A Study of Nutritional Factors With Special Reference to Their Effect on Teeth and Bone*

Presented by

THE NORTHERN CALIFORNIA COMPONENT OF THE
EDWARD H. ANGLE SOCIETY OF ORTHODONTIA

INTRODUCTION

This paper is presented as the combined effort of the Northern California Component and represents a summary of our studies during the past year.

We undertook as a project for the year, the consideration of the subject Diet and Nutrition, and secured a consulting nutritionist to direct our studies and discussions. Our desire was to coordinate and organize the results of various research workers in this field so that we would have a basic knowledge of the subject which would be fundamentally correct and which would enable us to recognize dietary deficiencies in our patients.

It was necessary first to find what an adequate diet was in order to recognize a deficiency diet,—that is, a diet that would produce normal reactions and normal development in individuals. McCollum and Simmonds used the term "optimal" in place of "normal," since it expressed more satisfactorily "the standard of excellence toward which we should strive in respect to physical development." They pointed out that some investigators assumed a diet was adequate if no symptoms of malnutrition were clinically recognizable, and they emphasized that "it is becoming constantly more evident that even a slight departure from the optional in the composition of the food may lead to states of nutritional instability which become contributing factors to physical breakdown when hygienic factors are unfavorable, or when infectious processes are operating," and "it is important to appreciate that in the aggregate it is borderline states of malnutrition that are the greatest menace to the individual when his health and efficiency over the life period is considered."

We have tried to briefly review the findings of most of the reasearch workers relative to deficiencies in the Vitamins, calcium-phosphorous balance and metabolism, and the acid and alkaline ash content of foods, especially as they affect tooth structure, the investing soft tissues and growth of bone.

We have not overlooked the fact that along with these phases of nutrition must be considered also the caloric content of foods, the value of proteins, carbohydrates and fats, and the various minerals such as iron, copper and manganese, if optimal health is desired, but to give them proper consideration here was thought to be beyond the scope of this paper.

Historical Facts

The first suggestion that other substances in addition to the recognized dietary units of proteins, carbohydrates and salts, which were equally indispensable for life, came from Lunin, as far back as 1881. The anti-scurvy value of lemon juice was well known to the British Navy in 1800, and Chartier, as early as 1535, had found a fresh extract of pine needles efficacious against outbreaks of scurvy among his crew.

In 1881, Lunin was investigating the significance of inorganic salts in

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the nutrition of animals. He found that his experimental animals, while capable of living and maintaining health on a diet of milk, were unable to live on the separate ingredients of milk-caseinogen, milk fat, milk sugar, and the ash of milk.

Other early attempts were made by Socin (1891), Pasqualis (1895), Jacob (1906), Salta and Noegerrath (1906), McCollum (1909), and others, to nourish animals on diets composed of purified proteins, fats, carbohydrates and salts, and many theories were advanced to explain the repeated failures.

One research worker, Rohman (1903, 1908), claimed to have been able not only to maintain mice in health on diets consisting of a mixture of isolated and "purified" components but, also, to insure increase of weight and even reproduction. In the light of subsequent research it would seem probable that the purification of the food substances that he used had not been carried out with sufficient thoroughness to destroy the constituents now known to be necessary for satisfactory maintenance.

In the meantime work had been proceeding in another field, which eventually led to the discovery of a chemical entity of a basic nature which was designated by the word, *"Vitamin."*

W. O. Halliburton (1914), writes, "The very term vitamin is itself a source of fallacy, especially if the word vital is used as its adjectival form. Vital may mean one of two things. It may be used in its literal sense as equivalent to living, or it may be used in a semi-figurative sense and mean necessary or essential. When we say that vitamins are vital constituents of diet we ought to mean that they are indispensable, and not imply that the vitamins possess the characters connoted by the word "life."

The fundamental facts of the necessity of certain non-artificial substances had been confirmed also by McCollum and Davis (1913). The basal diet used by these workers and which they found inadequate for maintenance, included purified casein, carbohydrates (lactose), starch, dextrin, lard and agar. McCollum and Davis made many tentative attempts to render this diet satisfactory but discovered that, while the addition of an ethereal extract of eggs or butter was successful, lard and olive oil gave no result. They concluded that the ether-soluble extracts of egg-yolk and butter contained certain organic complexes without which the animals could not grow, though they could be maintained in fairly good health for extended periods. They thought it possible that the necessary substances might be either phosphatides or foreign bodies accompanying them.

