

## RELATIONSHIP OF BLOOD PLASMA VITAMIN C LEVEL TO GINGIVAL AND PERIODONTAL DISEASE<sup>1</sup>

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In the years since vitamins were first discovered much has been learned of many of the vitamins, but the relationships between them and oral health have remained obscure. It is a pleasant and worthwhile undertaking, therefore, to try to add even a little to the store of knowledge of those relationships.

Vitamin C is one of several vitamins which may be necessary for maintenance of oral health. The oral effects of a deficiency of vitamin C may be confused with, and complicated by, a number of other factors. Improper mouth hygiene, deposits on the teeth, faulty tooth brushing, malocclusion, and other local causes may be partly or wholly responsible in any one case for the symptoms which may seem to be chargeable to lack of vitamin C. Deficiencies of several vitamins at once might produce changes in the mouth comparable to changes caused by more severe deficiencies of vitamin C alone.

For these reasons, the study of the relationship between vitamin C and the condition of the gingival and periodontal tissues should depend on data from a large number of cases. If the number is large enough it may be possible to discount many variables and learn the effects of low levels of vitamin C alone. In the present paper records of 1396 patients are considered in an attempt to determine what correlation there may be between vitamin C levels in the blood plasma and the common afflictions, gingivitis and periodontal disease.

### REVIEW

When guinea pigs are kept on a diet deficient in vitamin C, changes occur in the gingiva, periodontal membrane and alveolar bone similar to the changes observed in mouths of humans suffering from gingivitis and periodontal disease. The same changes occur less quickly and less severely in guinea pigs when the diet is low, but not lacking in vitamin C. This has been shown by Howe, Westin, Wohlbach, Hojer, Day, Fish, Harris, Boyle and Bessey (1 to 11), each substantially confirming the results reported by the others.

It is not clear that the same thing is true of human subjects. Crandon, Lund and Dill (12) reported the results of an experiment on a human subject whose mouth was in good condition after 6 months on a diet entirely lacking in vitamin C. One slight gingival hemorrhage occurred after a fatigue test, but otherwise there was no sign of gingivitis and the only periodontal change noted was

<sup>1</sup> Read at the 20th General Meeting of the International Association for Dental Research, New York, March 14 and 15, 1942 (*J. D. Res.*, 21: 330, 1942). Received for publication March 26, 1942.

in x-ray pictures showing slight interruptions in the lamina dura at the end of the experiment.

Tishler (13), Freeman and Glass (14), Kirkpatrick (15), and Radusch (16) found no significant relationship between vitamin C and mouth conditions. On the other hand, Boyle, Bessey and Wohlbach (17) reported definite correlations between low vitamin C level and rarefactions of the alveolar bone not attributable to local causes. Pelzer (18) found a tendency in vitamin C deficient cases toward bleeding, cyanosis and bloating of the gingivae. Westin (19) reported marginal atrophy of the alveolar bone in human scurvy cases. Weisberger, Young and Morse (20) reported that all of their cases whose blood vitamin C levels were low were afflicted with marginal gingivitis. They noted improvement upon administration of 2000 mg. of the vitamin over a period of 2 weeks.

Sorin (21) and Fitzsimmons (22) found that systemic or dietary factors were operative in only a few of the cases in the groups studied, and that local causes were operative in most.

Hanke (23, 24, 25) and Hawkins (26) have reported improvement in gingival conditions upon the addition of ample orange juice to the diet. These reports are not necessarily pertinent to the question of whether lack of vitamin C is an etiologic factor in gingivitis and periodontal disease, because it is possible that administration of excess vitamins might produce improvement in the mouth tissues where the disturbance was due to other things than vitamin deficiency. Also it is possible that the orange juice contains some active ingredient other than the vitamin C.

The literature indicates that vitamin C deficiency may be entirely responsible for gingival troubles in some cases, and partly responsible in many, but that many cases of gingivitis will clear up entirely if the local causes are removed. There may be a lowered tissue resistance traceable to vitamin deficiency. The diversity of the published opinions may be due to differences in methods, to different standards by which mouth conditions are judged, or possibly to the use of relatively small numbers of patients.

