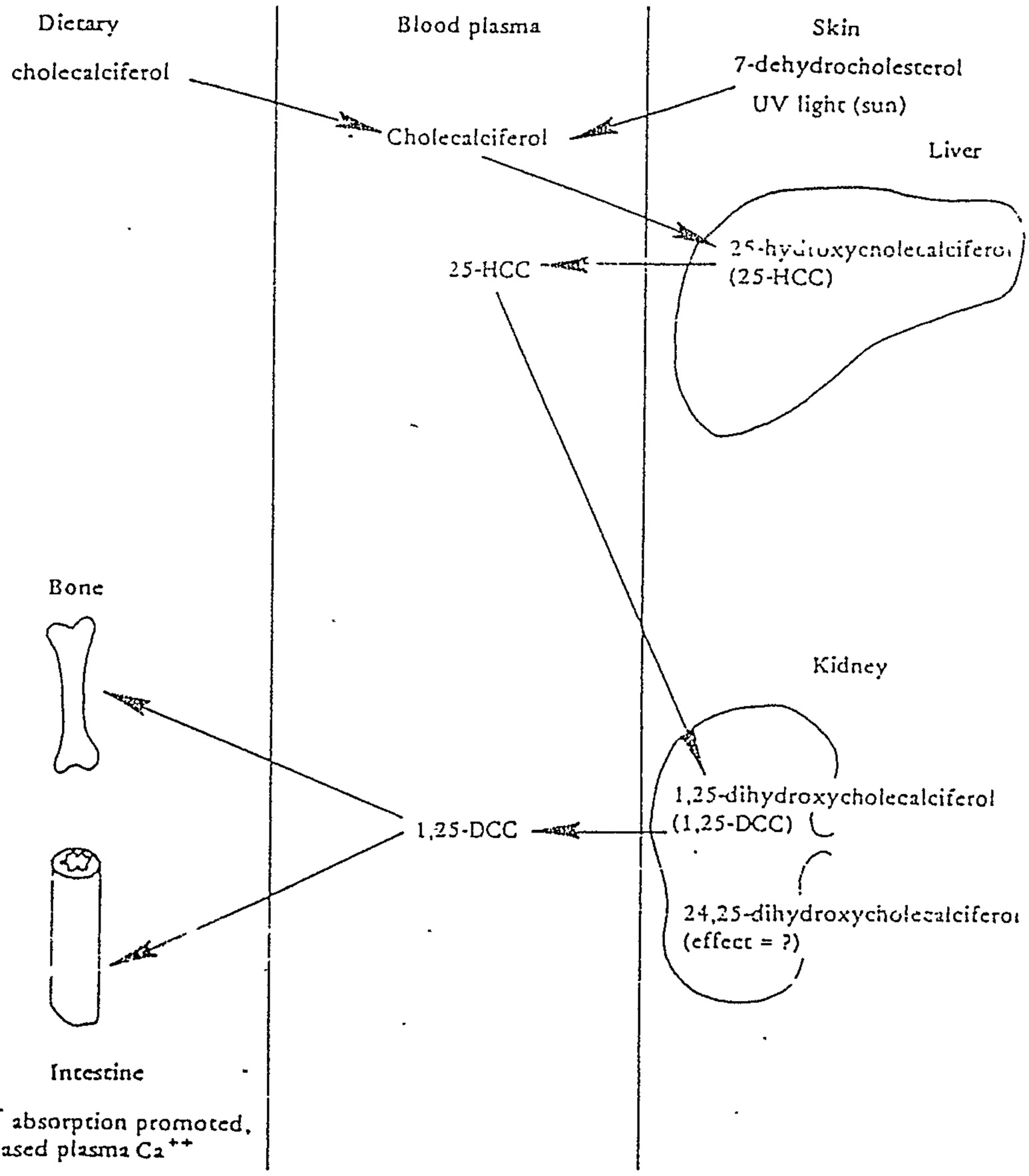
Nizel (1981) stated that recent research has shown that vitamin D must be converted to at least two biologically active metabolites before it can induce physiological changes. Vitamin D is initially hydroxylated in the liver and intestine

to 25 - hydroxycholecalciferol (25HCC) and is then carried to the kidney for further hydroxylation to form 1, 25 - dihydroxycholecalciferol (1,25.DHCC). This is the most biologically active form of vitamin D. The conversion of 25 HCC to 1,25 DHCC is regulated by circulating calcium, parathyroid hormone, and calcitonin.

According to Nizel (1981) vitamin D metabolism is shown in figure 6.

Figure 6 Vitamin D metabolism

(Nizel 1981 p191)



4.6.3 MECHANISM OF VITAMIN D

Nizel (1981) has stated that vitamin D is absorbed from the intestinal tract in the presence of bile salts and fats and is transported into the circulation via chylomicrons in much the same way as vitamin A.

Factors that increase or interfere with fat absorption will influence the rate at which vitamin D is absorbed. In the blood, vitamin D is carried on an alpha globulin to the liver where it is converted to 25-hydroxycholeciferol and stored. It is also found in skin and brain, with small quantities in the lungs, spleen, and bones.

5 THE MECHANISMS OF INCREASED TOOTH RESISTANCE BY DIET

According to Nizel(1981) the goal of good nutrition is to provide daily an adequate and well-balanced supply of all nutrients throughout the various periods of life with appropriate adjustments during times of altered need. To maintain an optimal nutritious diet each individual must be considered and provided for on the basis of his/her background, preferences, way of life, and specific needs. Nizel (1981) has considered that fulfillment of this goal requires not only the availability of appropriate high quality food, but, in addition, the food should be prepared to conserve nutritional values and served in a palatable and esthetically attractive fashion with special attention to the provision of varied menus.

Nizel (1981) has stated that inadequacy of fluoride or deficiencies of calcium, phosphorus, or vitamin D during tooth development are typical examples of nutritional problems with sequelae that cannot be erased by later addition of these food factors to the diet. He considers that the chemical composition and the histologic integrity of the teeth indelibly reflect the circumstances during mineralization and serve as physiologic kymographs.