Osborne and Mendel (1914) now took up a more detailed investigation of the growth-promoting properties of the different fats. They found that while a diet composed of edestin, starch, butter, fat, lard, and protein-free milk would allow maintenance and reproduction to the third generation, replacement of the butter fat portion by an equal weight of lard led to the death of the animals in 90 to 120 days. Neither olive oil nor cotton seed oil were able to cause resumption of growth, and incidentally they observed that the loss of weight was often accompanied by "infectious eye disease." It was apparent from these experiments that all fats had not the same nutritive value, that some contained substances and possessed properties of which others were devoid. Later (1916) Osborne and Mendel located the active principle in the butter fat fraction of the butter and since this fraction was free from nitrogen and phosphorus and contained no water-soluble or ash-yielding substances they considered that the accessory factor in question could not be identical with the water-soluble factor postulated by Funk. The latter worker, like Hopkins and Neville, doubted the complete purification of their butter fat and claimed to have extracted nitrogen-containing substances from their preparation.

The Vitamins

It remained for McCollum and Davis (1915) to make the actual assumption that two distinct essential factors must exist in natural foodstuffs. In studying the dietary deficiencies of mice, they found that while the addition of purified casein, of a "growth-promoting" variety of fat, and of mineral substances did not render it a completely satisfactory food, the addition of small quantities of wheat germ or milk powder furnished a sufficient quantity of some other substance whose presence was essential for normal growth. They called the substance "water-soluble B" in contradistinction to the "fat-soluble A" present in fats.

With diets composed of protein, starch, milk sugar, salts and fats, it had been found that prolonged growth was secured when butter fat was used. The butter fat had been dissolved in ether and passed through filter paper in order to make certain that no traces of any ingredients of the milk except fats and substances having the same solubilities were present. Egg yolk fats behaved like the purified butter fat, whereas little growth and early failure resulted when olive oil or lard were the only fats in the diet. McCollum and Davis recorded their findings that purified butter fat, and likewise egg yolk fats, contain something which greatly promotes growth, and that lard and olive oil did not possess this property. This "something" is now known as *Vitamin A*.

Drummond, Rosenheim and Coward (1925) prepared cholesterol from cod liver oil or brain. After eight recrystallizations these cholesterol samples, when irradiated with a quartz mercury vapor lamp, induced prompt resumption of growth in rats declining on a Vitamin A deficiency diet, when daily doses of one mg. per rat were given. The irradiated cholesterol gave certain color reactions not given by cholesterol or oxycholesterol. They found their irradiated cholesterol to be quantitatively precipitated by digitonin, and inferred from this that the extent of chemical change effected by irradiation must have been very small. This result would seem to indicate that either cholesterol or some substance which cannot be separated from it by repeated crystallization, is capable of activation to form vitamin A by the action of ultra-violet rays.

Rosenheim and Drummond (1925) observed that cod liver oil gives, with arsenic trichloride, a brilliant ultra-marine blue color reaction, which they believe to be a specific test for Vitamin A. The color tests of this Vitamin, while interesting, are not entirely acceptable, the only definite test so far being the animal assay.

The origin of Vitamin A was demonstrated by Drummond and Coward during the years 1919-22. These observers showed that dried seeds contained little vitamin A, and that this amount was not increased by germination but that as soon as the seeds formed green leaves a considerable amount of Vitamin A appeared. Experiments made with Tradescantia shoots grown on Sach's solution also showed that green plants could synthesise Vitamin A from inorganic salts. The production of Vitamin A was shown to be dependent upon the presence of chlorophyll in plants, for etiolated seedlings contained no Vitamin A, nor did white leaves from the interior of cabbages. In green seaweeds, containing chlorophyll, Vitamin A was present, but red seaweeds contained none. Mushrooms were found to be almost completely deficient in Vitamin A. It appears, therefore, that the presence of chlorophyll is essential for the synthesis of Vitamin A, and that chlorophyll-containing plants can synthesise Vitamin A when fed on a pure synthetic diet. Widemark (1924) states that when plants lose ability to form chlorophyll or lipochrome, they also lose their ability to form Vitamin A, even if kept in full illumination.

The vegetable kingdom is one of the primary sources of Vitamin A, and the fact that it can be stored in the animal body, and especially in the liver, has made the animal tissues one of the most constant and important sources.

The outstanding effects of a definite experimental deficiency of Vitamin A are lack of growth and affections of the eye leading to a generalized opthalmia. Besides these, there are specific tissue changes, including epithelial hypertrophy and hyperplasia, a characteristic disturbance of reproductive function, and various metabolic changes. Recent studies have also ascribed to Vitamin A a peculiar role in resistance to infection, so that it has been termed the "anti-infective vitamin."

A pre-deficiency state is described by Mouriquand, Rollet, and Chaix (1930), in which conditions recognizable as due to deficiency of Vitamin A, precede the onset of clinically definable symptoms. They state that it has been found possible, in the case of rats, to detect ulceration of the cornea, microscopically, twenty days after commencing a Vitamin A-deficient diet, and twenty days before the onset of clinically recognizable symptoms of xerophthalmia. The administration of cod liver oil clears up the ulceration in a few days.