#### METHODS

Over a period of 24 months, records have been kept showing the gingival condition, the periodontal condition, and the blood plasma vitamin C levels of 1396 patients coming into the clinic of the Dental School. The patients were not selected on the basis of gingival condition or plasma vitamin C level or in any other way, except that the vitamin C determination was made on some because the gingival condition raised a question of possible deficiency. Unfortunately, there was no uniformity in the vitamin C levels in these particular cases. The inclusion of such cases raises somewhat the proportion of those having severe gingivitis.

Each case was examined by one or another of 4 instructors in the diagnosis clinic. The gingival and periodontal conditions were noted. The vitamin C determination was then made by a technician who was not informed of the results of the examination. The results of the vitamin determination were not known until later, when they were recorded on the examination chart by the departmental secretary.

The degree of gingival inflammation was designated by the figures 1, 2 or 3 on the record; 1 indicating no visible inflammation, 2 a moderate amount, and 3 severe inflammation. This system of grading depends on the judgment of the observer, so that there probably is some overlap between the cases marked 2 and those marked 3. There is less chance that

cases marked 1, where there was no visible inflammation, should be confused with cases marked 2 or 3 where inflammation was clearly present.

The periodontal condition was recorded in a like manner. The figure 1 indicated that there were no abnormally deep gingival crevices, 2 that the pockets were very few or shallow, or both, and 3 that there were many deep pockets. Three mm. was considered a moderate pocket depth. Pockets 4 or more mm. deep called for a designation of 3 if there were more than 1 or 2 such pockets. The recording of the periodontal condition was checked by reference to roentgenograms where possible, but no attempt is made in this study to distinguish between the diffuse, and the deeper and more local forms of periodontosis. As with the recordings of gingivitis, the periodontosis records depend on personal observations, so that there is probability of confusion between the 2 and 3 cases, but less probability of confusion between these and the cases marked 1.

The age of the patient and the date of the examination were noted and record was made of the presence of calculus, malocclusion or any other condition which might provide a local cause of gingival disturbance. It is possible that this notation was not made in all cases where it should have been. If there was any specific gingival disturbance present, such as Vincent's infection, the fact was noted. Such cases were thought to be not comparable and are not included with the others in this study.

Record was also made of what the patient last had to eat and of the time elapsed since he ate it. This information was of value in excluding cases whose vitamin C level may have been raised because of recent intake of vitamin rich foods. The records of patients who had partaken of citrus fruits or tomatoes within 3½ hours before the vitamin determination was made were later grouped separately and are not included in the other groups of cases.

The blood plasma vitamin C level was determined by the micro-method of Farmer and Abt (27). In this determination, 0.2 cc. of blood is drawn from the finger into a tube in which has been placed a small amount of lithium oxalate. The blood is centrifuged to free the plasma of cells. The plasma is then drawn off with a pipette and placed in another tube, where m-phosphoric acid is added to precipitate the proteins. It is again centrifuged and the protein-free fluid drawn off and titrated with 2-6-dichlorophenolindophenol. The results are expressed as mg. of ascorbic acid per 100 cc. of blood plasma.

In many cases several vitamin C determinations were made on different dates, but only the determinations made on the same day as the recorded examinations are considered here, and no repeat for any patient is included in the figures.

In preparing the data for study, the pertinent figures were transcribed from the examination charts to small cards which could then be rearranged according to any particular phase of the question.

## RESULTS

It was found that the blood plasma vitamin C determinations ranged from 0.04 mg. per 100 cc. of plasma to 2.16 mg. per 100 cc. This range was substantially the same for all types of cases. The lowest reading was found in a patient under 20 with no gingivitis, and the highest was in a middle aged patient with moderate gingivitis. By inspection no correlation could be discovered between the vitamin C value and the condition of the mouth. Only when the cases were grouped in large numbers did any differences appear. These differences were small. In every case the differences between the means, medians, or modes of different groups were small compared to the ranges of individual readings within each group.

### 1. *Vitamin C and Gingivitis*

After removing the records of those patients who had taken citrus fruits or other sources of vitamin C within 3½ hours, the remaining cases were sorted

into 3 groups according to the gingivitis record of each. The cases within each group were then arranged in the increasing order of the vitamin C values. In Table I the total numbers of cases, the range of vitamin C readings and the mean, median and mode for each group are stated.

