# Extraordinary Implant Failure

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Every attempt must be made to keep implant failures to a minimum. Dental implant failure can roughly be divided into 3 broad categories: bacterial factors, occlusal (mechanical factors), and systemic and psychologic factors. All failures should be carefully analyzed and evaluated to identify their causes in order to prevent future reoccurrence. Failures should be documented and used to advantage when treatment planning future implant cases. A panoramic radiograph, mounted diagnostic casts, medical and dental histories, and surgical guides are accepted standards of care prior to beginning oral implant procedures. The identification and management of nutritional deficiencies is a useful adjunct to successful implant treatment.

***Key Words: implant failure, nutrition, bone, taste and smell, xerostomia, seasoning of foods, smoking, tongue cleaning, diagnosis, treatment planning***

## INTRODUCTION

One of the most dramatic services the dental profession has to offer is the replacement of missing teeth with implants. Implants are not new to dentistry. Seashell fragments were used to replace 3 missing mandibular incisors as early as 600 AD, and human transplants were used in many diverse early cultures. In recent years, oral implantology has undergone a well-deserved rebirth or rediscovery, and implants are now considered the treatment of choice in an increasing number of carefully selected cases. Today, implant prosthodontics has reached the point at which it can be successfully performed by both general dentists and specialists.

Unfortunately, implants often fail. In the words of an old song, ''Nothing is forever. Always is a lie.'' The results of a plethora of clinical investigations have been published, using an infinite number of variables and methods. As can be predicted, the results vary from investigator to investigator and from study to study.

The Dental Implant Clinical Research Group (DICRG), under the direction of Drs Harold F. Morris and Shigeru Ochi, initiated a long-term clinical study in 1991 to investigate the influence of clinical design, application, and site of placement on clinical success and crestal bone height. Over 3000 implants were placed in approximately 700 patients at 32 sites in the United States. Evaluation visits continued until 7 years after placement of the appropriate prostheses. Results show an approximate 90% success rate when all implants and patients are taken into consideration (DICRG, unpublished data).

Dental implant failure can roughly be divided into 3 broad categories: bacterial factors, occlusal (mechanical) factors, and systemic and psychologic factors. Generally, there is no one factor that causes implants to fail. Implant failure is usually multifactorial. This article will be concerned primarily with systemic and psychologic factors, with an emphasis on the role of nutrition in the success (or failure) of dental implants.

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## Nutrition

Nutrition is one of the factors under human control that can influence the health of the implant patient. A good general diet is essential to the supporting tissues of natural teeth and implants. A lack of essential nutrients can cause tissue friability and depress the potential for repair.[1]

The diets of implant patients are often nutritionally inadequate. It is essential for the implant patient to retain an interest in food. Many implant patients exist on inadequate diets, not realizing or caring about the effects on their overall health. The diets of implant patients must include the proper amounts of protein, fats, carbohydrates, vitamins, and minerals, and even more important—water. Unhealthy (nutritionally deficient) oral tissues will not provide a satisfactory foundation for successful implant service no matter how carefully the procedures are executed.

### *Protein*

Muscle accounts for 45% of body weight in young adults. This drops to 27% in the very old, who chronically show a marked decrease in the size and strength of all skeletal muscle.[2] Chronic dietary protein inadequacy may be involved in depressed immune function, decreasing muscle strength, and poor wound healing in older adults.[3]

Muscle changes are conspicuous in the small muscles of the hands and face and in the muscles of mastication. The facial muscles sag and become imbalanced. Learning how to manipulate these flaccid muscles is difficult for the elderly, especially when a new implant prosthesis, which is foreign to the oral environment, is inserted into the oral cavity.