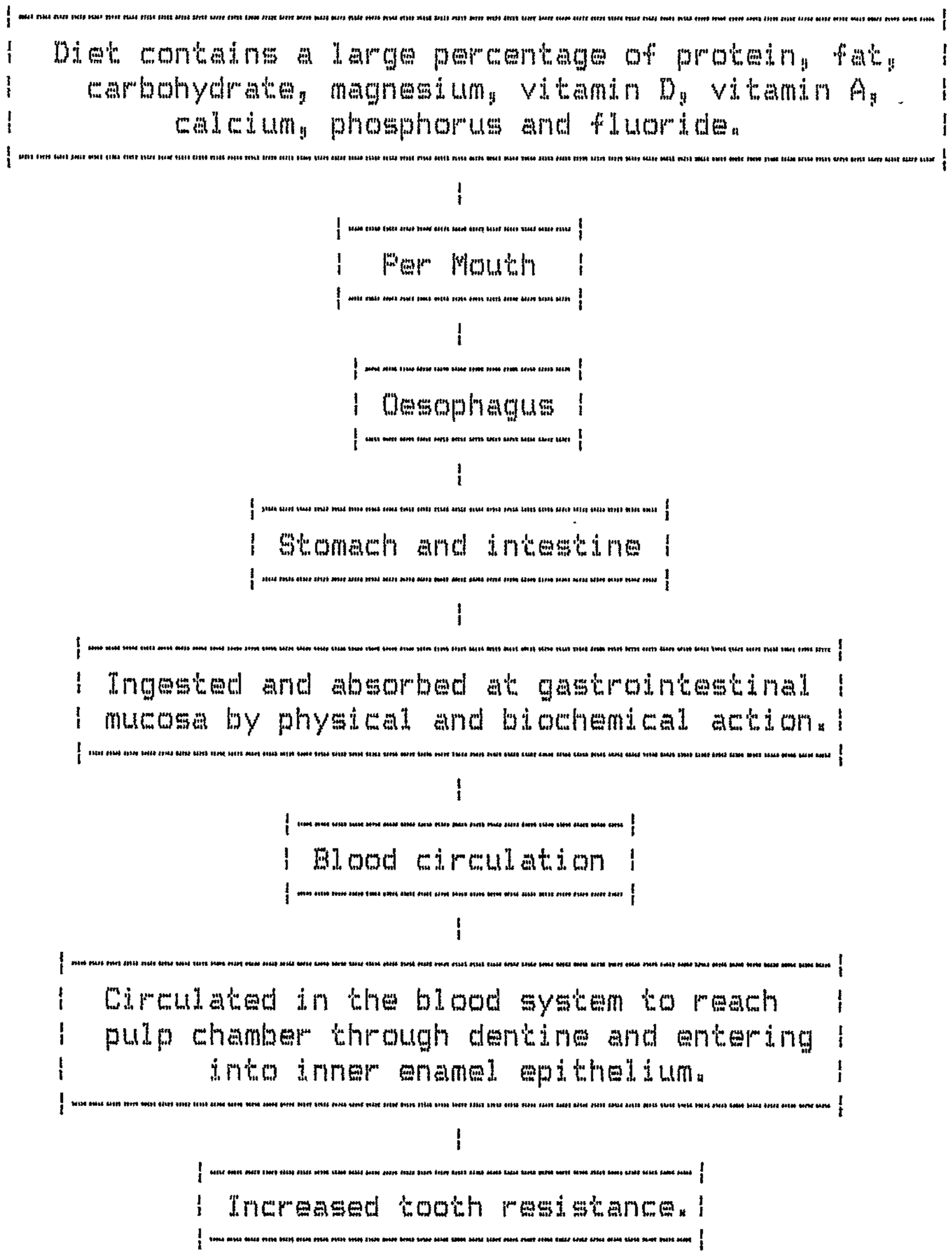
Diet affects the teeth in two ways, first, while the tooth is forming and developing before eruption and, second, a local oral effect after the tooth has erupted into the mouth. The former is the systemic effect via blood circulation to reach the inner enamel epithelium and benefit enamel, and the latter

is the local effect via systemic fluoride excreted in small amounts into oral fluids through the salivary glands and crevicular fluid.

Once the crowns of the teeth are fully formed, calcium, phosphorus and vitamin D intake cease to have much effect.

5.1 SYSTEMIC EFFECT BY BLOOD CIRCULATION TO REACH INNER ENAMEL EPITHELIUM WHEN TOOTH IS DEVELOPING

The mechanism of building a stronger tooth structure by means of systemic effect is shown as follows:



1. PROTEIN

Shaw and Griff (1963), Sweeny and Navia (1966) have stated that severe protein deficiency causes delay in tooth eruption and may lead to slightly increased susceptibility to caries. Menaker and Navia (1973) pointed out that protein deficiency may result in changes in the morphology and eruption patterns of teeth. Nizel (1966) explained that human dental enamel is made up of 0.2 to 0.4 percent organic matter which contains an insolubie protein .

2. FATS

Fat is an excellent dietary source of energy, if needed, or is stored in adipose tissue.

3. CARBOHYDRATES

Carbohdrates are principally a source of dietary energy. Stack (1956) has found that 10 times as much carbohydrate is found in the outer layer of enamel as in the inner. Nizel (1966) explained that carbohydrates play a role as part of the structure of other biologically important materials, such as glycolipids, glycoproteins nucleic acid and heparin.

4. MAGNESIUM

The magnesium content of teeth is approximately 0.4 percent in enamel and 0.9 percent in dentine. Magnesium is a cofactor in the transfer of phosphate and the mobilization of calcium.

If there is a dietary deficiency in magnesium, the enamel and dentine will be hypoplastic because a deficiency in this mineral produces degenerative changes in ameloblasts and odontoblasts.

5. VITAMIN D

Nizel (1981) has stated that the principal action of vitamin D is to promote intestinal calcium and phosphorous utilization and mineralization of the teeth .

Nizel (1981) and Shaw (1952) stated that nutritional influences are greatest during development. Apart from fluoride and possibly other trace elements, the only nutritional factor which has been shown to have a direct effect on subsequent susceptibility to caries, is vitamin D

6. VITAMIN A

Donsbach (1983) has stated that the chief function of vitamin A is to maintain the health of epithelial tissue and to ensure proper formation of tooth enamel.