The groups, 0.20-0.40 and 0.40-0.60, were used to express the mode because it was found that steps of that magnitude were necessary to avoid minor and confusing variations in the curves obtained.

Because of the undue importance which the mean determination gives to scattered very high vitamin C levels, it is thought that the median is the most reliable index of the vitamin status of each group. If the median of the gingivitis 1 group is taken as normal, there are in this group as many cases above 0.52 mg. as there are below this level. A division of the other groups into cases above and below 0.52 mg. gives the results shown in Table II.

TABLE I

	NO. CASES	RANGE	VIT. C-LEVEL IN MG. PER 100 CC. PLASMA		
			Mean	Median	Mode
Gingivitis 1.....	743	0.04-1.92	0.56	0.52	0.40-0.60
Gingivitis 2.....	410	0.08-2.16	0.50	0.40	0.20-0.40
Gingivitis 3.....	107	0.08-1.96	0.49	0.40	0.20-0.40

TABLE II

	PER CENT CASES ABOVE THE NORM (0.52 MG. VIT. C)	PER CENT CASES BELOW THE NORM (0.52 MG. VIT. C)
No gingivitis (1).....	50	50
Moderate gingivitis (2).....	36.3	63.7
Severe gingivitis (3).....	34.9	65.1

These figures show that there is some connection between the vitamin C level and the condition of the gingivae, but in view of the wide and almost identical ranges of the groups, that is, from 0.04 or 0.08 to 1.98 or 2.16, it is clear that the vitamin C level is but one factor among others. There is clearly a tendency either for low vitamin C cases to have gingivitis, or for gingivitis cases to have a low vitamin C, but whether the low vitamin C is responsible for certain cases and other factors for other cases, or whether all factors tend to operate in most of the cases cannot be ascertained from these figures. The trend of the figures may indicate only a correlation between neglect of the mouth and neglect of the diet.

An attempt to eliminate at least some of the other factors was made by taking out of the groups those cases in which there was note of calculus deposits, malocclusion, and the like which, in themselves, may constitute causes of gingivitis and thus complicate the vitamin C picture. After elimination of these cases, the figures for the 3 groups were as indicated in Table III. No changes were made

in group 1 because no causes of gingivitis were operating effectively in those cases.

Comparing Tables I and III, it is apparent that when the cases known to have local causes of gingivitis are excluded, the values for the vitamin C level in groups 2 and 3 are slightly higher. In other words, the inclusion of the cases having calculus and the like lowered the vitamin C figures for groups 2 and 3. From this again, it may be concluded that a low vitamin C level and general mouth neglect tend to be associated. It is quite probable that both are the result of the generally neglectful and careless habits of the patients.

It was thought that the inclusion of children and adolescents in the groups with adults might have introduced a disturbing factor, but after cases below the age of 20 were taken from the groups the figures were the same. Gingivitis, unlike periodontosis, appears to attack children to much the same extent as it does adults, and in them bears no different relationship to the vitamin C level of the blood plasma.

TABLE III

	NO. CASES	RANGE	VIT. C LEVELS (MG. PER 100 CC. PLASMA)		
			Mean	Median	Mode
Ging. 1.....	743	0.04-1.92	0.56	0.52	0.40-0.60
Ging. 2 (minus known causes).....	288	0.08-2.16	0.516	0.42	0.20-0.40
Ging. 3 (minus known causes).....	63	0.08-1.96	0.525	0.40	0.20-0.40

### 2. Vitamin C and Periodontal Disease

In the study of the relationship between the vitamin C content of the blood plasma and the incidence of periodontal disease it was thought best to exclude from the figures the records of all patients under 20 years of age. Below that age it was found that the incidence of the disease was practically zero, and the inclusion of such records might have falsified the whole group. This is in accord with the findings of other workers such as Brekhus (28), who showed that there were practically no extractions for periodontosis up to the age of 20. As with the gingivitis cases, the periodontal cases were graded 1, 2 and 3, indicating respectively no periodontal trouble, moderate, and severe periodontal disease. The ranges in vitamin C level and the means, medians and modes for these groups are shown in Table IV.