Until recently, it was thought that adults over 50 years of age should ingest 0.8 g of protein per kilogram of weight daily,[4] but recent guidelines have suggested from 1 to 1.25 g of high-quality protein per kilogram of weight daily.[5,6] The best sources of protein are meat and fish. These foods should be boiled (poached or braised), not fried; boiling prepares meats and fish for the gastrointestinal tract by breaking down the complex proteins into the more easily digested proteoses, whereas frying denatures and coagulates the proteins and makes them difficult to digest.[2]

### *Fat*

The United States Food and Drug Administration guidelines recommend a diet with 25% to 35% of its daily caloric intake in the form of fat. In addition, it advises that saturated fat intake be reduced to less than 10% of daily calories, and that cholesterol be limited to less than 300 mg daily.[7,8] These recommendations are for all adults, with no differentiation for the elderly.

### *Carbohydrates*

Current dietary guidelines from the United States Department of Agriculture[7] suggest that carbohydrates should compose from 45% to 65% of daily calories, and the complex carbohydrates (starches) are preferred over simple carbohydrates (sugars). More recently, carbohydrate intake of 130 g/d has been suggested for adults over 70 years of age, with a recommendation that ''added sugars'' (soft drinks, candy, desserts, etc) make up no more than 25% of total energy intake.[9]

### *Vitamins*

Vitamins are essential cofactors in many functions of the body, including wound healing. Vitamin C (ascorbic acid) is essential in the synthesis of collagen. Vitamin C deficiency will produce a marked alteration in the healing process: without it, the primary sequence of amino acids in the collagen protein is improperly elaborated, the procollagen protein cannot be secreted from the fibroblast, and self-assembly of the

collagen polymer cannot occur because vitamin C is required for the hydroxylation of proline residues.

Consequences of vitamin C deficiency are incomplete wound healing and an increased risk for wound dehiscence.[10] Scurvy is the clinical disease resulting from vitamin C deficiency, manifested as decreased integrity of bone, soft tissue, and small blood vessels. Since vitamin C is water-soluble, it is excreted renally and must be replenished frequently. The recommended daily allowance (RDA) for vitamin C is 60 mg per day. It has been suggested that adequate supplementation of vitamin C be given both pre- and postoperatively, in view of the possibility that surgical patients require more ascorbic acid than healthy persons.[11]

''Denture sore mouth'' (pain and burning of the denture-supporting tissues with the resultant inability to wear dentures) has been treated successfully by Payne (S. H. Payne, oral communication) and others by flooding the body and, therefore, the mouth with vitamin C. Payne recommends 1500 mg per day, 2 tablets of 250 mg taken with each meal, for a 4-week period. He then reduces the dosage to 750 mg per day, 1 tablet of 250 mg with each meal, which is continued indefinitely. It should be stressed that vitamin therapy by itself is not a substitute for a well-balanced diet.

### *Minerals*

Minerals play critical and interrelated roles in wound healing, especially in the processes involved in the synthesis of collagen. The enzymes essential to the synthetic process require cofactors to be present to catalyze the steps in the synthesis. These cofactors include magnesium,[12] iron, manganese, copper, and calcium.[13] Studies to date have not implicated nutritional deficiencies of manganese or copper in impairment of wound healing in patients with good oral intake, primarily because these elements are present in enough different foods that deficiency usually does not occur.

Severe iron deficiency anemia may reduce the bactericidal competence of leukocytes; this may be offset by a concomitant reduction in rate of bacterial growth.[14] Iron is essential for the restoration of normal red blood cell numbers following blood loss from surgery. The serum level of transferrin, a protein used to transport iron, will be higher than normal in the iron-deficient patient, and its level of saturation with iron will be low. Iron is also used as a cofactor in the hydroxylation of proline in the collagen synthetic pathway. A deficiency of iron will decrease the structural integrity of collagen and, hence, decrease wound strength.

In contrast to the trace minerals, a deficiency of zinc will have markedly adverse effects on wound healing by decreasing the rate of epithelialization, reducing the rate of increase in wound strength, and reducing collagen strength. Zinc has been found to be a cofactor of enzymes responsible for cellular proliferation and protein synthesis (DNA polymerase, RNA polymerase, reverse transcriptase, and ribosomes).[15] A deficiency would interfere with the cellular proliferation required in the wound healing process, including that of inflammatory cells, epithelial cells, and fibroblasts.