7. CALCIUM

Donsbach (1983) stated that calcium is the most abundant mineral in the body. It is estimated that 99 percent of the calcium in the body is deposited in the teeth and the bones. Mature human enamel is about 96% inorganic matter and mature human dentine is about 70% inorganic matter. Kirschmann and Dunne (1984) have mentioned that the major function of calcium is to act in coorporation with phosphorus to build and maintain teeth and bones.

Enamel and dentine are calcified tissues; the major function of calcium is to provide crystalline rigidity and strength to the teeth.

8 PHOSPHORUS

The function of phosphorus is to build a strong tooth. Donsbach (1983) has emphasized that a calcium phosphorus balance exists in the body and is very important to maintain normal body function.

Nizel and Harris have emphasized that phosphate supplements to the diet have been shown in recent years to lead to significant reduction in the incidence of caries experimental animals.

9 FLUORIDE

(1) EFFECTS ON ENAMEL SOLUBILITY

Silverstone (1981) stated that some fluorapatite is formed in enamel when fluoride is presented systemically during the time of tooth development. After development, fluoride may be acquired by enamel pre-eruptively due to a process of ion exchange between some of OH^- ions of hydroxyapatite and the F^- ions present in the tissue fluid bathing the tooth. The enamel may therefore be regarded as a mixture of inorganic phases and may best be described as fluorohydroxyapatite.

$Ca_{10}(PO_4)_6(OH)_2 + 2F \longrightarrow Ca_{10}(PO_4)_6F_2 + 2(OH)^-$

$Ca_{10}(PO_4)_6(OH)_2 + F \longrightarrow Ca_{10}(PO_4)_6F_2 + (OH)^-$

Both fluorapatite and fluorohydroxyapatite are a more stable and perfect crystal than hydroxyapatite, and hence the effect of fluoride is to reduce enamel solubility.

(2) EFFECT ON BACTERIAL METABOLISM

Jenkins (1974) reported that samples of plaque from residents in a fluoridated area were less able to form acid when rinsed with sucrose than samples from a low fluoride area. This result implies either inhibition by plaque fluoride of bacterial metabolism of an altered plaque ecology as a result of fluoride ingestion.

(3) EFFECT MEDIATED BY SURFACE ADSORPTION

Ericson and Ercsson (1967) have reported that the ability of powered hydroxyapatite to absorb salivary proteins was reduced when partial substitution of its hydroxyl groups by fluoride had taken place. Thus, fluoride incorporated in the enamel might alter the surface charge or free energy and in this way the deposition of pellicle and its subsequent bacterial colonisation.

(4) EFFECT MEDIATED BY TOOTH MORPHOLOGY

Lovius et al (1969) and Aasenden et al (1974) pointed out that comparisons were made between the teeth of children in two matched neighbouring communities, one of which was supplied with fluoridated water, while in the second fluoride supplements were given to a group of infants for the first three years of life. An increase in the prevalance of atypically shallow pits and fissures was observed in the fluoride groups in both of these two studies.

5.2 LOCAL EFFECT OF DIET ON ENAMEL SURFACE

Fluoride is ingested and absorbed into the body and circulated through the blood system. Systemic fluoride is excreted in small amounts into the oral fluids through the salivary glands and crevicular fluid to produce a protective topical effect.

The action of topical fluoride is the deposition of fluoride onto the surface layer of tooth enamel to form fluorapatite, so as to decrease caries susceptibility.

Apatite $Ca_{10}(PO_4)_6X_2$

where X=OH (Hydroxy apatite)

X=F (Fluorapatite)

X=FOH (Hydroxyfluorapatite)

$Ca_{10}(PO_4)_6(OH)_2 + 2F \longrightarrow Ca_{10}(PO_4)_6F_2 + 2OH^-$

Enamel hydroxyapatite + fluoride ——> fluorapatite + hydroxyl

According to Silverstone (1978) the mechanisms whereby fluoride reduces caries are complex, but may be summarized under the following headings.

(1) BY RENDERING ENAMEL MORE RESISTANT TO ACID DISSOLUTION UNDER THE INFLUENCE OF FLUORIDE

(a) Layer enamel crystals are formed with fewer inperfections. This stabilizes the lattice and presents a smaller surface area per unit volume for dissolution.

(b) Enamel has a lower carbonate content, thus giving reduced solubility.

(c) Reprecipitation of calcium phosphate occurs and fluoride favours their crystallization as apatite.

Cray et al (1962) have stated that the initial rate of dissolution of hydroxyapatite is the same as fluorapatite. However, the subseqent formation of secondary precipitates (such as calcium fluoride) on the surface of the enamel crystals reduces the rate of diffusion of hydrogen ions and of undissociated acid to the crystals, thus reducing their rate of solution.

(2) BY INHIBITING BACTERIAL ENZYME SYSTEMS WHICH CONVERT SUGARS INTO ACIDS IN PLAQUE

For this to occur, fluoride must be present as free ionic fluoride and not be bound up in plaque. (Jenkins 1967)

(3) BY INHIBITING STORAGE OF INTRACELLULAR POLYSACACCHARIDES

In this way the accumulation of carbohydrate within the cell is prevented. This could otherwise be used to form acids between meals.

(4) AT HIGH CONCENTRATION FLUORIDE IS TOXIC TO BACTERIA

Certain species may therefore be eliminated for short periods after topical fluoride therapy. However, this is obviously only a temporary benefit of topical fluoride therapy.

(5) BY REDUCING THE TENDENCY OF THE ENAMEL SURFACE TO ABSORB PROTEINS

Several in vitro reports have shown that plaque does not build

up so readily on enamel surfaces treated with fluoride. This may be because fluoride reduces the surface energy of the teeth (Glantz 1969) and the tendency of the enamel surface to adsorb proteins. (Ericson and Ericsson 1967) Pearlman and Joyston-Bechal (1973) have stated that clinical trials have failed to demonstrate any plaque-reducing effect.