When the 3 periodontal groups were subdivided according to the gingival conditions it was found that there were no marked differences in the vitamin C levels. It is interesting to note, however, that the gingivitis and periodontal diseases have a strong association. Table V is added to show this relationship, giving the percentage of each gingival condition to be found within each of the periodontal groups.

If a low vitamin C level were the principal etiologic factor in both gingivitis

and periodontosis, or in cases which combined the two diseases, the vitamin C in cases having both severe periodontal and severe gingival trouble would be lower than in any other group. This was not true. It was found that for the group of such cases, combining both severe gingivitis and severe periodontal disturbance, the mean vitamin C level was 0.499 and the median 0.42. These figures are not appreciably different from the levels of the 2 and 3 gingivitis groups or the 2 and 3 periodontal groups alone. They tend to show only that the neglect of hygiene and the neglect of proper diet are associated, and express only the nature of the person, rather than any direct cause and effect relationship between the diet and the mouth condition.

TABLE IV

	NO. CASES	RANGE	VIT. C LEVELS (MG. PER 100 CC. PLASMA)		
			Mean	Median	Mode
Periodontal 1. ....	533	0.08-2.16	0.559	0.48	0.40-0.60
Periodontal 2. ....	320	0.08-2.04	0.496	0.42	0.20-0.40
Periodontal 3. ....	118	0.08-2.00	0.508	0.40	0.20-0.40

TABLE V

	GINGIVITIS 1	GINGIVITIS 2 AND 3
Periodontal 1. ....	82.5%	17.5%
Periodontal 2. ....	26.2%	73.8%
Periodontal 3. ....	5.0%	95.0%

TABLE VI

	PER CENT CASES ABOVE THE NORM (0.52 MG. VIT. C)	PER CENT CASES BELOW THE NORM (0.52 MG. VIT. C)
No periodontal disease (1).....	46.8	53.2
Moderate periodontal disease (2).....	40.6	59.4
Severe periodontal disease (3).....	39.8	60.2

The median for the cases having neither gingivitis nor periodontal disease was found to be 0.52, the same as that of the group selected on the basis of freedom from gingivitis alone. The percentages of cases above and below this level in each of the periodontal groups are shown in Table VI.

It is to be noted that various gingival conditions are included in each of the above periodontal groups. Less difference is shown between the different groups in the above table than was shown between the groups selected on the basis of gingival condition, as shown in Table II. While the differences between the two sets of figures are not great, they appear to indicate that there is less relationship between the vitamin C level and the periodontal condition, than between the vitamin C level and the gingival condition. This appears reasonable, but not

significant. Both the gingival condition and the vitamin C level can change rapidly, so that one could change along with variations in the other. Periodontal disease, on the other hand, is a more permanent change in the supporting tissues, and, even if caused by a long continued low vitamin C level would tend not to show a comparable degree of repair in response to an increase in the vitamin C level. For this reason these figures do not afford any real basis for considering that either disease is more the result of a dietary deficiency than is the other.

### 3. *The Effects of Citrus Fruit Intake*

The foregoing data has not included any case in which there was a record of citrus fruit intake within 3½ hours previous to the vitamin C determination. There were 135 such cases excluded. A study of these cases raises interesting questions. The median for this group was 0.64 mg. vitamin C per 100 cc. plasma. The medians for all other groups were between 0.40 and 0.52 mg., with 0.52 accepted as normal. The difference between 0.52 and 0.64 probably indicates the average increase in the vitamin C level caused by the citrus fruits.

It is possible, however, that the citrus fruit records represent, at least to a fair degree, the diet habits of the people from whom the records were obtained. In this group it was found that the percentage incidence of gingivitis was 33.3, while for all groups without citrus fruits the incidence was 44.1. The incidence of periodontal disease among those over 20 years of age who partook of citrus fruits was 43.5 per cent while that among those who did not was 49.9 per cent. This may indicate that the inclusion of adequate citrus fruits in the diet may help to prevent gingivitis and, to a lesser extent, periodontitis, either by supplying vitamin C or in some other way. If this is a proper interpretation, it is in agreement with the findings of Hanke and Hawkins, previously referred to (23-26) which were to the effect that when diet was supplemented with orange juice, gingivitis tended to clear up. On the other hand, it must be pointed out that it might just as well be said that the persons who regularly included citrus fruits in their diet were probably of the type who would try to take care of their mouths, and would therefore be in better condition for that reason.

