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Alzheimer's Disease and Periodontal Disease: Mechanisms Underlying A Potential Bi-directional Relationship

Maintaining Oral Health in the Aging Population: The Importance of the Periodontal-Systemic Connection in the Elderly (3 CEUs)

The Promise of Transdisciplinary Nurse-Dental Hygienist Collaboration in Achieving Health-Related Quality of Life for Elderly Nursing Home Residents

MAINTAINING ORAL HEALTH IN THE AGING POPULATION: THE IMPORTANCE OF THE PERIODONTAL-SYSTEMIC CONNECTION IN THE ELDERLY

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Introduction

The number of elderly Americans surpassed 35 million in 2000, and by 2030 twenty percent of Americans will be 65 or older.¹ Rapid growth of this population will dramatically impact dentistry, since in this era, increased numbers of older adults retain their teeth.^{2,3} Additionally, ethnic/cultural minorities account for a larger percentage of the elderly population, and individuals aged 85 and older are the fastest growing segment of the elderly population.¹ Thus, the diversity and number of frail/functionally-dependent elderly persons requiring care in nontraditional or institutionalized settings is increasing. The landmark 2000 report on oral health by the US Surgeon General documented profound disparities in the oral health status of older Americans.⁴ Over 25% of people aged 65-74 have severe periodontal disease, and at any given time 5% of Americans aged 65 and older (currently approximately 1.7 million people) live in a long-term care facility where dental care is inadequate. In 2003, Oral Health America released its national grading report emphasizing that the oral health of older Americans is in a "state of decay".⁵ Every state received failing or near failing grades in all categories of dental services for older adults, especially preventive and periodontal care.^{6,7}

Adequate numbers of properly trained dental professionals are needed to ensure quality oral health care for older adults. These professionals must play a greater collaborative role with healthcare management teams as the community practice environment moves to a transdisciplinary care model.² For the dental profession to participate in this dynamic practice environment, practitioners must be prepared to address specific geriatric issues related to access, risk assessment, prevention, cultural diversity, confounding medical conditions, and psychosocial influences, in addition to primary dental care.^{8,9} Access is particularly important as low-income, minority, and institutionalized/homebound elderly are at high risk for oral disease but are the least likely to receive services.¹⁰ A recent study by the Centers for Disease Control (CDC) reported that only 15% of these elderly had satisfactory oral health.¹¹

The current state of geriatric dental expertise in the US is woefully inadequate.^{8,12,13} Clinicians competent in geriatric issues are not being trained in numbers sufficient enough to meet projected workforce needs.¹⁰ A recent report by the Institute of Medicine (IOM) criticized the lack of geriatric dental expertise, stating that "linkages between dentistry and medicine are insufficient to prepare practitioners for patients with complex medical problems".¹⁴ Additionally, it noted that "the traditional isolation of dentistry from the rest of the healthcare team has been detrimental to the profession".¹⁴ Transdisciplinary practice is a vital component of geriatric dental expertise because it exposes dental professionals to contributions of other health disciplines and fosters communication.^{8,10} Other healthcare professionals must also develop appreciation for the abilities of dental personnel to manage oral health needs of the elderly. Such a transdisciplinary team management approach improves the prognosis of the elderly. In fact, studies demonstrate that elderly individuals whose comprehensive management includes dental care develop fewer co-morbid conditions and require less expenditure of healthcare dollars.¹⁰

The transdisciplinary concept has long been supported by the Health Resource Services Administration - Bureau of Health Professions (HRSA-BHPr), as noted in their white papers for health professions education.¹⁵ Yet, inclusion of other healthcare disciplines in geriatric dental practice or oral health education for non-dental health professions is inadequate and lacks uniformity.^{10,15} Dental professionals must be able to provide education and training for other healthcare practitioners and caregivers regarding 1) the relationship of oral health to general health, 2) the importance of daily oral care, 3) the means to provide basic oral care, and 4) the referral to a dental professional when necessary.^{8,11,12}

Achieving an optimal level of transdisciplinary practice required for the elderly requires cooperation of like-minded healthcare professionals in community-based study clubs emphasizing transdisciplinary approaches. Involving dental professionals with these groups would provide comprehensive exposure to attitudes and skills required to provide dental care to older adults. As patients become disabled or experience cognitive dysfunction, dental teams will also need to address ethical issues relevant to dental diagnosis, treatment planning, and how care is provided.^{8,11,12} In geriatric treatment planning, the focus should be on identifying an optimal level of care for the patient (ranging from none to very extensive). In other words, optimal care should not by definition be highest level technically possible. Rather, it should be to establish a level of care appropriate to maintain oral and general health. Other issues that should be considered within this framework are alternative treatment procedures or techniques, expanding the oral care team to include other health professionals or paraprofessionals, and the potential interactions of oral disease with systemic conditions in the elderly.