However, a recent pilot study on humans demonstrated a significant reduction in plaque in fluoride-treated quadrants relative to controls after topical application of fluoride gel.

(6) MODIFICATION IN SIZE AND SHAPE OF TEETH

Forrest (1956) stated that animal experiments have suggested that fluoride intake during tooth development may reduce the size of teeth and produce more rounded cusps and shallower fissures. Such observations have been recorded in humans from high-fluoride areas in the United Kingdom. However, the scientific basis for this is poor.

(7) REMINERALIZATION

McCann and Brudevold (1966) stated that fluoride favours precipitation of calcium and phosphate ions in the form of apatite rather than as soluble calcium phosphates.

Silverstone(1972) explained that experiments on remineralization of carious human enamel in vitro have shown that the presence of low concentrations of fluoride greatly enhances the reprecipitation of mineral ions to the damaged enamel.

5.3 CONTROL OF DIET

DePaola (1979) has stated that oral structures are susceptible to unique destructive processes which may be influenced locally by the physical and biological characteristics of the diet and systemically by the body's natural defence system which is in part determined by diet. DePaola (1979) has explained that in addition to the local effects of refined carbohydrates on the dental caries process, diet affects teeth and their supporting structures during development and maintenance of the dentition.

Menaker and Navia (1973) and Navia et al (1970) have emphasized that pre and/or postnatal dietary deficiencies of calories and/or protein may result in changes in the morphology and eruption patterns of teeth.

Slack (1981) stated that there are two components of diet which have a significant relationship to increased tooth resistance: nutritive value and local action in the mouth.

Mellanby (1934) has pointed out that diet is, of course, of fundamental importance to the general development, growth, and health of the individual. In the early years of this century it was shown that inadequate nutrition during childhood interferes with tooth development, leading to gross or microscopic effects in enamel, either hypoplasia or hypomineralization.

Day and Sedwick (1934) and Staz(1944) explained that it was assumed that the more perfect a tooth, the more resistant it would be to caries, and great emphasis was, therefore, placed on diet.

Shaw (1952) stated that nutritional influences are greatest during tooth development. Apart from fluoride and possibly other trace elements the only nutritional factor which has been shown to have a direct effect on subsequent susceptibility to caries, is vitamin D.

Shaw and Griffiths (1963) and Sweeney and Guzman (1966) have emphasized that severe protein deficiency causes delay in tooth eruption and may lead to slightly increased susceptibility to caries.

Losee and Adkin (1969) have stated that studies of caries-free recruits to the United States Navy have shown that a high proportion of them come from geographic areas with drinking water containing relatively high levels of strontium, molybdnum, lithium and boron, and low levels of selenium.

Losee and Adkins (1971) explained that there is evidence that the method of cooking or preparation of vegetables has a major effect on the consumption of trace elements.

Curzon and Losee (1977) and Curzon et al (1978) have stated that recent research has shown that strontium is the most important of these trace elements; that there is an association between caries and the strontium content of drinking water and tooth enamel, and that the lowest caries prevalence occurs in towns with 5-6 mg strontium per litre of drinking water.

5.3.1 DECREASE OF INTAKE OF SUGAR

Dental caries is a destructive disease of the hard tissues of the teeth and there is good evidence that it is initiated by

acids produced by the fermentation of carbohydrate substrates by bacteria in dental plaque.

Dental plaque seems to be essential for the development of caries. It provides the bacteria and the conditions under which they can be supplied with carbohydrate substrates and allowed to ferment them. Plaque also localizes the resultant acid on the tooth surface, preventing its dilution and buffering by the saliva. It contains a great variety of types of microorganisms, many of which can ferment carbohydrates to produce acid.

Stephen (1940) was the first to show that, in the presence of a limited, liquid sugar challenge, the plaque pH rapidly falls, often to levels of about pH 5.0. This is then followed by a slow pH rise. If the availability of the substrate is prolonged, as with repeated exposure to sugar, the pH tends to remain low for a protracted period of time and then slowly increases.

Fehr von der et al (1970) demonstrated that rinsing with a 50% sucrose solution, nine times a day, produced incipient carious lesions in a period of 21 days. Gustafsson et al (1954) demonstrated that the frequent consumption of solid sugar-containing substances leads to an increase in the incidence of caries. Volker et al (1947) and Kleinberg(1970) have stated that it is likely that both the frequent intake of the sugar solution coupled with its relative inability to stimulate the flow of saliva contributed to this rapid formation of caries. Mormann and Muhlemann(1981) and Sreebny (1982) have emphasized that evidence exists that starch, in addition to, the

mono and dissaccharides, contributes to the development of caries.

Raw sugar is less harmful to our teeth than white refined sugar, but all sugars act as substrate to the microorganisms on our teeth. Silverstone(1981) stated that there seem to be three approaches to reduce dental caries via diet.

(1) The limitation of consumption of sucrose items preferably in a non-sticky form, to mealtimes. This is a matter of education of the public, or by individual dentists advising their own patients.

(2) The replacement of sucrose by other sweetening agents in foods and beverages. This is more difficult and involves economic and industrial considerations, palatability and consistency, as well as health and safety factors. What is desirable for dental health is not the substituition of costly protein, or fat, for carbohydrate, but the replacement of more cariogenic carbohydrates by less cariogenic carbohydrates.

(3) The third possibilty for dietary modification is that certain additives which are known to have an inhibitory effect on the initiation and development of caries, might be included in the diet either by adding them to a wide range of foods, or by educating the public to choose specific items that contain them.

5.3.2 DECREASE OF INTAKE OF STICKY FOOD

All the sticky sugar containing foods feed the microorganisms responsible for carbohydrate fermentation. A study by Lundgvist (1952) attempted to establish the oral sugar clearance time of common foodstuffs and thus to grade their cariogenicity. The foods containing sucrose together and with a high tendency to stick to the teeth appear most cariogenic.

The following list provided by Moss(1977) indicates the sticky and/or easily fermentable foods that are most responsible for tooth decay. If the diet does include these foods, immediate brushing of the teeth after meals must be emphasized.