### 4. *Seasonal Variations in Vitamin C Level and Gingivitis*

Weisberger, Young and Morse (20) reported that administration of vitamin C produced improvement in the mouth conditions within 2 weeks. From this it would be expected that if vitamin C and gingivitis are linked in a cause and effect relationship, changes in the gingival condition should follow changes in the vitamin C level with a lag of not more than two weeks. It might be assumed that more people would partake of citrus fruit more frequently when the supply was good and the price low. Whether this assumption is correct is problematical, because it was found that the proportion of cases giving record of recent citrus fruit intake was substantially the same for each month or quarter.

The records in this study were collected over the whole of a 2 year period, and the number of cases is great enough to give fairly reliable results, so that a consideration by seasons is justifiable. When the figures for gingivitis are arranged

by quarters, it is found that the percentage incidence of gingivitis is lowest in the winter quarter and highest in the spring quarter. This relationship is shown in *fig. 1*.

A similar variation occurs in the vitamin C levels, as judged by the medians. The vitamin C level is high in the gingivitis-free cases at the same time as the

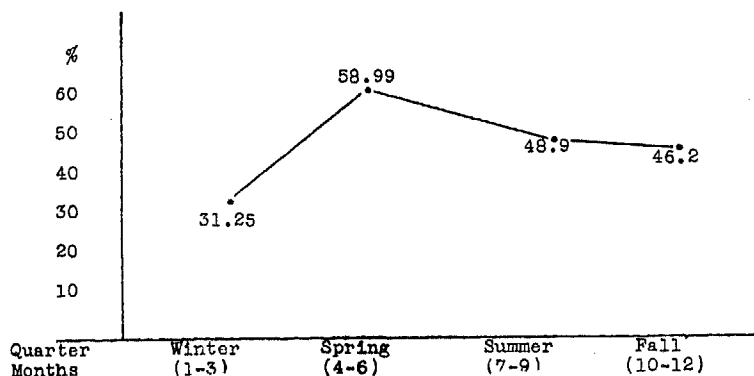


FIG. 1. Percentage incidence of gingivitis by seasons

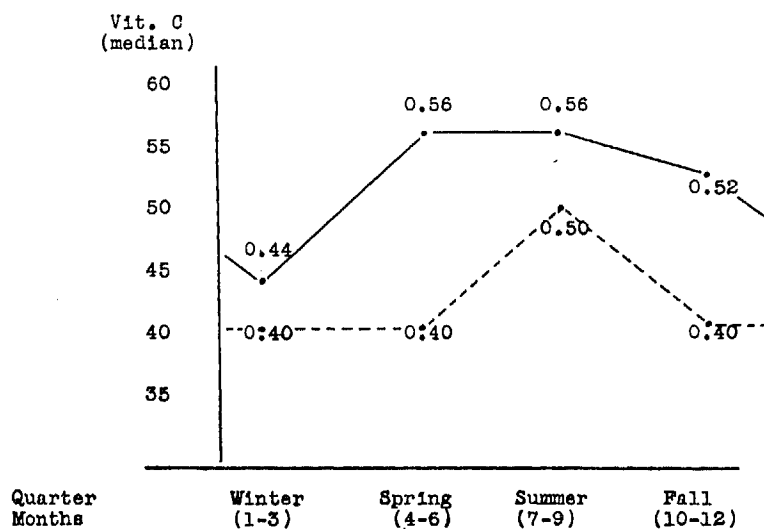


FIG. 2. Seasonal variations in vitamin C level. —, gingivitis-free cases (1); - - -, gingivitis cases (2 and 3).

percentage of gingivitis cases is high, but there is no elevation at that time in the vitamin C level of the cases having gingival disease. The seasonal variations in vitamin C level are shown in *fig. 2*.