The field of geriatric practice will evolve as research is applied to patient care. Thus, dental professionals will need lifelong education in using

health technology/informatics resources to update their skills.^{16,17} Currently dental professionals need to be better acquainted with diagnosis/management of complex transdisciplinary cases and function more like oral physicians.¹⁸ The shift toward prevention-oriented models must continue so that the traditional “repair” approach to dental care is transformed to one of early diagnosis and prevention. For the elderly population, professionals must familiarize themselves with evidence-based decision making and understand transdisciplinary management of complex cases in addition to acquiring expertise in restorative procedures and fabrication of dental appliances.^{8,12,18} The most accessible and comprehensive transdisciplinary Web-based resource providing guidelines relevant to oral health in the elderly is currently available through the Wisconsin Geriatric Education Center and Marquette University School of Dentistry.¹⁹

Importance of the Periodontal-Systemic Connection in the Elderly

Recently the concept of a periodontal-systemic connection linking periodontal disease to systemic effects has emerged.²⁰ The implications of this connection, however, for the aging population have not been considered in depth.²¹ In terms of public health impact, there is no doubt that poor oral health negatively impacts general health, particularly in the elderly.²² Most chronic inflammatory diseases and conditions, including periodontal disease, are cumulative and thus manifested later in life. Decades of oral neglect contribute to additional health problems in the elderly population, which already consumes the majority of healthcare dollars nationwide, an outcome that places a significant burden on the healthcare system.^{10,11} Given that periodontal disease has already been linked to development or exacerbation of systemic disease, maintaining optimal periodontal health in midlife may do more to reduce healthcare expenditures in one’s remaining lifespan than any other public health measure. Thus, optimal oral health cannot be reserved only for those who can afford basic care, but it must be a national priority to improve the overall health of all citizens.²²

Many chronic inflammatory conditions share some common physiological and biochemical elements with periodontal disease (periodontitis).²³ Periodontitis is more than a localized oral infection. Recent data indicate that periodontitis may initiate changes in systemic physiology and biochemistry that alter immune function, serum cytokine/lipid levels, and tissue homeostasis.²³⁻²⁵

Periodontal Disease, Diabetes, and Insulin Resistance

The interrelationship of periodontitis and diabetes is the most obvious example of a systemic disease predisposing one to oral infection, and once that infection is established, it may in turn exacerbate the disease.²⁵⁻²⁷ However, in this case, an oral infection might also predispose otherwise healthy patients to systemic disease.²³⁻²⁵ Common cellular/molecular mechanisms underlie the reciprocity of diabetes and periodontitis and likely synergize when the conditions coexist. The proposed mechanistic link involves the broad axis of inflammation and includes activities of immune cells (polymorphonuclear leukocytes, monocytes, macrophages), serum lipid levels (low density lipoprotein cholesterol and triglycerides (LDL/TRG)), and tissue homeostasis.²³⁻³⁰

As a result of metabolic and enzymatic deficiencies, diabetic patients are prone to elevated serum LDL/TRG, even when blood glucose levels are controlled.³¹⁻³⁴ Elevated lipid levels alter immune cell function, producing an inflammatory immune cell phenotype (upregulation of pro-inflammatory cytokines from monocytes/polymorphonuclear leukocytes and downregulation of growth factors secreted from macrophages).^{28-30,35-38} This occurrence predisposes an individual to chronic inflammation and progressive tissue breakdown and diminishes tissue repair capacity. Periodontal tissues are frequently affected because they are constantly wounded by substances emanating from bacterial biofilms. Thus much clinical and epidemiological evidence supports the idea that individuals with diabetes (both type I and type II) show higher incidence of severe or rapidly progressing forms of periodontitis than non-diabetics.³⁹⁻⁴⁵