List of the sugar stickies:

Chocolate milk, condensed milk, cocoa,

All kinds of soda, sweet sauces,

Sweetened fruit-flavored drinks, white bread,

Pastries, cakes, cookies,

Macaronie, spaghetti,

Jems and jellies, ice cream, dried fruits,

Candy, marshmallows, chewing gum,

Processed or presweetened cereals, raisins.

If brushing of the teeth is not possible, dental health educators advise 'swish and swallow' to reduce the acid effect on the teeth.

Slack (1981) mentioned that food is more than just something to eat, often it satisfies an emotional need. Sometimes a person must have sweets but this is largely a matter of

conditioning, not a real physical need. In this case it is important for the person to realize the harm caused by the numbers of times during the day that sugar comes in contact with the teeth.

5.3.3 SUGAR BETWEEN MEALS

Slack (1981) has stated that although the nutritive value of food probably has little effect on dental caries, food has a dramatic local effect on the teeth. The classical study of this effect was conducted at the Vipeholm Hospital in Sweden by Gustafsson et al (1954) when 436 young adult patients were divided into groups and fed varying diets for a total 5-year period. The major differences between these diets were in the resence, type and amount of carbohydrate eaten between meals.

It was found that the control groups on the basic Swedish diet, and other groups given supplements of bread or sucrose at meal-times, developed relatively little caries(<2 DMF teeth) during the 5-year period.

Slack (1981) explained that groups given toffees, chocolate, or caramel between meals, however, developed large amounts of new caries. The largest amount of new caries was found in the group eating 24 toffees each day. This amount was so great that, to consume this number in a day, toffee was almost constantly present in the mouth during the waking hours. When between meals eating was discontinued, the caries increment in the following year was much smaller, being of a similar order to that found in the control group.

Figure 7 The Vipeholm Dental Caries Study

(Thylstrup 1986 p138)

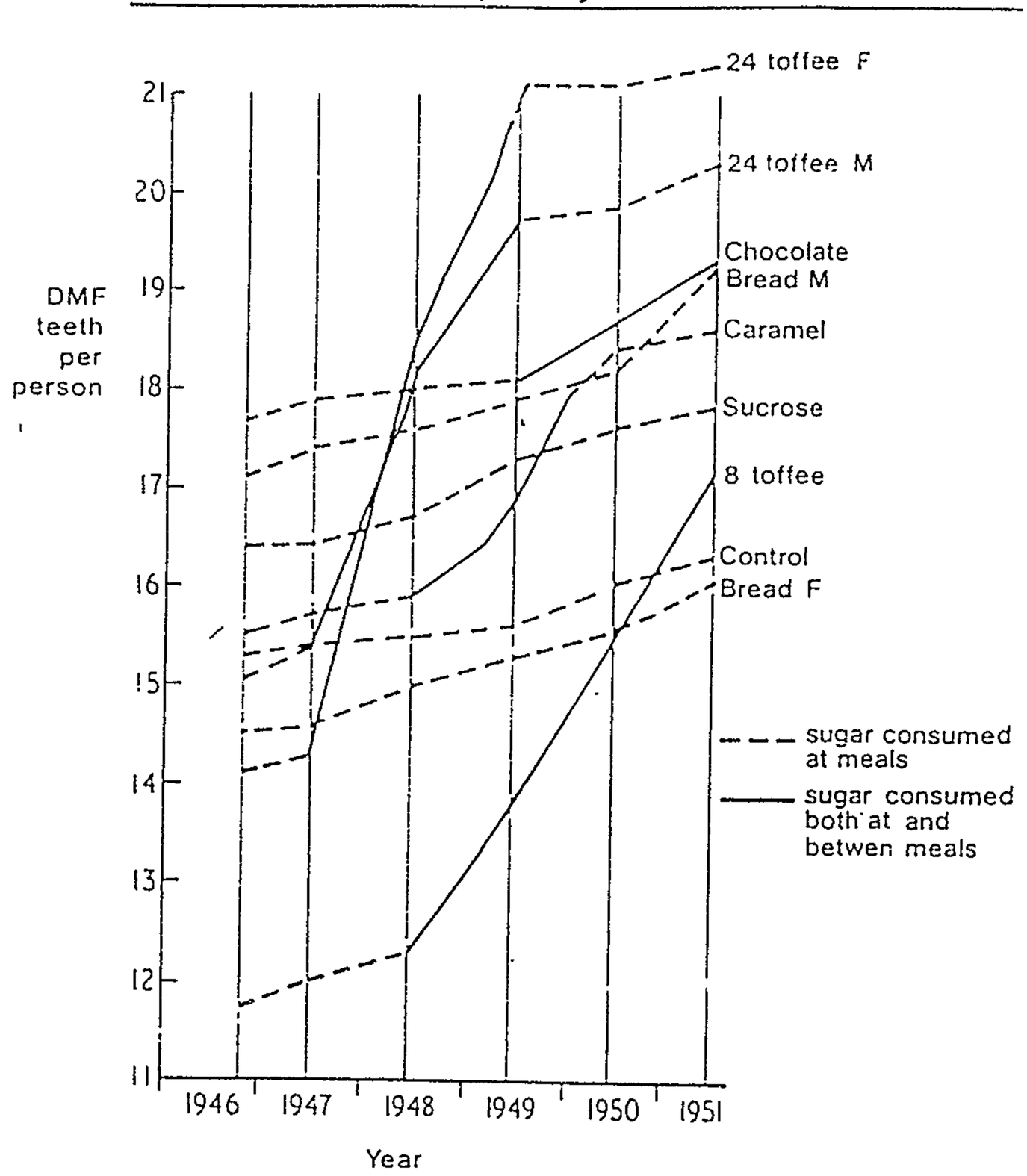


Figure 7 Dental caries expressed as number of decayed, missing and filled teeth per person in participants in the Vipeholm study[2]. The steepness of the curve is always less if consumption of the sugar is restricted to mealtimes. The form of administration of sucrose is also significant

Bradford and Crabb (1961) found that the caries prevalence in groups of dentists' children who had not had between-meals snacks was considerably lower than that in comparable groups of dentists' children to whom between-meal snacks had been available. Research has indicated the importance of eliminating sugar-filled snacks, especially between meals, as these constitute continuous substrate on the surface of the teeth throughout the day.