In addition, zinc acts to stabilize cell membranes by inhibiting lipid peroxidases, and may play a role in the storage of vitamin A in the liver.[14] Zinc deficiency also has a negative effect on the immune system by decreasing cellular and humoral immune function; the patient can become more susceptible to infections that may interfere with healing.

Experiments with high levels of zinc supplementation have been tried in the unsuccessful attempt to accelerate the healing process. It is known that insufficient zinc impairs wound healing, and that a return to normal blood levels will result in a return to

the normal rate of healing.[16,17] Excessive zinc interferes with copper metabolism and with wound healing by affecting lysyl oxidase, the enzyme crucial to collagen cross-linking.[14] The RDA for zinc is 15 mg for healthy adults.

Topical zinc oxide as a wound dressing has been found to enhance the reepithelialization of partial-thickness wounds[18] and to decrease inflammation.[19]

### *Water*

Water, the most important nutrient in the diet, is essential to all body functions. Water loss from perspiration, elimination, and the lungs must be balanced every day by an adequate intake from drinking water, beverages, soups, and other foods, especially vegetables. If this balance is not maintained, and if water loss exceeds intake, chronic dehydration can result. Geriatric patients are particularly susceptible to negative water balance, often caused by excessive water loss through insufficient or damaged kidneys.

Mucosal surfaces become dry and easily irritated in the dehydrated implant patient. Insufficient fluid consumption in general (and water consumption in particular) can have a deleterious effect on salivary gland function and on overall health. The average sedentary male adult must consume at least 2900 mL of fluid daily, and the average sedentary female adult at least 2200 mL per day, in the form of noncaffeinated, nonalcoholic beverages, soups, and foods. Solid foods contribute approximately 1000 mL of water, with an additional 250 mL derived from the water of oxidation.[20]

## Bone

Bone serves as the skeletal structure to which the muscles are attached and acts as a storehouse for calcium. Calcium is an essential mineral that is necessary for many functions in the body, including transmission of nerve impulses (lack of calcium leads to convulsions), cell membrane integrity, and blood coagulation. Bone serves as the internal source of calcium when the exogenous sources (dietary) become deficient.[2]

### *Osteoporosis*

Osteoporosis results when the internal bony sources of calcium are drawn on to compensate for the lack of calcium intake, failure in absorption, or deficient transport. In elderly persons, severe osteoporosis results from a combination of all 3 deficiency states. The result is a weakening of the supporting trabeculae of bone and subsequent fractures.

Osteoporosis affects the alveolar bone just as it does other components of the skeletal system, such as the vertebral column.[21–24] Bone loss occurs throughout the body as well as in the mandible and maxilla. Blomqvist et al,[25] in a retrospective study, concluded that general disorders such as osteoporosis must be considered in case of excessive implant loss. Starck and Epker[26] reported a case where 5 endosseous implants that had successfully integrated and had been restored with a mandibular hybrid prosthesis were lost approximately 6 months after diphosphonate therapy for osteoporosis was started.

Baxter and Fattore[24] surveyed the medical literature and concluded that osteoporosis and related bone pathologies are increasing in epidemic proportions. Although the exact etiology of osteoporosis is unknown, dietary, hormonal, and genetic factors all contribute to the related loss of bone density.

After a review of the literature and the results of a series of patient treatments, Dao et al[27] concluded that a compelling theoretical or practical basis does not exist to consider osteoporosis a risk factor for dental implants. Successful implant treatment of patients with osteoporosis have been reported by Friberg[28] and Fujimoto et al.[29]

### *Calcium*

Adequate calcium intake is essential for implant patients of all ages. Milk and milk products are the best sources of calcium. Almost all of the approximately 2 to 3 pounds of calcium present in the body is concentrated in the bones and teeth. The calcium needs of elderly implant patients are about 1000 mg per day.