The growth factor in Vitamin A is much more potent in the case of the growing animal than in the adult. In the young animal, deprivation of Vitamin A results in a cessation of growth, which can be restored by administration of substances containing the vitamin. Until McCollum and his co-workers (1922) first definitely demonstrated that Vitamin A was a substance quite distinct from the antirachitic factor, or Vitamin D, this resumption of growth was taken as a criterion of the presence and amount of Vitamin A in the diet. Steenbock and his colleagues (1923, 1924), however, showed that the cessation of growth in animals on a standard Vitamin A-deficiency diet might, in some cases, be due not only to deficiency of Vitamin A, but also, to a co-existing deficiency of Vitamin D. Their results were confirmed by other workers.

The changes in bone tissue, due to deprivation of Vitamin A, have been investigated by Frances M. Tozer, who has attempted, at the same time, to differentiate them from those which occur in Vitamin C deficiency. She found that the bones of animals whose diet contained no Vitamin A, but a sufficiency of Vitamin C, were fragile and exhibited minute ridges at the rib junction. The teeth, also, were brittle and worn down.

Hirai (1923) reports that animals fed for one and one-half months with a diet deficient in Vitamin A, develop marked hyperglucemia. Happ and Wagner (1923) state that in tuberculous children a deficiency of Vitamin A has an unfavorable effect upon the disease process, while the abundant administration of this vitamin tends to overcome tuberculosis.

Daniels (1926) reported an interesting observation showing an adverse effect of Vitamin A deficiency on absorptive power of the intestine. Artificially-fed babies, like experimental animals on low Vitamin A diets, develop infection of the upper respiratory tract.

In cases of xerophthalmia, (one of the specific results of Vitamin A deficiency) the inference seems justified that, although many of the infants were doubtless suffering from latent scurvy and underfeeding, lack of sufficient Vitamin A was a prominent factor in their nutrition.

Deficiency of Vitamin A in the diet of pigs, chickens, and cows, results in nervous symptoms characterized by impaired vision, incoordination, and spasm. It was found that nerve trunks and tracts in the central nervous system of pigs, showing these symptoms, had undergone degeneration.

Results obtained by feeding rats on a diet deficient in Vitamin A showed that in the majority of cases, proliferative changes occurred in the tracheal mucous membrane, together with a distension of a large proportion of the thyroid follicles with colloid material. It is suggested that there may be some relation of food, having an insufficiency of Vitamin A, to chronic hypertrophy of the tonsils, to hyperplasia of the naso-pharyngeal adenoid tissues, to iodine metabolism, and to colloid goitre formation.

May Mellanby (1929) reports that Vitamin A and the substance responsible for the calcification of teeth are in many ways similar, both as regards distribution and properties. There are sufficient differences, however, in distribution and properties (apart from the crucial evidence depending on the influence of ultra-violet radiations), to show that Vitamin A and the substance controlling calcification of the teeth are different entities, although the method of determining Vitamin A, by growth-promotion of young animals, is complicated by the fact that Vitamin D, the calcifying vitamin, has more potent powers in this respect. Consequently, in the past, estimations of Vitamin A have often really been estimations of Vitamin D.

Margaret Smith and Edith Lantz found that hand in hand with cessation of growth and appearance of ophthalmia, which result from Vitamin A deficiency, there is loss of the normal orange-pigment of the incisors, which become dull-white and opaque. Decrease in hardness is indicated by excessive abrasion, the lower incisors, especially, becoming shorter. Litter-mates, receiving the same basal ration but with a daily addition of three drops of cod liver oil, did not show these changes. The dull-white incisors of Vitamin A-deficient animals regained their normal pigmented translucency after the addition of cod liver oil to their daily ration. That these abnormalities were due to a Vitamin A-deficiency is inferred from the fact that the ration used was supposedly adequate in all respects except Vitamin A, and the changes in the incisors began to be noticeable when cessation of growth and infection of the eyes gave evidence of the exhaustion of the animal's store of Vitamin A. The observed changes were not prevented by irradiation of the animals, nor by daily feeding of one-half drop of 100 D Viosterol, in addition to indicated cholesterol in the basal ration. On the other hand, the incisors were normal in appearance when Vitamin A-rich alfalfa or butter-fat was added to the basal ration. A higher percentage of calcium and lower percentage of phosphorus in the ash of the Vitamin A-deficient incisors, with a resulting higher Ca:P ration, were noted. Addition of Vitamin A in cod liver oil lowered the percentage of calcium, and accordingly the Ca:P ratio. This suggests the possibility that the decrease in hardness of the teeth, and their lessened resistance to wear, may be due to a decrease in the proportion of calcium that is deposited in combination with the phosphate radical, and to an associated increase in the proportion deposited as a carbonate or in some other combination.