Periodontitis-induced bacteremia/endotoxemia also elevates levels of serum pro-inflammatory cytokines such as interleukin-1 beta (IL-1 β) and tumor necrosis factor-alpha (TNF- α).⁴⁶⁻⁴⁸ The activities of both cytokines alters lipid metabolism and leads to hyperlipidemia similar to that observed in diabetes. Additionally, these factors can produce an insulin resistance syndrome similar to that observed in pre-diabetes and may initiate destruction of pancreatic β -cells, leading to diabetes. Elevated IL-1 β levels play a role in the development of type I diabetes through destruction of pancreatic β -cells.⁴⁹⁻⁵² TNF- α has also been implicated as a causative factor in insulin resistance and type II diabetes, as elevated TNF- α levels alter intracellular signaling stimulated by insulin, reduce synthesis of the insulin-responsive glucose transporter, and mediate macrophage-dependent cytotoxicity in pancreatic islets.⁵³⁻⁵⁷ Infection-induced insulin resistance syndromes, if long-standing or chronic, are precursors of active diabetes because of the pancreatic β -cell destruction resulting from sustained elevation in IL-1 β /TNF- α .^{51,53,57} In fact, a pro-inflammatory imbalance created by excess IL-1 β /TNF- α may be one of the most critical determinants of β -cell loss in diabetes.⁵⁸ Thus, periodontitis may potentially exacerbate conditions associated with diabetes.

Recent clinical studies provide strong support for such a hypothesis, particularly with regard to insulin resistance.⁵⁹ The degree of insulin resistance has been shown to be directly related to the severity of periodontitis⁶⁰, and some investigators have demonstrated a relationship between pre-diabetes and periodontitis in non-diabetic patients.⁶¹ Such reciprocity is further illustrated by recent studies demonstrating the effect of either periodontal disease or successful treatment of such disease on diabetes-induced hyperglycemia.⁶²⁻⁶⁴ Periodontal treatment actually improved glycemic status, especially in type II diabetes, where controlled trials have shown improvement of glycemic control after periodontal therapy.⁶⁵ In another study, effective treatment of periodontal infection and reduction of periodontal inflammation were associated with lower levels of glycated hemoglobin.⁶⁶ Thus, chronic untreated periodontitis may induce diabetes.

Periodontal Disease and Atherosclerosis-induced Diseases

Investigators have hypothesized that periodontitis-induced elevations of IL-1 β and TNF- α and subsequent elevation of serum LDL/TRG levels trigger development of other systemic conditions that disproportionately affect the elderly, particularly cardiovascular disease (CVD), cerebrovascular disease (CBVD), rheumatoid arthritis (RA), and dementia.^{23,24,67-71} In fact, recent studies suggest that in advanced periodontitis, serum levels of IL-1 β , TNF- α , and other inflammatory mediators/biomarkers are sufficiently elevated to be considered a significant systemic health risk, even in the absence of overt clinical symptoms of disease.^{46,72,73} Even at low levels, these cytokines can initiate significant systemic responses, including inflammatory tissue and organ damage. Interestingly, chronic periodontitis is one of the strongest and most reliable elevators of serum pro-inflammatory cytokine/lipid levels, and treatment of periodontitis has been shown to significantly reduce serum levels of these factors.^{23-27,48,67,74,75}

The impact of periodontal disease on CVD and CBVD is closely tied to mechanisms underlying initiation and progression of atherosclerosis. This effect involves a combination of a systemic inflammatory state and dysregulation of lipid metabolism plus direct interaction of periodontal pathogens with vascular walls. Increasing evidence confirms that periodontitis facilitates atheroma formation.⁶⁷ The contribution of systemic inflammation and elevated serum LDL/TRG to atherosclerosis has been thoroughly described.⁷⁶ Periodontitis-induced elevation of serum pro-inflammatory cytokines, inflammatory biomarkers, and serum LDL/TRG has also been well documented.^{23-27,67,72-74,77-81} Other studies demonstrate that periodontal pathogens interact with vascular endothelial cells (either directly or through inflammatory responses to antibodies directed against periodontal pathogens) and colonize developing atheromas, contributing to thickening of arterial walls and atheroma formation.^{67,82-89} Thus, there is likely more than a casual relationship between periodontitis and pathogenic mechanisms underlying atherosclerosis. In the presence of systemic periodontal pathogens and antibody-mediated reactions to those pathogens, periodontitis-induced elevated serum LDL/TRG and pro-inflammatory cytokines may damage vascular endothelial cells, leading to recruitment of macrophages or foam cell formation and development of atheromatous plaques.