6 CONCLUSION AND RECOMMENDATION

The writer has placed great emphasis on diet as a means to increase tooth resistance and to form a stronger structure of dental enamel, dentine, and cementum. A review of some of the most important known essential vitamins, minerals, and trace elements, proteins, fats, and carbohydrates; and their importance in increasing tooth resistance, have all been presented in this thesis. Calcium, phosphorus, magnesium, vitamin A, vitamin D, fluoride and protein are all essential to tooth health and diseases such as: enamel hypoplasia, enamel dysplasia, focal hypomaturation, amelogenesis imperfecta, regional odontodysplasia; which all may arise from a lack of these essential substances in the diet.

Fluoride acts in several ways to increase tooth resistance and make a stronger tooth structure. When ingested during the period of tooth development it is deposited in enamel to produce more acid resistant enamel. When applied topically, fluoride continues to strengthen enamel; aids remineralization and exerts an antibacterial action.

While the tooth is developing, and before the crowns of the teeth are fully formed, calcium and phosphorus are important in enamel composition. It is estimated that enamel is about 96 per cent inorganic matter, and dentine is about 70 per cent inorganic matter (calcium and phosphorus). Enamel and dentine are calcified tissue and the major function of calcium and phosphorus is to provide crystalline rigidity and strength to the teeth.

Nizel (1981) stated that the principal function of vitamin D is to promote intestinal calcium and phosphorus utilization and mineralization of the teeth. Apart from fluoride and possibly other trace elements, the only nutrional factor which has been shown to have a direct effect on on subsequent susceptibility to caries, is vitamin D. Vitamin D also has remineralization and recrystallization action to increase tooth resistance.

Manganese is a cofactor in the transfer of phosphate and the mobilization of calcium. If there is a dietary deficiency in magnesium the enamel and dentine will be hypoplastic. The deficiency in this mineral produces degenerative changes in ameloblasts and odontoblasts.

Vitamin A ensures proper formation of tooth enamel.

Protein also plays an important role; severe protein deficiency causes delay in tooth eruption and may lead to slightly increased susceptibility to caries which may result from changes in the morphology and eruption patterns of teeth. Human dental enamel is made up of 0.2 to 0.4 percent organic matter which contains an insoluble protein.

The following tables have been selected by the writer from the Recommended Dietary Allowance of the National Research Council (USA) 1989. Nutrient Allowance Charts are provided for three categories: children, girls and women, and boys and men. Each category is further divided into different ages and weights.

Table 12 Nutrient Allowance Chart for Children.

(Modified from Kirschmann and Dunne 1984 p285-286).

	Children (Boys and Girls)				
Age	0–6 mo	6–1 mo yr	1–3 yr	4–6 yr	7–10 yr
Weight, lb	14	20	28	44	66
Weight, kg	6	9	13	20	30
Calories required for Resting metabolic rate					
Light activity	770		1100	1600	2200
Carbohydrates, g	115		165	240	330
Fats, g	28		38	58	80
Protein, g	14	14	23	30	34
MINERALS					
Calcium, mg	360	540	800	800	800
Magnesium, mg	50	70	150	200	250
Phosphorus, mg	240	360	800	800	800
VITAMINS					
Vitamin A, IU	1400	2000	2000	2500	3300
Vitamin D, IU	400	400	400	400	400
TRACE MINERALS					
Fluoride, mg	.1–.5	.2–1.0	.5–1.5	1.0–2.5	1.5–2.5

Table 13 Nutrient Allowance Chart for Girls and Women.

(Modified from Kirschmann and Dunne 1984 p285-286).

	Girls			Women			
Age	11–14 yr	15–18 yr	19–22 yr	23–50 yr	Pregnant	Lactating	51 and over
Weight, lb	97	119	128	128			128
Weight, kg	44	54	58	58			58
Calories required for Resting metabolic rate				1620			
Light activity	2300	2300	2000	2000	+300	+500	1850
Carbohydrates, g	345	345	345	300			277
Fats, g	80	78	79	66			59
Protein, g	46	46	44	44	+30 g	+20 g	44
MINERALS							
Calcium, mg	1200	1200	800	800	1200	1200	800
Magnesium, mg	300	300	300	300	450	450	300
Phosphorus, mg	1200	1200	800	800	1200	1200	800
VITAMINS							
Vitamin A, IU	4000	4000	4000	4000	5000	6000	4000
Vitamin D, IU	Adequate daily intake 400 IU				Adequate daily intake 400–800 IU		
TRACE MINERALS							
Fluoride, mg	1.5–2.5	Adequate daily intake 1.5–4 mg			Adequate daily intake 2.5–5 mg		

Table 14 Nutrient Allowance Chart for Boys and Men.

(Kirschmann and Dunne 1984 p285-286).

	Boys			Men	
Age	11–14 yr	15–18 yr	19–22 yr	23–50 yr	51 and over
Weight, lb	97	134	147	154	154
Weight, kg	44	61	67	70	70
Calories required for					
Resting metabolic rate					
Light activity	2600	3000	3000	2600	2600
Carbohydrates, g	—	—	—	390	390
Fats, g				87	87
Protein, g	45	56	56	56	56
MINERALS					
Calcium, mg	1200	1200	800	800	800
Magnesium, mg	350	400	350	350	350
Phosphorus, mg	1200	1200	800	800	800
VITAMINS					
Vitamin A, IU	5000	5000	5000	5000	5000
Vitamin D, IU	Adequate daily intake 400 IU				
TRACE MINERALS					
Fluoride, mg	1.5–2.5	Adequate daily intake 1.5–4 mg			

The writer has also compiled the following four tables which contain foods believed to be more likely to increase tooth resistance to dental caries. The tables also show foods and food composition. In compiling these tables, the writer referred to tables of food composition provided by the National Academy of Science (1980).

The tables containing foods believed to be more likely to increase tooth resistance are provided for four groups:

Table 15 Foods believed more likely to increase tooth resistance to caries: meat, poultry, fish, and beans group.

(Modified from Kirschman and Dunne 1984 p263-273).