Experimental work, with monkeys, on a diet deficient in Vitamin A, has shown that they suffered from root absorption due to tooth movement, and, after pressure was removed, the resorbed areas were not rapidly rebuilt. Monkeys, fed on a diet high in Vitamin A, showed rapid rebuilding of bone following tooth movement. Animals on a low Vitamin A diet developed hypoplasia of the teeth, and also showed poorly developed jaws and alveolar processes.

The daily requirement of Vitamin A is not actually known, but it is thought to be between six and ten thousand units. One tablespoon of cod liver oil or one three-minim capsule of plain haliver oil contains an adequate daily amount required for a normal person. The Vitamin A content of natural foods varies with the amount of sunshine to which the growing foods have been exposed, the greener the leaves, the greater the Vitamin A content.

Vitamin B

Vitamin B, the antineuritic vitamin, was discovered in the search for the cause of the disease beri-beri. This disease is found in China, Japan, and in institutions such as prisons, asylums, and the like, where the food supply is largely refined starches. Eiijkman produced the symptoms of beri-beri in pigeons in 1890, by feeding a diet of polished rice; he then cured the birds by feeding a diet including the germ and polishings.

The symptoms of Vitamin B deficiency are characterized, chiefly, by abrupt loss of appetite, followed by constipation, vomiting and impaired function of the entire nervous system.

McCarrison also observed functional and degenerative changes in every tissue of the body, the severity of the atrophy affecting the various organs in the following order:—thymus, testicles, spleen, ovaries, pancreas, heart, liver, kidney, stomach, thyroid, and brain. While the disease, beri-beri, is rarely found in North America today, yet there is a widely spread tendency to Vitamin B deficiency which shows all of the sub-acute symptoms. As McCollum says, "Now that we know more about the nutritive needs of the body and more about the foodstuffs and their composition, we realize there are many grades of malnutrition and a diet is not necessarily adequate because there are no acute clinical findings." Symptoms of Vitamin B deficiency may be detected in people whose diet chiefly consists of refined milled products. Since Vitamin B is water-soluble, it is not stored in the body. Therefore, it is necessary that there be an adequate amount in each day's diet. The best sources are in the following products, in the order named: Brewer's yeast, wheat germ, bran middlings, wholewheat, rye, corn, and barley. Some of the best commercial sources are vitavose, dextro-maltose and Mead's cereal. Prolonged cooking destroys Vitamin B. Therefore, when raw materials are used as a source of Vitamin B, care should be taken in their preparation.

There is no connection between dental disorders and Vitamin B deficiency, yet this vitamin acts so profoundly on the general health of the individual that, indirectly, it does affect the teeth.

Only recently Vitamin G has been separated from Vitamin B, but very little collaborated work has been done on it as yet. Smith and Hendrick made the important discovery that yeast, autoclaved at fifteen pounds pressure until all of the antineuritic Vitamin B was destroyed, still contained a substance which has recently become known as Vitamin G. This substance cures pellagra, but further research is now in process and will perhaps reveal the exact usefulness of this accessory food substance, of which so little is known at present.

Vitamin C

Vitamin C, known as the antiscorbutic vitamin, because of its power to cure scurvy when added to a diet deficient in Vitamin C, was first demonstrated in 1912, by Holst and Frolich, at the University of Christiania.

Scurvy has a longer and more definite history than the other deficiency diseases. It is recorded in the thirteenth century among the armies of the Crusaders. Later, as explorers went on long sea voyages, it became more common and was known as the "Calamity of Sailors."

Rough experiments were made, occasionally, in an effort to find means of combating the disease. It became known, from clinical experience, that it was caused by deficiency in diet and that lemon juice, fresh fruits and vegetables acted as remedial agents, but these were used empirically. The real agent responsible for the curative effects remained quite obscure until 1912.

Vitamin C is produced during the germination of seeds. Beyond this, very little is known regarding its origin. Its physiological function in the plant is not known, neither has the nature of its forerunners in the seed been learned for a certainty. It is highly concentrated in different parts of the plants, as in the leaves, (cabbage), the fruits, (lemons, oranges, etc.,) and the roots, (Swedish turnips).

The most important experimental work has been done on guinea pigs and monkeys, both highly susceptible to scurvy. Symptoms of Vitamin C deficiency in guinea pigs, used as the experimental animals, are a tenderness of the wrists, ankles and knees, developing in the order named. Within a day or two, the affected parts become swollen, often two or three times the natural size. Spontaneous fractures occur and, in older animals, hind legs may become paralyzed.