Periodontal Disease and Rheumatoid Arthritis

Periodontitis and RA share common pathogenic mechanisms and immunological/pathological outcomes. Patients with severe periodontitis or RA exhibit similar blood cytokine profiles distinct from disease-free individuals.⁶⁸ Recent evidence suggests a strong correlation between the extent and severity of periodontal disease and RA. Individuals with advanced RA will likely experience more significant periodontal problems than normal individuals and vice-versa.⁶⁹ Thus these conditions could be closely related through the systemic inflammatory state previously described, as accumulating evidence supports the notion that elevated pro-inflammatory cytokines and reduced tissue repair capacity are manifested in both conditions.⁶⁹ Additionally, some periodontal pathogens expressing the enzyme peptidylarginine deaminase (PAD) may generate antigens capable of stimulating production of rheumatoid factor-containing immune complexes and initiating inflammation in the synovium.⁹⁰ Of the pathologies previously described, evidence for this relationship is preliminary. Nonetheless, the immediate clinical lesson is that the periodontal status of patients with RA should be carefully monitored.

Periodontal Disease and Neurodegenerative Diseases

The inflammatory hypothesis of neurodegenerative diseases such as Alzheimer's and Parkinson's (the most common neurodegenerative disorders leading to dementia in the elderly) has moved from medical speculation to mainstream thinking.^{70,71} Brain mononuclear phagocytes, particularly microglia (brain resident macrophages), protect the nervous system by acting as debris scavengers, killers of microbial pathogens, and regulators of immune responses. Microglia are activated by numerous environmental stimuli including pro-inflammatory cytokines and bacterial lipopolysaccharides, initiating a cascade of neuroinflammatory events.⁷⁰ Systemic inflammation is associated with signals transferred from blood to brain via perivascular macrophages and microglia.⁹¹ Resultant neuroinflammatory responses include secretion of neurotoxic factors mediating neuronal cell injury and death. Over time a slow, smoldering inflammation in the brain may destroy sufficient neurons to cause clinical manifestations of Alzheimer's or Parkinson's dementia. Indeed, a recent population-based prospective cohort study showed that serum C-reactive protein and pro-inflammatory cytokine levels are increased prior to the clinical onset of dementia.⁹² These interactions suggest that systemic infections, or indeed any challenge promoting a systemic inflammatory response, may contribute to the progression of chronic neurodegenerative disease and provide a potential link between early periodontitis-induced bacteremia/endotoxemia and subsequent neuronal injury.

Memory can be impacted by insulin activity. Insulin resistance is associated with age-related memory impairment and Alzheimer's disease.⁹³ Thus, the previously described periodontitis-induced insulin resistance may contribute to pathologic mechanisms underlying neurodegeneration, as might the described links between periodontitis and vascular disease. Increasing evidence indicates that several pathogenic mechanisms promoting atherosclerosis also function in neurodegenerative diseases.⁹⁴ Vascular disease and Alzheimer's disease share some biological mechanisms and risk factors, such as lipid metabolism dysregulation and systemic inflammation. Although the evidence for such a relationship is preliminary, atherosclerosis may be another important mechanistic link between periodontitis and neurodegeneration affecting the elderly.

Periodontal Disease and Respiratory Diseases

Periodontal disease may be connected more directly to respiratory disease. Although some studies of chronic obstructive pulmonary disease describe significant associations with periodontal disease and propose systemic mechanisms relating to inflammation and/or physiologic linkages, this data requires further support.⁹⁵⁻⁹⁸ A stronger case has been made that bacterial components of dental plaque are a major cause of respiratory infections in older adults, especially those in institutions.⁹⁹⁻¹⁰² Up to 48% of infections seen in nursing homes result from aspiration pneumonia, and the cost to treat patients developing pneumonia in these institutions has increased dramatically.⁹⁹ Aspiration pneumonia is a significant cause of morbidity, hospitalization, and mortality in the nursing home population.¹⁰⁰