Vitamin D is essential in the diet. Calcium therapy plus vitamin D have been used successfully in treating osteoporosis. Small amounts of fluoride may increase the effectiveness of calcium-vitamin D therapy. An adequate well-balanced diet, sunshine, and exercise are also recommended.[30]

## Diminished Taste and Smell

Diminished appetite has many causes, physical, psychological, and social that can interact to interfere with the ability or desire to purchase, prepare, or eat food.[31] Depressed taste and smell contribute to loss of appetite. Forty percent of US adults with chronic chemosensory problems (1.5 million persons) are 65 years of age or older.[32] In addition to aging, a decline in taste and smell can be caused by medications,[33] radiotherapy,[34] dental conditions or prostheses, and disease. A decline in taste and smell can contribute to inadequate food intake and nutrition.

### *Taste*

Taste buds can detect 4 primary taste sensations—sour, salty, sweet, and bitter. Acids produce a sour taste; the more acidic the food, the stronger the sensation. Ionized salts, mainly cations, stimulate a salty taste. Various classes of chemicals (mainly organic) produce sweet and bitter sensations. Other taste sensations, such as metallic, also have been suggested.[35]

Although it was once thought that particular areas of the tongue specialized in detecting specific tastes, investigators now believe that every taste bud has some degree of sensitivity to all of the primary taste sensations, and the brain detects the type of taste by the ratio or pattern of stimulation that different taste buds receive.[36] There are considerable differences between young and elderly persons in their sensory perceptions and their capacity to detect the pleasantness of food flavors.[37,38] Weiffenbach et al[39] found that while acuity of salty and bitter tastes declines with age, perceptivity of sweet and sour tastes does not. Many studies suggest that the sense of smell is more impaired by aging than is the sense of taste.

Taste buds in a healthy adult reproduce approximately every 10 days. Renewal is slower in the elderly, especially in postmenopausal women who have an estrogen deficiency. Protein and zinc shortages can also retard taste bud renewal.

### *Smell*

The olfactory cells are the receptor cells for smell. In young people, olfactory cells are renewed approximately every 30 days.[40] This renewal process is slowed by aging. In very old people, it may stop altogether, resulting in the loss of the sense of smell (anosmia).

Reports have indicated that there may be as many as 50 or more sensations of smell.[41] Much of the mechanism pertaining to how different odors are distinguished is not known. Individual receptor cells are attuned to a narrow range of odorants with common chemical features, although the precise number of different odorant types and corresponding cell types is unknown.[42]

Olfactory acuity declines with age. Older people generally have greater difficulty differentiating among food odors than do younger people. They can, however, best discriminate fruits from other stimuli and also appear to prefer fruit odors compared with other stimuli.[43]

### *Diseases*

Diseases that can affect the senses of taste and smell include nervous system disorders (particularly Alzheimer and Parkinson diseases), chronic renal problems, chronic liver disease, endocrine disorders (diabetes mellitus, hypothyroidism, Cushing syndrome), local ENT ailments, and viral infections.[35,44] Specific nutritional deficiencies (zinc and vitamins $B_3$ and $B_{12}$) and the nutritional problems relating to cancer can also be involved.[35]

### *Medications*

Clinical studies have implicated more than 250 drugs in altered taste sensations.[33] These include lipid-lowering drugs, antihistamines, antimicrobial medications, antineoplastic medications, asthma medications, antihypertensives and other cardiac medications, muscle relaxants, antidepressants, anticonvulsants, and vasodilators. Although little is known about how or where medications can reduce a person's sense of taste or smell, it is recognized that these medications act at several levels, including in the peripheral receptors, chemosensory neural pathways, and the brain.