Two of the most noticeable conditions to be found at autopsies are hemorrhage and fragility of the bones; the stomach, intestines and the cecum may show congestion, hemorrhage, or an ulcerous condition.

The characteristic picture of the effect of scurvy on the tissues other than the teeth and bones, is atrophy. Thus, in the connective tissues, there will be a general atrophy especially attacking the collagen fibrils and vascular walls, although it will be noticed that the muscular and lymphoid tissue, the liver, salivary glands, adrenals and kidneys, show atrophy combined with necrosis (McCarrison, 1921, and Brouwer, 1927).

No marked change is shown in the blood picture, but the endothelium of the capillaries becomes swollen and degenerated. This results in a stagnation of blood in the capillaries which appears to be one of the factors leading to deficient oxygenation of the tissues and finally to death. (T. M. Findley, 1921.)

With monkeys used as experimental animals it was found that their symptoms closely resembled those of human scurvy, showing sponginess and bleeding of the gums, loosening of the teeth, and ultimately paralysis of the legs. Their bones also became fragile with enlargements and disruptions of the rib junctions.

The significance of Vitamin C upon the teeth was first called to attention by Jackson and Moore in 1916. Experiments were performed by others and the concensus of opinion was that the first organs of the body to show the effect of Vitamin C deficiency were the teeth; and, further, that the teeth were so susceptible to the lack of this vitamin that they would show reactions when none could be recognized in other parts of the body.

In studying microscopic changes in the teeth of guinea pigs, Howe noticed that marked changes occurred in the odontoblasts of those subjects deficient in Vitamin C. In from five to ten days, the odontoblasts cease to form dentin and the pulp begins to shrink away. When orange juice is added to the diet, a new formation is noticed within twenty-four hours, and the odontoblasts become actively engaged in laying down new dentin between the pulp and the old layer.

Other distinct changes are noticed. There is a disturbance in the capillary circulation of the gingivae showing a condition of swelling and hemorrhage. The teeth show a marked decalcification and loosening; the alveolar process exhibits the effect of absorption and the gums bleed easily. The loosening of the teeth and the absorption of the alveolar process may easily be a contributing factor in some cases of malocclusion, especially Class I cases.

In subjects receiving a deficient amount of Vitamin C there is lessening in the amount of intercellular substance formed, especially shown in bone or dentin. It is stated by Howe that, through the action of Vitamin C, the cells of the body are able to produce and maintain intercellular substance but without it the cells cannot function properly.

It is interesting to note that in a group of sixty-one people whose teeth were effected by caries, the diets were invariably deficient in Vitamin C, and in thirty-nine of these cases there was no other demonstrable dietary deficiency. This indicates that it is possible to have active caries in persons whose blood calcium and phosphorus are normal and whose diet is apparently not deficient in Vitamin D. In other groups showing caries associated with gingivitis and in groups with no caries, but having gingivitis and pyorrhea, the predominant dietary deficiency was Vitamin C. This survey led to the conclusion that lack of Vitamin C may be the important factor in the initiation of dental diseases. (Hanke)

An observation was made at Mooseheart of three hundred and forty children, ranging in age from ten to seventeen years. These were examined over a period of one year during which time they received the standard Mooseheart diet. This first year was used as a control period. At the end of the year ninety-nine children showed no signs of gingivitis. The remaining two hundred and forty-one children showed signs of gingivitis ranging from mild to severe and even spongy gingivae.

The following year was used as a test period. During this time each child received a pint of orange juice and the juice of one lemon daily, in addition to the standard diet.

The changes in the gingivae were as follows: The ninety-nine children who had been free from gingivitis during the control period did not develop gingivitis during the test period. Eighty-two children, who were classed as having mild gingivitis during the control period, became free of all signs of gingivitis by the end of the test period. A third group consisted of eighty children who had severe gingivitis, four of whom showed calculus deposited upon the teeth. During the test period, in one of these four, the gums receded from the deposits and became healthy. The condition was improved in another, but the gums had not become healthy. In the remaining two cases, there was no apparent improvement. This was undoubtedly due to the irritation of the deposits of calculus.

In twenty-seven of this third group of eighty, there were present materia alba and plaques, or plaques alone, and it is interesting to note that in all of these cases, the gingivitis disappeared. We assume, then, that the irritation was caused by the deficiency in diet rather than from the materia alba or plaques. We know that a deficiency of Vitamin C causes an occlusion of the capillaries during which time the tissue becomes edematous and is easily infected.

The results of the experiment with five of these children strengthens the belief that Vitamin C is an important factor in maintaining the health of the gingivae. These cases showed a profound swelling of the gum tissue in certain regions with the absence of inflammation. Throughout the test period this tissue gradually decreased in thickness and became healthy in appearance. The belief is that the thickening was due to an excessive amount of fibrous tissue. From the investigations of Walbach and Howe upon guinea pigs, we learn that the ingestion of foods containing Vitamin C leads to a lessening of fibrous tissue in certain parts of the body and that the converse is true.