	Measure	Beef[1] Club steak	Lamb[1] Liver	Chops	Pork Bacon	Chicken[1] Dark meat	Duck Domesticated	Goose Domesticated	Turkey Light meat
Measure		1 lb	1 lb	1 lb	1 lb	1 lb	1 lb	1 lb	1 lb
Weight	gm	454	454	454	454	160	287	320	180
Calories		1443	617	1146	2523	379	1159	1187	286
Protein	gm	58.9	95.3	63.7	39	26.7	33	50.7	39
Carbohydrate	gm	0	13.2	0	.42	0	0	0	0
VITAMINS Vitamin A	IU	260	229070	—	0	273	483	176	12
Vitamin D	IU	—	—	—	—	—	—	—	—
MINERALS Calcium	mg	34	45	35	34	18	30	38	23
Magnesium	mg	81	.64	55	39	30	42	59	43
Phosphorus	mg	539	1583	567	646	217	398	748	331
Fluoride	mg	—	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	132	19.6	97	261	29.3	115	107	13.2

	Measure	Crab	SEAFOOD AND SEAWEED Salmon	Oysters	Lobster	Shrimp	Tuna	Herring	NUTS Peanuts	Sunflower seeds	EGG Whole
Measure		1 lb	1 lb	1 lb	1 lb	1 lb	1 C.	1 lb	1 C.	1 C.	1 lge
Weight	gm	453	453	453	453	453	160	453	144	145	50
Calories		422	984	299	413	413	315	798	838	812	79
Protein	gm	78.5	102	38.1	76.7	82.1	46.1	78.5	37.7	34.8	6.07
Carbohydrate	gm	2.3	0	15.4	2.3	6.8	0	0	29.7	28.9	.6
VITAMINS Vitamin A	IU	9830	1359	1410		40.5	130	520		70	260
Vitamin D	IU	—	14 22	—	—	—	14 16	149 5	—	—	—
MINERALS Calcium	mg	195	358	426	132	286	13	258	104	174	28
Magnesium	mg	154	131	145	78	190	—	118	586	57	6
Phosphorus	mg	794	844	649	839	753	374	1161	7	1214	90
Fluoride	mg	—	—	—	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	8.6	60 8	8.2	8.6	3.6	13 1	28.1	70.1	69.9	5.58

Table 16 Foods believed to be more likely to increase tooth resistance to caries: milk and cheese group.
(Modified from Kirschmann and Dunne 1984 p252-256)

	Measure	Cream Cheese	Edam	Cottage, creamed	Cheddar	Cheshire	Milk Lowfat, 2%	Milk Whole
Measure		1 oz	1 oz	1 C.	1 oz	1 oz	1 C.	1 C.
Weight	gm	28	28	210	28	28	244	244
Calories		99	101	217	114	110	121	150
Protein	gm	2.14	7.08	26.2	7.06	6.62	8.12	8.03
Carbohydrate	gm	.75	.4	5.63	.36	1.36	11.7	11.37
VITAMINS Vitamin A	IU	405	260	342	300	279	500	307
Vitamin D	IU	—	—	—	—	—	—	—
MINERALS Calcium	mg	23	207	126	204	182	297	291
Magnesium	mg	2	8	11	8	6	33	33
Phosphorus	mg	30	152	277	145	131	232	228
Fluoride	mg	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	9.89	7.88	9.45	9.4	8.68	4.68	8.15

	Measure	Whole, dry	Skim	Nonfat, dry	Yogurt Plain	Plain, lowfat	Cream Whipping, light	Whipping, heavy
Measure		1 C.	1 C.	1 C.	1 C.	1 C.	1 C.	1 C.
Weight	gm	128	245	120	227	227	239	238
Calories		635	86	435	139	144	699	821
Protein	gm	33.6	8.35	43.4	7.88	11.9	5.19	4.88
Carbohydrate	gm	49	11.8	62.3	10.5	16	7.07	6.64
VITAMINS Vitamin A	IU	1180	500	43	279	150	2694	3499
Vitamin D	IU	—	—	—	—	—	—	—
MINERALS Calcium	mg	1168	302	1508	274	415	166	154
Magnesium	mg	108	28	132	26	40	17	17
Phosphorus	mg	993	247	1162	215	326	146	149
Fluoride	mg	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	34.2	44	92	7.38	3.52	73.8	88

Table 17 Foods believed to be more likely to increase tooth resistance to caries: vegetables and fruits group (Modified from Kirschmann and Dunne 1984, p258-262, 272-281).

	Measure	Alfalfa, sprouts	Broccoli	Cabbage, Chinese	Carrots	Carrot juice	Cauliflower	Celery	Corn
Measure		1 C.	1 C.	1 C.	1 C.	1 C.	1 C.	1 C.	1 C.
Weight	gm	33	88	70	110	227	100	120	154
Calories		10	24	9	48	96	24	18	132
Protein	gm	1.32	2.6	1.05	1	2.47	1.98	.8	4.96
Carbohydrate	gm	1.25	4.6	1.53	11	22	4.9	4.36	29
VITAMINS Vitamin A	IU	51	1356	2100	30942	24750	16	152	432
Vitamin D	IU	—	—	—	—	—	—	—	—
MINERALS Calcium	mg	10	42	74	30	8.3	28	44	4
Magnesium	mg	9	13	22	16	51	14	14	58
Phosphorus	mg	23	26	58	48	81	46	32	138
Fluoride	mg	—	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	.33	.14	.3	.2	—	.18	.14	1.8

	Measure	Potato	Tomato	Apple	Banana	Grapes, adherent skin	Lemon juice	Parsley	Orange	Avocado
Measure		1 C.	1	1	1	1 C.	1 T.	1 C.	1	1
Weight	gm	150	123	150[1]	175[1]	160	15.2	60	180[1]	272[1]
Calories		114	24	81	105	114	3	26	62	324
Protein	gm	3.2	1.1	.27	1.18	1.06	.06	2.2	1.23	3.99
Carbohydrate	gm	25.7	5.3	21	26.7	28.4	.99	5.1	15.4	14.8
VITAMINS Vitamin A	IU	—	1394	74	92	117	2	5100	296	1230
Vitamin D	IU	—	—	—	—	—	—	—	—	—
MINERALS Calcium	mg	11	8	10	7	17	2	122	52	22
Magnesium	mg	51	14	6	33	10	1	24.5	13	79
Phosphorus	mg	80	29	10	22	21	1	38	18	83
Fluoride	mg	—	—	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	.2	.26	.49	.55	.92	.04	.4	.16	30.8

Table 18 Foods believed to be more likely to increase tooth resistance to caries: bread and cereal group. (Modified from Kirschmann and Dunne 1984 p243-245).