When host defense mechanisms are compromised because of disease, aging, poor nutrition, or other conditions associated with elderly patients in nursing homes, the aspiration of a large pathogenic inoculum from periodontally involved teeth overwhelms normal flora and significantly increases the risk of respiratory infection.¹⁰³ Bacteria constitute approximately 70% to 80% of solid plaque material and 1 mm³ of plaque contains more than 106 bacteria of 300 different aerobic and anaerobic species.⁹⁹ Aspiration of plaque bacteria by older patients often leads to lower respiratory tract infections, such as aspiration pneumonia or pneumonitis, and recent evidence links anaerobic bacteria from periodontopathic biofilms with aspiration pneumonia in elderly persons.^{103,104} Thus, poor periodontal health and accumulation of dental plaque is a major contributory factor in respiratory infections.^{99,100,105} Furthermore, addressing periodontal health in nursing home patients is critical not only because older adults are now more likely to retain their teeth but because younger persons are being admitted to such facilities.^{101,102}

Effect of Aging on the Periodontal-Systemic Connection

Age may also predispose individuals to the periodontal-systemic connection. It is well known that the incidence of periodontitis and the severity of untreated periodontal disease increase with age.¹⁰⁶⁻¹⁰⁸ Secretion of pro-inflammatory cytokines from monocytes/macrophages and levels of soluble TNF- α receptor normally increase with age.^{109,110} Thus, further increases in serum cytokines induced by periodontitis would not only be cumulative but could create a more destructive scenario through enhanced receptor interactions. Serum lipid levels also increase with age, particularly LDL.^{111,112} Similar to the pro-inflammatory cytokines, periodontitis-induced LDL/TRG elevation could be more damaging in this context and further increase pathological lipid levels.

Aging is associated with increased insulin resistance.^{113,114} Likewise, the incidence and severity of diabetes also increases with age.^{115,116} These conditions may result from loss of an individual's capacity to respond to environmental challenges.¹¹⁵ Some investigators attribute this association to an imbalance of important intracellular divalent cations such as calcium and magnesium that make cells vulnerable to ionic disturbances.¹¹⁶ Many other systemic diseases/conditions associated with chronic inflammation also demonstrate increased incidence and severity with advancing age.^{117,118} The specific mechanisms by which advanced age promotes chronic inflammation are not yet understood. Nonetheless, age-related increases in pro-inflammatory cytokine/cytokine receptor expression and oxidative stress, along with decreased bioavailability of free radical scavenging systems, likely exacerbate the systemic inflammatory state in the elderly and promote development of chronic inflammatory diseases.^{118,119}

Thus, with advancing age, factors mediating the periodontal-systemic connection are positioned to act synergistically, putting even healthy patients at risk to develop periodontitis. An overview of the link between periodontitis and systemic diseases/conditions predominantly affecting the elderly is shown in Figure 1 (previous page). Of perhaps greater significance relative to morbidity/mortality, elderly patients with chronic periodontitis also may be at risk for developing any systemic disease or condition associated with elevated pro-inflammatory cytokines/serum lipids. Future clinical studies are required to validate this premise.

Although recent discussions of the periodontal-systemic connection have focused on systemic diseases/conditions, there is significant evidence associating dietary imbalance with systemic illnesses. Oral health significantly influences dietary intake, particularly aspects of oral health related to masticatory function and edentulism.¹²²⁻¹²⁹

Mastication is the first step in digestion and is absolutely essential to optimize dietary intake. Masticatory function in older individuals is influenced by two variables: the number and health of natural teeth and the functional status of dental prostheses. Older people tend to have fewer natural teeth and there are higher rates of edentulism with increasing age. That pattern is, however, changing with a projected reduction in edentulism over the next 20 years.^{2,3} Nevertheless, many older people rely on dentures for oral function, and even those who are dentate may require either partial dentures or a full denture in one jaw opposed by some natural teeth. Masticatory function in this group is often not much better than that seen in individuals who rely on full dentures.^{124,127} Additionally, over 25% of those aged 65-74 have severe periodontal disease likely accompanied by varying levels of pain or dysfunction.⁴ Compromised masticatory function causes variation in food choice to foods that an individual with impaired chewing can tolerate.¹²²⁻¹²⁹ Thus, poor oral health, especially poor periodontal health and edentulism, may negatively impact systemic health by disturbing nutritional intake.