### *Dental problems and treatments*

Reduced taste and smell sensations can be the result of dental problems and treatments, including oral trauma, xerostomia, periodontal disease, burning mouth syndrome, denture-related stomatitis, and chemosensory problems such as dysosmia and halitosis.[45] Common dental treatments identified with decreased sensory sensations include removable prostheses (with or without resilient liners) and over-the-counter preparations such as dentifrices, denture adhesives and cleaners, and mouthwashes.[46,47]

*Implant patients may not be aware of taste and smell changes until their attention is drawn to the mouth during the fabrication of implant or conventional prostheses. When they realize foods do not taste as they used to, they may very well attribute it to the prostheses.*[47,48]

### Xerostomia

Solid foods must be dissolved before taste buds can be stimulated. Slow and thorough chewing and adequate salivary function are essential to sensing taste.

Decreased salivary flow can result from a number of medical problems (diabetes mellitus and insipidus, nephritis, pernicious anemia, Sjögren syndrome) and medications (over 300 in the *Physicians' Desk Reference*). Other conditions such as menopause, dehydration, vitamin deficiencies, mouth breathing, and head and neck irradiation can also cause xerostomia. A temporary decrease in salivation can be caused by a severe emotional reaction or sialolithiasis (salivary duct blockage caused by calculus).

A decrease in salivary flow can interfere with denture retention and the ability to taste foods. It also will make mastication and deglutition difficult because a bolus of food must be moist when swallowed. If dry mouth is caused by a decrease of salivary gland secretions, the use of artificial saliva and frequent mouth rinses, particularly during meals, may be helpful.

Sialogogues, drugs that stimulate the flow of saliva without affecting the ptyalin content, can be prescribed if some glandular function is still present. It has been found that 5-mg pilocarpine hydrochloride tablets, taken 4 times a day, produce improvements in dry-mouth symptoms in patients with Sjögren syndrome.[48] Adverse reactions to pilocarpine hydrochloride are severe sweating, nausea, rhinitis, chills, flushing, urinary frequency, dizziness, diarrhea, headaches, and weakness, which accounts for its infrequent use.

The treatment of xerostomia is generally unsuccessful. *If dry mouth is the result of the loss of glandular function, nothing can be done.*[47]

### Seasoning of Foods

Food can become tasteless and unappetizing as the result of declining taste and smell perception. Flavoring agents, such as vanilla, orange, strawberry and cherry, and spices and salt substitutes, such as caraway, chili powder, chives, cinnamon, cloves, curry, garlic (not garlic salt), ginger, lemon juice, mint, dry mustard, peppers, sage, tarragon and vinegar, should be added to foods instead of salt and sugar.

*Implant patients, especially older adults, should be encouraged to add seasoning to their food instead of relying on excessive salt and sugar.*[47,48] A variety of flavors and textures in the diet, along with a healthy dentition and satisfactory conventional and implant prostheses to replace missing teeth, can result in maximum enjoyment of meals.

### Smoking

Smoking not only diminishes the taste of food, but it also makes flavorful foods taste flat and unappetizing.[40] A large number of investigators have reported that smoking significantly increases the risk of dental implant failure.[49,50] Patients who smoke often experience delayed healing, dehiscence, and infection after surgical procedures, which probably are the result of the actions of the toxins (nicotine, carbon monoxide, and cyanide) in cigarette smoke. Many dental practitioners refuse to provide implant service for smokers.

Smokers should be strongly encouraged to stop. If potential implant patients do not wish to discontinue the use of tobacco, the dentist can also stress the possible adverse cardiac and cancerous effects of cigarette, pipe, and cigar smoking. Other dental reasons to discontinue smoking include periodontal disease, halitosis, tooth staining, stomatitis nicotina, and gingival bleeding.

### Tongue Cleaning

Implant patients should add tongue brushing to their home care regimen. A thick white mucoid coating, evident on arising and persisting after breakfast, is common in the elderly.[20] This coating can be easily removed by using a soft toothbrush or a dry gauze pad and by eating so-called ''detergent'' foods (hard bread, dry cereal, uncooked vegetables, and fibrous meats). Commercially available tongue cleaners can also be used to advantage.