In the remaining forty-nine of these eighty, a severe gingivitis persisted throughout the control period. The habits or routine of mouth hygiene were not changed in any of these children during the two years of observation. In view of this fact, it is quite remarkable that in all but one, the gingivae became healthy during the test period. It is of particular interest to us that this one obstinate case was a child who had a marked malocclusion. Hanke says "The failure may possibly be ascribed to malocclusion."

Of the remaining seventy-nine who showed spongy gums, calculus was present in thirty-nine; of these, thirteen showed no signs of improvement, fifteen showed considerable improvement, while in eleven cases the gingivae became healthy in spite of the calculus. The cases showed that no additional calculus was formed during the test period. Of the remaining forty in this group, the gingivae became healthy in all but four by the end of the test period. These four, like the preceding obstinate one, had extreme malocclusion.

Through this clinical observation we can see that orange and lemon juice contain something that is antagonistic to gingivitis. It is intriguing to believe that this something may be Vitamin C. The final test would be to determine the action of pure Vitamin C in cases of gingivitis, and it is hoped that this can soon be accomplished.

Complete deprivation of Vitamin C produces scurvy but it has been shown that partial deprivation produces pathology of the gingival tissue, porosity of the jawbone, irregularity of the dentin and susceptibility to caries. Vitamin C is the most unstable of the vitamins and is destroyed by cooking and oxidation. Although it is spread more widely in nature it is likely to be low in the diet because of the waste through cooking and oxidation. Oranges, grapefruit, lemons, tomatoes, and raw cabbage are excellent sources. Food sources of Vitamin C are also raw strawberries, pineapple, young carrots, rutabaga, turnips, spinach, lettuce, kale, bananas, green peppers, and peas. Fair sources of Vitamin C are cherries, pears, apricots, peaches, plums, prunes, canned spinach and potatoes. Milk is not a dependable source.

Since Vitamin C is not stored in the body, it must be in the diet every day, and the required dose varies with the individual. For optimum health, one eight-ounce glass of orange juice or tomato juice, with one or more salads a day, will probably be sufficient for the average individual. Tomato juice contains 3% sugar and is less fattening than orange juice, which contains 20 to 25% sugar.

Vitamin E

Vitamin E, discovered in 1925, is closely associated with reproduction, and is known as the essential anti-sterility dietary factor. Research on this vitamin is quite recent, and it has only been within the last ten years that its efficacy in this condition has been determined. Sterility affects males and females differently. In the male (rats and mice), a gradual loss of reproductive power leads (without addition of Vitamin E) to a complete and incurable sterility. In the female rendered sterile by depriving her of Vitamin E, the ovaries and ovulation are unimpaired throughout life, and when the proportion of successful matings is within normal limits, instead of the birth of a litter at term, the foetuses die in the uterus and are resorbed.

There are other dietary deficiencies that cause sterility in the female, but the sterility is the result of interferences with other steps in the mechanism of reproduction rather than those involved in the lack of Vitamin E, usually by preventing ovulation, fertilization, or implantation. Sterility caused by a lack of Vitamin E always shows this peculiar form of resorption of the foetus after implantation.

Vitamin E sterility is curable in the female by the injection of this substance in adequate amounts, and will always permit a successful gestation.

Even as late as the fifth day after mating, the administration of Vitamin E will insure success.

Vitamin E is fat-soluble and has been found in muscle, fat, pancreas, spleen, liver, heart, placenta, and other structures. Vitamin E is also found in green leaves, dried lettuce, alfalfa, peas, corn, oats, and wheat. It is transferred from mother to offspring during intrauterine life, for the tissue of new born rats will cure Vitamin E sterility in the female.

To those engaged in the breeding of rats for experimental purposes, the discovery of Vitamin E has a practical importance, and some work of Vogt-Möoller and Bay (1931) show that it may be important to stock breeders because of their success with sterility in cows.

Vitamin D

Vitamin D is known as the antirachitic, calcifying vitamin, and it has the specific function of controlling the deposit of Calcium and Phosphorus in the tissues. A deficiency of it in children is the prime factor in the cause of rickets, defectively formed teeth, and infantile tetany. In adults, the deficiency results in osteomalacia, caused by insufficient direct radiation of the sun and an improperly balanced diet.

All of the factors which have a bearing on the occurrence of rickets, when Vitamin D is given in only limited amounts, are not known, but it is definitely known, except in a few pathological cases, Vitamin D, when added in liberal amounts, can counteract all of them.