Tooth loss is correlated with changes in diet that may contribute to increased risk of developing chronic diseases.¹² Losing natural teeth and/or pain associated with oral infection impairs masticatory function.¹²⁴ This outcome is particularly relevant to people residing in institutional settings where mastication may not be monitored. Furthermore, the use of dental prostheses may not always restore full masticatory function, resulting in significant dietary changes through altered food choices or food preparation methods.¹²³ Indeed, denture wearers are often not aware of gradual adjustments made in food choice. As masticatory efficiency declines, people report increasing difficulty chewing foods and may choose not to eat foods difficult to chew, such as beef or steak, raw vegetables, or dry solid food like crusty bread. People handicapped by their dentition consequently suffer impaired intake of fruits, vegetables, and some key nutrients. Decreased intake of total calories, proteins, non-starch polysaccharides (dietary fiber) and vitamins is often accompanied by increased consumption of sugars and fats. These dietary links are supported by evidence by several large cross-sectional and longitudinal studies in Europe and the US linking oral health status to biochemical analyte levels of key micronutrients.¹³⁰ These studies (the National Diet and Nutrition Surveys in the UK and the National Health and Nutrition Examination Surveys in the US) cited significant reductions in some micronutrients (vitamin C, retinol, folate and β carotene) in edentulous subjects compared with those with natural teeth. The outcomes were independent of effects of age, gender, regional variation within a country and socioeconomic group.

The negative impact of masticatory dysfunction is likely compounded by food preparation. Fresh foods can be over-prepared (by removing skin from fruits and vegetables) or over-cooked by or for a person with reduced chewing efficiency and nutrients are consequently lost. Those nutrients might prevent or antagonize disease and facilitate cellular defenses and combat aging (anti-oxidant vitamins C and E).^{131,132}

Reduction in dietary fiber (non-starch polysaccharides or dietary fiber) and in fruit and vegetable consumption is associated with increased risk of CVD and certain cancers (breast, prostate, cervical, pancreatic, gastric and colorectal), most likely because of the lipid-lowering capabilities of soluble fiber and the beneficial effects of anti-oxidants in fruits and vegetables.¹³¹⁻¹³⁹ Many dietary components that form an essential part of the cellular defenses against oxidative damage to DNA may be lost because of over-cooked meals. They include the trace elements selenium, zinc and manganese, vitamins A, C and E and other plant-derived micronutrients (β carotene, luteine, lycopene and plant flavenoids).^{131,132} The role of these factors in maintaining homeostasis is becoming increasingly apparent. Links have been demonstrated between deficiencies of these micronutrients, tissue breakdown, and cardio-vascular disease and stroke in the elderly.¹³⁵⁻¹³⁸

Recent studies confirm a direct relationship between compromised masticatory function and malnutrition in both community-dwelling and institutionalized older adults.¹²⁵⁻¹²⁹ Elderly people with persistent untreated periodontal disease and/or dysfunctional prostheses had lower Healthy Eating Index (HEI) scores and significantly lower intake of vitamins A and B6.¹²⁵ Poor nutritional status demonstrated by the Mini Nutritional Assessment (MNA) and a questionnaire on eating problems was significantly associated with periodontal problems, edentulism, and dysfunctional prostheses.¹²⁶ These findings emphasize the importance of tools such as the MNA or HEI to assess nutrition along with dental evaluation for oral problems in a comprehensive care plan. Poorly fitting prostheses or chronic periodontitis as well as the potential for associated lesions and pain are of concern for individuals suffering from dementia or conditions that prevent them from articulating the cause for difficulty in chewing food.¹⁴⁰⁻¹⁴³ Often, institutionalized elderly patients undergo rapid weight loss after being fitted for new dentures that are not monitored for comfort and functional efficiency.^{141,142} Most often, poorly fitting dentures can be confirmed through the presence of lesions at the borders of the prostheses such as tissue overgrowth (epulis fissuratum) or ulcerations (denture ulcers).