These figures are for patients as they first entered the clinic and are not repeated observations on the same patients. It will be noted that the incidence of gingivitis (*fig. 1*) was lowest during the winter quarter, when the vitamin C levels



were low for all groups. If a low vitamin C level were the cause of gingivitis it would seem that the incidence of gingivitis should be up when the vitamin C is low. In the group of cases numbered 2 and 3, having gingivitis, the vitamin C is high only during the summer, when the incidence of gingivitis has dropped well below its peak. These figures make it difficult to see a direct relationship between low blood plasma vitamin C and gingivitis.

It may be that the seasonal changes in the computed incidence of gingivitis represent a tendency for the gingivitis patients to come into the clinic more at one time of the year than at others. If this is true, the figures on seasonal incidence do not show the facts. Whether such explanation is correct cannot be learned from the present data, but the possibility must be kept in mind to induce some skepticism of the results.

From *fig. 1*, it will be noted that the low incidence of gingivitis follows the sunshine season. In the summer not only is there more sunshine to generate vitamin D in the body, but also more fruits, green vegetables and salads rich in vitamins A, B, and C are available. Vitamins A and D are said to be stored in the body for long periods. Vitamin C may perhaps be stored for many weeks. The low incidence of gingivitis in the winter quarter, therefore, may coincide with an adequate supply of these vitamins in the body, stored up from summer. In spring, when it may be supposed that the stored up vitamins are being exhausted, the incidence of gingivitis is highest. In summer and fall the body is recovering from the shortage of the spring and is storing up vitamins A and D again, and it is found that the incidence of gingivitis is dropping.

It will be noted in *fig. 2* that the vitamin C level for the gingivitis-free cases was high in the spring. Possibly the supply of citrus fruits is greatest and the prices lowest at this time. The change may mean nothing more than that those people who are inclined to have an adequate diet when possible, and may also be inclined to take care of themselves in other ways as well, are taking advantage of market conditions.

Another possibility is that some people may not absorb the vitamin C properly or may require more of it, so that their blood levels change more slowly than those of their more fortunate brothers, requiring increased intake of citrus fruits over a longer time before any result is shown. A third possibility is that the maintenance of good mouth conditions may require adequate supplies of many food factors, some of which may not be sufficient, or some of which may not be absorbed, in the absence of others. The absence of gingivitis in the experimental scurvy reported by Crandon, Lund and Dill (12) may give support to this idea. The answers to the questions thus raised do not lie in the present data.

#### SUMMARY AND CONCLUSIONS

Information concerning the gingival and periodontal conditions and the level of vitamin C in the blood plasma of 1396 patients has been collected over a period of two years. The resulting figures have been studied to determine whether there is any causal relationship between low vitamin C levels and the presence of gingivitis and periodontosis.

It was found that the blood plasma vitamin C levels tended to be lower in the cases having gingivitis than in those free from gingivitis. The cases with periodontal disease also tended to show lower vitamin C levels than those without. In proportion to the range or amount of variation in vitamin C levels within each group, however, the differences between groups were very small and are probably not significant. The seasonal variations in vitamin C level and incidence of gingivitis were such that no causal relationship between low vitamin C and the presence of gingivitis was apparent.

These findings suggest that a patient who will neglect his mouth will be likely to neglect his diet, so that gingivitis and periodontosis may arise from the same neglect that allows the vitamin C level to be low. The poor nutritional condition and the poor mouth condition may proceed from the same cause rather than the one from the other.