The old and common belief that the greater the amount of carbohydrates taken, either in cereals, starches, or sugars, the poorer the development of the teeth, is thought to be partly explained that if carbohydrates are taken on a low D deficiency diet, the increased weight, resulting from the increased energy-producing part of the diet, demands a greater supply of Vitamin D. Poorly calcified teeth will be the result of the relatively greater Vitamin D deficiency. This belief has not been satisfactorily proved, however, as white flour and rice gave the least trouble, oatmeal the most, and rye, barley, and maize were midway in their effects upon the teeth. This anti-calcifying action of cereal in the experiments on puppies was observed only when Vitamin D was deficient. By adding this vitamin, the teeth developed normally, even on a high cereal diet.

Some bone defects may develop independently of the Vitamin D intake, but those most common in man, viz., rickets, osteoporosis, and osteoma'acia, are directly influenced by its insufficiency. These pathologic conditions are also evidence of an abnormal calcium-phosphorus metabolism. Like scurvy, rickets is a disease with a long history. Even before there was any knowledge of vitamins, it was clinically known to be associated with an improper dietary condition.

The outstanding symptoms of Vitamin D deficiency are restlessness, constipation, irritibility, elongation of tendons and ligaments, and a flabby, pot-bellied appearance. The deformities in the bone are evidenced by "rachitic rosary," knock-knees, bowed legs, or both, enlargement of the wrists and elbows, and a delayed closing of the fontanelles.

Osteomalacia, which develops in adults through a lack of Vitamin D in the diet, or a lack of sunlight, causes bones to become soft and to show, in structure, a much less amount of calcium salts than normal. When cod liver oil is given, together with good food and plenty of sunlight, most cases will recover, and the bone structure will return to normal.

Rickets definitely has its effect upon dentition. Children low in Vitamin D show evidence of progressive malocclusion. It is very possible that future experimental work will show a definite relation between malocclusion (especially cases presenting Class I malocclusion) and Vitamin D deficiency.

Marshall produced in dogs a condition not unlike human peridontosis, with the teeth sore and protruding from their sockets, accompanied by a severe gingivitis. Many investigators have found similar changes, and all seem to agree that on rachitic diets there will be found thin pigmented enamel or the enamel structure of the teeth may be missing entirely. There will be poorly calcified dentin, showing many interglobular spaces. The dental pulp exhibits cell degeneration; the capillaries, excessive swelling and hemorrhage.

In a D deficiency, the deposition of calcium salts is not only severely disturbed but is actually delayed. When it is delayed, the poorly calcified enamel is likely to collapse and the surface will be marked by irregularity or hypoplasia. The "stripes of Retzius," showing a lesser calcium disturbance, are marked by an alternating layer of well and poorly calcified substance. In such a tooth the dentin can be more readily attacked by bacteria in those spots not covered with enamel. Decay is easily spread, and for this reason, a lack of Vitamin D, results in a susceptibility to caries.

Certain complexities have been manifested in experiments with diets, as in the addition of high Vitamin D content and its effect on bones and teeth. Downs, in his experiments on rats, found that if Vitamin D is added to a diet low in phosphorus, the structure is poorer than when Vitamin D is not added. If the calcium content is lowered, the addition of Vitamin D apparently aids the tissue to use this mineral more effectively. The reason for these dissimilar actions is not known, but, unquestionably, it is inadvisable to indiscriminately prescribe a diet high in Vitamin D.

The two most dependable and accessible sources of Vitamin D are food and sunlight.

Since Vitamin D is fat-soluble, it is stored in tissues containing fat, especially fish livers. Small amounts are found in egg yolk, butter and cream, depending upon the amount of sunshine and the quality of the food supplied the animals. Cod liver oil is one of the best natural sources; it is especially valuable in that it contains, when not oxidized, Vitamin A, also fat soluble and just as essential to growth and health.

Vitamin D is best obtained by exposure of the entire body to the direct rays of the sun. The ultra-violet rays do not easily penetrate atmosphere laden with dust and fog; therefore, all climates cannot be equally depended upon to provide sufficient quantities of Vitamin D. In such climates it will be necessary to use the so-called ultra-violet lamp, but this should be done only under the direction of one skilled in its use.

A very common error is to recommend Viosterol in place of cod liver oil. Viosterol contains only Vitamin D. Cod liver oil and Haliver oil contain both Vitamin A and Vitamin D, both of which are necessary for optimum health.

Calcium and Phosphorus

The relation of Vitamin D to the calcium-phosphorus metabolism is the only known one expressed in chemical terms. When the calcium content in the blood is forty times that of phosphorus, it is normal. If it drops to between 30 and 40, the border line is reached, and under 30, rickets can be expected. By the addition of Vitamin D, both will return to normal and the patient will show improvement.