	Measure	Breads: Rolls, whole wheat	Wheat	Cracked wheat, enr	Rolls, hamburger/ hot dog, enr	Pita, whole wheat	Mixed grain	Rolls, dinner, enr
Measure		1		1 slice	1	1		1
Weight	gm	35	100	23	40	42	100	38
Calories		90	255	60	119	140	257	113
Protein	gm	3.5	9.55	2	3.3	6	9.96	3.1
Carbohydrate	gm	18.3	47	12	21.2	24	46.6	20.1
VITAMINS Vitamin A	IU	t	t	t	t	t	t	t
Vitamin D	IU	—	—	—	—	—	—	—
MINERALS Calcium	mg	37	126	122	30	40	104	28
Magnesium	mg	40	46	29	14	—	49	14
Phosphorus	mg	98	184	20	34	—	212	32
Fluoride	mg	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	t	4.1	.6	2.2	2	3.72	2.2

	Measure	Cereals: Whole wheat	Barley, pot or scotch	Rice, brown	Rice, white enr	Wheat germ, toasted	Corn flakes, Kellogg's	Oats, puffed, Cheerios	Flours: Gluten, wheat	Pastry, wheat
Measure		1 C.	1 C.	1 C.	1 C.	1 C.	1¼ C.	1¼ C.	1 C.	1 C.
Weight	gm	120	200	196	195	113	28	28.4	140	100
Calories		400	696	704	708	431	110	111	529	364
Protein	gm	16	19.2	14.8	13.1	32.9	2.3	4.3	58	7.5
Carbohydrate	gm	85.2	154	152	157	56.1	24.4	19.6	66.1	79.4
VITAMINS Vitamin A	IU	0	0	0	0		1250	1250	0	0
Vitamin D	IU	—	—	—	—	—	—	—	—	—
MINERALS Calcium	mg	49	68	64	47	362	1	48	56	17
Magnesium	mg	136	71.4	172	13	50	3	39	—	26
Phosphorus	mg	446	580	432	183	1294	18	134	196	73
Fluoride	mg	—	—	—	—	—	—	—	—	—
LIPIDS Total lipid (fat)	gm	2.4	2.2	3.6	1.5	12.1	.1	1.8	2.7	.8

The following information has been compiled by the writer to include daily food servings from the Nutrient Allowance Chart and the Tables of Foods and Food Composition, which are most likely to increase tooth resistance for a 12 year old boy.

Table 19 An example of dietary intake recommended to increase tooth resistance to caries in a 12 year old boy. (Recommended by writer).

	Measure	WHOLE MILK	EDAM CHEESE	WHEAT	RICE WHITE	BEEF CLUB STEAK	CHICKEN DARK MEAT	SALMON
Measure		3 cup						
Weight	gm	732	28	100	195	50	20	200
Calories		450	101	255	708	160	47	430
Protein	gm	24	7	9	13	6	3	44
Carbohydrate	gm	34	–	47	157	0	0	0
VITAMINS Vitamin A	IU	921	260	–	0	29	34	600
Vitamin D	IU	–	–	–	0	–	–	628
MINERALS Calcium	mg	873	207	126	47	4	2	158
Magnesium	mg	99	8	46	13	9	4	57
Phosphorus	mg	684	152	184	183	60	27	372
Fluoride	mg	1 PPM FLUORIDATED WATER						
LIPIDS Total lipid (fat)	gm	24	8	4	1	14	3	26

	Measure	EGG	POTATO	CABBAGE CHINESE	CELERY	AVOCADO	APPLE	SLIGIT ACTIVITY	TODAY'S SERVING
Measure		1				1	1		
Weight	gm	50	150	70	120	272	150		
Calories		79	114	9	18	324	81	2800	2846
Protein	gm	6	3	1	1	4	–	45	124
Carbohydrate	gm	–	25	1	4	15	21	–	304
VITAMINS Vitamin A	IU	260	t	2100	152	1230	–	5000	5586
Vitamin D	IU	–	–	–	–	–	–	400	628
MINERALS Calcium	mg	28	11	74	44	22	10	1200	1642
Magnesium	mg	6	51	22	14	79	6	350	414
Phosphorus	mg	90	80	58	32	83	10	1200	2015
Fluoride	mg	1 PPM FLUORIDATED WATER							
LIPIDS Total lipid (fat)	gm	5	–	–	–	30	–	–	115

Using the data provided in this thesis, similar recommended daily servings can be compiled according to age, sex, weight, and activity.

Diets provided in this thesis deal with the prevention of dental caries by increasing the resistance of the tooth.

Firstly, diet which is rich in vitamin A and protein will benefit the tooth eruption, tooth formation, and tooth maintenance; thus improving tooth morphology and increasing rate of maturation.

Secondly, diet which is full of calcium and phosphorus will improve enamel and dentine composition during development. It is essential to form a sound and healthy tooth.

Thirdly, diet which includes foods containing substantial amounts of fluoride, vitamin D, organic phosphate and inorganic phosphate will contribute to remineralization and recrystallization, thus increasing tooth resistance to dental caries.

Fourthly, diet which abounds in magnesium will transfer phosphate and mobilize calcium, the latter being of crucial importance in the development of strong teeth.

Finally, other functions of fluoride, organmic phosphate, inorganic phosphate and magnesium also play an important role in increasing tooth resistance to dental caries.

These other functions are:

(i) Antibacterial action.

(ii) Cariostatic action

(iii) Reduction of demineralization.

The evidence in this thesis clearly shows that the diet proposed is based on those nutrients which are more likely to lead to the prevention of caries by increasing the resistance of the tooth.

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