Tongue brushing is especially important for increasing taste acuity in implant patients.[47] A dirty mouth cannot distinguish the subtle flavors of good, well-prepared foods. The tongue should be cleaned twice daily, upon arising and before going to bed.

### Diagnosis and Treatment Planning

The value of diagnostic casts is critical in oral implantology because they assist in the determination of the number and location of ideal and optional implant sites and angulation requirements during the surgical phase. Surgical templates are often designed and made from diagnostic casts. Surgical templates assist in the placement of implants in predetermined sites at the correct angulation during the surgical phase of implant insertion.

The panoramic radiograph, along with diagnostic casts mounted on an articulator with an appropriately determined occlusal vertical dimension, provide the first data required for evaluation of the available

prosthetic space and the subsequent selection of implants and prosthetic components. Diagnostic casts marked with the position of each implant, along with a surgical template, should be available to assist the clinician during implant insertion.

A set of diagnostic casts can be used as a permanent record of pretreatment conditions, since nonreversible procedures may be performed. The making of diagnostic casts and surgical guides are accepted standards of care prior to beginning oral implant procedures.

A serious problem can arise when a patient is referred to the restorative dentist by an oral surgeon or periodontist after the implants have been placed. Often the specialist has given no consideration to the restorative component, and the dentist can be faced with implants in unfavorable positions, at incorrect angulations, and sometimes with insufficient space for prostheses.

Geriatric patients satisfied with their old dentures should not be persuaded to have implants inserted and overdentures fabricated. Geriatric patients who have been without teeth for many years and have no desire for implants and implant overdentures are best left alone.[51]

## Conclusions

Clinicians must make every attempt to keep implant failures to a minimum. All failures should be carefully analyzed and evaluated to identify their causes in order to prevent future reoccurrence. It has often been said that more can be learned from failures as compared with successes. Failures should be documented and used to advantage when treatment planning future implant cases.

A panoramic radiograph and diagnostic casts mounted on an articulator, with an appropriately determined occlusal vertical dimension, must be available before any implant treatment can be initiated. These diagnostic aids provide the first data required for evaluation of the available prosthetic space and the subsequent selection of implants and prosthetic components. A panoramic radiograph, diagnostic casts, medical and dental histories, and surgical guides are accepted standards of care prior to beginning oral implant procedures.

The identification and management of nutritional deficiencies is a useful adjunct to successful implant treatment.

## Note

This article is scheduled to appear as a chapter in the 2009 edition of *Theories and Techniques of Oral Implantology*, by Leonard I. Linkow. Information about the 2009 edition can be obtained from Dr Linkow at leonardlinkow@yahoo.coorim.

## Abbreviation

RDA: recommended daily allowance

## References

1. Winkler S. Oral aspects of aging. In: Calkins E, Ford AB, Katz PR, eds. *Practice of Geriatrics*. 2nd ed. Philadelphia, Pa: WB Saunders; 1992:502–512.

2. Massler M. Nutrition and the denture-bearing tissues. In: Winkler S, ed. *Essentials of Complete Denture Prosthodontics*. 3rd ed. Delhi, India: AITBS Publishers; 2009:15–21.

3. Chernoff R. Effects of age on nutrient requirements. *Clin Geriatr Med*. 1995;11:641–651.

4. Munro HN, Young VR. Protein metabolism is the elderly: observations relating to dietary needs. *Postgrad Med*. 1978;63:143–148.

5. Campbell WW, Crim MC, Dallal GE, et al. Increased protein requirements in elderly people: new data and retrospective assessments. *Am J Clin Nutr*. 1994;60:501–509.

6. Castaneda C, Charnley JM, Evans WJ, et al. Elderly women accommodate to a low-protein diet with losses of body cell mass, muscle function, and immune response. *Am J Clin Nutr*. 1995;62:30–39.