In recent years there has been a great deal of attention and study given to the subject of calcium deficiency in the average American dietary, and sufficient data has been compiled to show that a special effort must be made to assure an adequate amount of Vitamin D in order to preserve the structure of the teeth and bones. The importance of this is materially increased during orthodontic treatment.

Calcium is obtained indirectly from the soil through plants and more indirectly through animal products of which milk is generally considered the best available source. The American dietary is low in milk and dairy products, especially compared with that of some European peoples whose milk consumption is large. According to Tigerstedt, the diet of the Finns contains from two to six grams of calcium daily, while Sherman found the calcium content of the American diet to be .45 of a gram. It has been noted that the nations having the largest calcium intake are the greatest in stature. For instance, Finns, Bulgarians, Arabs, and Swedes are tall and have the greatest calcium intake while the Orientals, a far smaller race, have the lowest calcium intake, probably .1 to .2 of a gram daily.

A normal adult should consume one gram of calcium daily. Cheese and milk must be included in the diet if this is to be obtained. A rapidly growing child should have two to three grams daily, depending on the rate of growth. From 3 to 16 years, a child should average a daily storage of .10 gram beyond the amount necessary for maintenance. Every child should have at least one quart of milk daily. Calcium is normally retained in the skeleton of the body and under pathologic conditions it may be readily mobolized even to the detriment of the bones and teeth. Therefore, in order to maintain the normal calcium content it becomes necessary to increase the intake during the periods of normal health.

Sherman found that the phosphorus intake in American dietaries was nearly as low as that of calcium, although it is much more widely distributed in foods. Each day an adult should have .88 of a gram of phosphorus to 70 kilograms of body weight and a child should have one and one-half times that amount. McCollum stresses the importance of a correct ratio between calcium and phosphorus. A normal child should be in positive balance, that is, larger amounts of calcium and phosphorus are retained than excreted, thereby allowing some of the minerals for storage. A normal adult, after growth has ceased, should be in equilibrium; that is, the intake of calcium and phosphorus should be the same as the output. Negative balance is the loss of calcium and phosphorus below the necessary amount for maintenance. It has been found that Vitamin D is necessary for the assimilation of calcium and phosphorous, and that, by its addition, a negative balance may be changed to a positive balance.

Surplus calcium and phosphorus are stored in the body when not needed for immediate use. They may be found in the trabeculae at the ends of long bones, situated near the blood supply and easily obtained in times of shortage. Calcium and phosphorus are mainly absorbed in the upper portion of the small intestine. However, this absorption is dependent upon many factors which influence the solubility of these respective salts.

It is interesting to note that cereals, meats, and eggs are neutral before absorption, but later they develop acidity and leave a residue in the blood stream. The majority of fruit juices are acid in the intestine but become alkaline after combustion and, therefore, aid in calcium and phosphorus absorption. Generally speaking, vegetables are neutral until after combustion, when they leave alkaline ash in the bloodstream. Liberal amounts of fruits, milk, cheese, and nuts with a small amount of bread and cereal will produce the desired neutral or slightly alkaline ash.

A growing child undergoing orthodontic treatment should retain 2 or 3 grams of calcium daily. This can best be done by the addition of Vitamin D to force the assimilation of the mineral.

Shall the dentist, the orthodontist, or the physician prescribe the diet? This question has been widely discussed by Dr. John A. Marshall. His papers were based on letters sent to prominent men in the profession, including several Deans of Dental Schools, in which a leading question was, "Should the members of the dental profession take upon themselves the responsibility of prescribing diets for their patients?"

There was a diversity of opinion in the replies. His observation was "that the dentist should secure a more cordial cooperation with the patient and his physician." He believed dietary prescription to be primarily within the province of the physician but "recommendations on choice of food may be made by the dentist without assuming any responsibility."

We suggest that the orthodontist should give to each patient a chart on which he will tabulate each day the kind of foods and quantity of each taken into the body for that day. Head columns after these names as follows: Vitamin A, B, C, D, Ca, P, Acid Ash, Alkaline Ash, Fe, Other Minerals. This enables the orthodontist to check the list of foods, place them in the columns headed and in a few moments he is able to recognize any deficiency. These sample diets may be requested as often as the orthodontist deems necessary, and filed with the records of the case.

This check on the diet should be followed by recommendations for changing, augmenting, or improving it according to the knowledge at hand from the numerous experiments recently conducted. A simple chart may be devised on which are listed the essential foods or best sources of the Vitamins, Calcium, Phosphorus and other minerals. The foods and quantities necessary to maintain optimum health should be indicated on the chart.

We believe that the orthodontist, if he has made a serious study of diet, is qualified to and should consult with the pediatrician or dietician in recommending a diet for optimum health, for the prevention of dental diseases and for the increase of those elements in the system especially needed during orthodontic treatment.

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