## REFERENCES

1. HOWE, P. R., Effect of Scorbutic Diets upon the Teeth. *D. Cosmos*, **62**: 586, 1920.
2. *Idem*, Report on Studies of the Effect of Vitamin-Deficient Diet upon the Teeth. *D. Cosmos*, **63**: 1086, 1921.
3. *Idem*, Food Accessory Factors in Relation to the Teeth. *J. D. Res.*, **3**: 7, 1921.
4. *Idem*, Further Studies of the Effect of Diet Upon the Teeth and Bones. *J. A. D. A.*, **10**: 201, 1923.
5. WOLBACH, S. B., AND HOWE, P. R., The Effect of a Deficiency of the Anti-scorbutic Factor in Guinea-Pigs and of the Fat-Soluble A in Rats. *J. A. D. A.*, **13**: 1592, 1924.
6. HOJER, A., AND WESTIN, G., Jaws and Teeth in Scorbutic Guinea-Pigs. *D. Cosmos*, **67**: 1, 1925.
7. DAY, C. D. M., The Effect of Antiscorbutic Deficiency on the Pregnant Organism and Dental Tissues. *J. A. D. A.*, **20**: 1745, 1933.
8. FISH, E. W., AND HARRIS, L. J., The Effects of Vitamin C Deficiency on Tooth Structure in Guinea-Pigs. *Brit. D. J.*, **58**: 3, 1935.
9. BOYLE, P. E., BESSEY, O., AND WOLBACH, S. B., Experimental Production of the Diffuse Alveolar Bone Atrophy Type of Periodontal Disease by Diets Deficient in Ascorbic Acid (Vitamin C). *J. A. D. A.*, **24**: 1768, 1937.
10. BOYLE, P. E., Dietary Deficiencies as a Factor in the Etiology of Diffuse Alveolar Atrophy. *J. A. D. A.*, **25**: 1436, 1938.
11. *Idem*, Effect of Various Dietary Deficiencies on the Periodontal Tissues of the Guinea-Pig and of Man. *J. A. D. A.*, **28**: 1788, 1941.
12. CRANDON, J. H., LUND, C. C., AND DILL, D. B., Experimental Human Scurvy. *New England J. Med.*, **223**: 353, 1940.
13. TISHLER, B., Diet Analysis of One Hundred and One Periodontoclasia Cases. *J. A. D. A.*, **16**: 1037, 1929.
14. FREEMAN, W., AND GLASS, W. E., Some Clinical Studies on Vitamin C Deficiency. *J. Nutrition*, **15** Supp. 16, 1938.
15. KIRKPATRICK, R. M., Diet: A Predisposing Factor in the Aetiology of Vincent's Infection and Periodontitis. *D. J. of Australia*, **11**: 1, 1939.
16. RADUSCH, D. F., The Relationships between Periodontal Condition and Certain Dietary Factors. *J. D. Res.*, **18**: 305, 1939.
17. BOYLE, P. E., BESSEY, O. A., AND WOLBACH, S. B., Experimental Alveolar Bone Atrophy Produced by Ascorbic Acid Deficiency and its Relation to Pyorrhea Alveolaris. *Proc. Soc. Exp. Biol. & Med.*, **36**: 733, 1937.
18. PELZER, R. H., Report of a Study on the Etiology of Bleeding Gums. *J. Periodontology*, **9**: 25, 1938.

19. WESTIN, G., Scorbutic Changes in the Teeth and Jaws in Man. *D. Cosmos*, **67**: 868, 1925.
20. WEISBERGER, D., YOUNG, A. P., AND MORSE, F. W., Study of Ascorbic Acid Blood Levels in Dental Patients. *J. D. Res.*, **17**: 101, 1938.
21. SORRIN, SIDNEY, Periodontal Disease. *D. Cosmos*, **71**: 695, 1929.
22. FITZSIMMONS, L. J., Vitamin C Deficiency, A Cause of Periodontal Disease. *J. A. D. A.*, **28**: 76, 1941.
23. HANKE, T. M., Relation of Diet to General Health and Particularly to Inflammation of the Oral Tissues and Dental Caries. *J. A. D. A.*, **17**: 957, 1930.
24. HANKE, T. M., Nutritional Studies on Children. *D. Cosmos*, **75**: 570, 1933.
25. HANKE, T. M., *Diet and Dental Health*, (Univ. of Chicago Press, Chicago, Illinois: 1933).
26. HAWKINS, H. F., A Rational Technique for the Control of Caries and Systemic Pyorrhea. *J. D. Res.*, **11**: 201, 1931.
27. FARMER, C. J., AND ABT, A. F., Determination of Reduced Ascorbic Acid in Small Amounts of Blood. *Proc. Soc. Exp. Biol. & Med.*, **34**: 146, 1936.
28. BREKHUS, P. J., Dental Disease and its Relation to the Loss of Human Teeth. *J. A. D. A.*, **16**: 2237, 1929.