7. *Dietary Guidelines for Americans*. Home and Garden Bulletin No. 232. US Department of Agriculture. Washington, DC: US Government Printing Office; 2005.

8. Mayfield E. A consumer's guide to fats. In: *The FDA Consumer*. US Food and Drug Administration. Washington, DC: US Government Printing Office; 1999.

9. *Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients)*. Food and Nutrition Board of the Institute of Medicine of the National Academies. The National Academies Press; 2005:265–338.

10. Ruberg RL. Role of nutrition in wound healing. *Surg Clin North Am*. 1984;64:705–714.

11. Schwartz PL. Ascorbic acid in wound healing—a review. *J Am Diet Assoc*. 1970;56:497–503.

12. Pollack SV. Wound healing: a review. III. Nutritional factors affecting wound healing. *J Dermatol Surg Oncol*. 1979;5:615–619.

13. Mazzotta MY. Nutrition and wound healing. *J Am Podiatry Assoc*. 1994;84:456–462.

14. Levenson SM, Demetriou AA. Metabolic factors. In: Cohen IK, Diegmann RF, Lindblad WJ, eds. *Wound Healing: Biochemical and Clinical Aspects*. Philadelphia, Pa: WB Saunders; 1992:248–273.

15. Solomons NW. Zinc and copper. In: Shils ME, Young VR, eds. *Modern Nutrition in Health and Disease*. Philadelphia, Pa: Lea and Febiger; 1988:238–262.

16. Chvapil M. Zinc and other factors of the pharmacology of wound healing. In: Hunt TK, ed. *Wound Healing and Wound Infection: Theory and Surgical Practice*. New York, NY: Appleton-Century Crofts; 1980:135–149.

17. Liszewski RF. The effect of zinc on wound healing: a collective review. *J Am Osteopath Assoc*. 1981;81:104–106.

18. Ågren MA, Chvapil M, Franzén L. Enhancement of re-epithelialization with topical zinc oxide in porcine partial-thickness wounds. *J Surg Res*. 1991;50:101–105.

19. Guillard O, Masson P, Piriou A, et al. Comparison of the anti-inflammatory activity of sodium acexamate and zinc acexamate in healing skin wounds in rabbits. *Pharmacology*. 1987;34:296–300.

20. Kleiner SM. Water: an essential but overlooked nutrient. *J Am Diet Assoc*. 1999;99:200–206.

21. Albanese AA, Edelson AH, Lorenze EJ, et al. Quantitative radiographic survey technique for detection of bone loss. *J Am Geriatr Soc*. 1969;17:142–154.

22. Jowsey J. Why is mineral nutrition important in osteoporosis? *Geriatrics*. 1978;33:39–48.

23. Massler M. Geriatric nutrition. I. Osteoporosis. *J Prosthet Dent*. 1979;42:252–254.

24. Baxter JC, Fattore L. Osteoporosis and osseointegration of implants. *J Prosthodont*. 1993;2:120–125.

25. Blomqvist JE, Alberius P, Isaksson S, et al. Factors in implant integration failure after bone grafting. An osteometric and endocrinologic matched analysis. *Int J Oral Maxillofac Surg*. 1996;25:63–68.

26. Starck WJ, Epker BN. Failure of osseointegrated dental implants after diphosphonate therapy for osteoporosis: a case report. *Int J Oral Maxillofac Implants*. 1995;10:74–78.

27. Dao TTT, Anderson JD, Zarb GA. Is osteoporosis a risk factor for osseointegration of dental implants? *Int J Oral Maxillofac Implants*. 1993;8:137–144.

28. Friberg B. Treatment with dental implants in patients with severe osteoporosis: a case report. *Int J Periodontics Restorative Dent*. 1994;14:348–353.

29. Fujimoto T, Niimi A, Nakai H, et al. Osseointegrated implants in a patient with osteoporosis: a case report. *Int J Oral Maxillofac Implants*. 1996;11:539–542.

30. Garg AK, Winkler S, Bakaeen LG, et al. Dental implants and the geriatric patient. *Implant Dent*. 1997;6:168–173.

31. Russell RM, Sahyoun NR. The elderly. In: Paige EM, ed. *Clinical Nutrition*, 2nd ed. St. Louis, Mo: CV Mosby; 1988:110–116.

32. Hoffman HJ, Ishii EK, Macturk RH. Age-related changes in the prevalence of smell/taste problems among the United States adult population. Results of the 1994 Disability Supplement to the National Health Interview Survey (NHIS). *Ann NY Acad Sci*. 1998;855:716–722.

33. Schiffman SS. Drugs influencing taste and smell perception. In: Getchell TV, Doty RL, Bartoshuk LM, Snow JB, eds. *Smell and Taste in Health and Disease*. New York, NY: Raven Press; 1991:845–850.

34. Beaven DW, Brooks SE. *Color Atlas of the Tongue in Clinical Diagnosis*. Ipswich, England: Wolfe Medical Publishers; 1988:16.

35. Schiffman SS. Taste and smell losses in normal aging and disease. *JAMA*. 1997;278:1357–1362.

36. Hess MA. Taste: the neglected nutritional factor. *J Am Diet Assoc*. 1997;97(10 suppl 2):S205–S207.

37. Hyde RJ, Feller RP, Sharon IM. Tongue brushing, dentifrice, and age effects on taste and smell. *J Dent Res*. 1981;60:1730–1734.

38. de Graaf C, Polet P, van Staveren WA. Sensory perception and pleasantness of food flavors in elderly subjects. *J Gerontol*. 1994;49:P93–P99.

39. Weiffenbach JM, Baum BJ, Burghauser R. Taste thresholds: quality specific variation with human aging. *J Gerontol*. 1982;37:372–377.

40. Massler M. Geriatric nutrition: the role of taste and smell in appetite. *J Prosthet Dent*. 1980;43:247–250.

41. Guyton AC. The chemical senses: taste and smell. In: Guyton AC, Hall JE, eds. *Textbook of Medical Physiology*. 8th ed. Philadelphia, Pa: WB Saunders; 1991:581–587.

42. Berry MM, Standring SM, Barnister LH. Peripheral apparatus of the special senses. In: Williams PL, ed. *Gray's Anatomy*, 38th ed. New York, NY: Churchill Livingstone; 1995:1312–1314.

43. Schiffman S, Pasternak M. Decreased discrimination of food odors in the elderly. *J Gerontol*. 1979;34:73–79.

44. Mowe M, Bohmer T. Nutritional problems among home-living elderly people may lead to disease and hospitalization. *Nutr Rev*. 1996;54:S22–S24.

45. Ship JA, Duffy V, Jones JA, et al. Geriatric oral health and its impact on eating. *J Am Geriatr Soc*. 1996;44:456–464.

46. Winkler S, ed. *Essentials of Complete Denture Prosthodontics*. 3rd ed. Delhi, India: AITBS Publishers; 2009:453–454.

47. Winkler S, Garg AK, Mekayarajjananonth T, et al. Depressed taste and smell in geriatric patients. *J Am Dent Assoc*. 1999;130:1759–1765.

48. Winkler S, Mekayarajjananonth T, Garg AK, et al. Nutrition and the geriatric implant patient. *Implant Dent*. 1997;6:291–294.

49. Gorman LM, Lambert PM, Morris HF, et al. The effect of smoking on implant survival at second-stage surgery: DICRG interim report no. 5. *Implant Dent*. 1994;3:165–168.

50. Lambert PM, Morris HF, Ochi S. The influence of smoking on 3-year clinical success of osseointegrated dental implants. *Ann Periodontol*. 2000;5:79–89.

51. Winkler S, ed. *Essentials of Complete Denture Prosthodontics*. 3rd ed. Delhi, India: AITBS Publishers; 2009:447.