Restoration of masticatory function by dental intervention alone will not necessarily lead to improved nutritional intake. Dental services should always be complemented by nutritional counsel, as has been confirmed in a recent clinical study where impaired chewing ability caused avoidance of hard and fibrous foods including fruits, vegetables and whole grains leading to a very low intake of non-starch polysaccharides and micronutrients.¹²³ In this case, provision of prostheses did not improve the diet. However, individualized dietary advice provided at the time of denture insertion resulted in increased consumption of fruits and vegetables and improved intake of non-starch polysaccharides. It is important to note that an individual's ability to respond to nutritional advice will be moderated by their oral health status. For example, an edentulous patient who has had a stroke resulting in paresis of the facial musculature will have considerable difficulty chewing foods because their ability to stabilize a complete denture during function will be impaired. The dental professional will need to work with the comprehensive care team to encourage a diverse and healthy dietary pattern. This could be accomplished in part while the patient receives instructions for use of complete dentures by challenging the patient to explore new foods and chewing methods. Dietary support and advice should always be given to patients being converted to edentulism for the first time, since using complete dentures as a masticatory tool is a challenge that will often be met by the blender unless positive support and advice is forthcoming from the dental team. It is widely recognized that a significant proportion of elderly people admitted to hospitals suffer from nutritional deficiencies and that adequate nutrient intake is an important determinant of recovery from illness.¹⁴⁴⁻¹⁴⁷ Specific plans for nutritional support may be required for edentulous subjects during such recovery, and professional dental help may be required to help such patients cope with poorly fitting dentures.

Two case studies shown below, (Figures 2 and 3), provide strong support for the importance of maintaining oral and periodontal health in aging patients.

Case 2. Clinical presentation of severe periodontal disease in an 82-year-old widow living in a nursing home for the past six years.

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The Ethics of Oral Neglect in Geriatric Care: Are We Running Away From the Truth?

Casey Hein

Charles M. Cobb

What explains such neglect in providing oral health care in elderly populations? Have healthcare providers been conditioned to believe that suffering and premature death from chronic diseases is just an inevitability of the aging process? Or, perhaps we have become paralyzed by the overwhelming task of meeting the oral health needs of elderly persons. Whatever the reason, someplace along the way, it seems the healthcare delivery system gave up on elderly people. In truth, timely delivery of adequate oral care to the elderly population never really existed. Indeed, the vulnerability of elderly persons to oral conditions that are undiagnosed and/or untreated and the impact of those oral conditions on co-existing, multifactorial chronic diseases present an ethical quandary that can no longer be considered a subtle dilemma.

The impact of tooth loss on an elderly person's overall physical and emotional health has been reported extensively throughout geriatric literature. What has not been well discussed is the elderly population's increased susceptibility to infection of oral origin. Discussion of the influence of gram-negative periodontal pathogens and the resultant systemic inflammation in exacerbating an existing chronic disease such as diabetes or increasing risk for aspiration pneumonia in an elderly person has not been a priority, at least until now.

This issue of Grand Rounds brings to the forefront the consequences and grim nature of the lack of oral care for elderly persons. However, raising awareness is only the beginning of change. In proposing a possible solution to this ethical quandary, a geriatric specialist nurse practitioner (Coleman) joins two dental hygienists (Gurenlian and Hein) in exposing the barriers to oral health in nursing homes and exploring a transdisciplinary model of care that relies on collaboration between nurses and dental hygienists. To bolster this proposal, Iacopino's cut-to-the-chase article draws into question the ability and willingness of dental professionals to participate in geriatric care. His presentation of several case studies provides excellent examples of the importance of maintaining oral health in the aging population and progressive care plans that inevitably have a positive effect on quality of life. Most exciting is the contribution of Stein, Scheff, and Dawson. This original manuscript unravels the suspected link between periodontal disease and Alzheimer's disease by suggesting several biologically plausible mechanisms to explain a potential association. We are tremendously honored by these coauthors' willingness to debut this developing body of knowledge in Grand Rounds. And finally, we feel very privileged that Edmund Duthie, M.D. accepted our invitation to author the guest editorial for this issue. Duthie is perhaps one of the most highly respected geriatric physicians in the world, and his editorial discussing the importance of dental professionals' participation in the care of the elderly population provides a very compelling call to action.

Delivering adequate oral health care for elderly persons is already a challenge, let alone facing the demographics of the future. By 2030, almost 1 out of 5 Americans - approximately 72 million people - will be 65 years of age or older. This urgently demands a change in delivery systems. Instead of running away from the truth about the void in oral health care for elderly people, the time has arrived to intercede by developing novel, effective, and efficient models of care. And, most importantly, the first step in creating sustainable solutions is the recognition that this reality and its inherent responsibilities belong to us all.

Sincerely yours,

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Alzheimer's Disease and Periodontal Disease: Mechanisms Underlying a Potential Bi-directional Relationship

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Introduction

All countries are experiencing an increase in the number of people over the age of 65. In the US, changing demographics suggest a much higher number of elderly in the population.¹ Periodontal disease and Alzheimer's Disease (AD) are chronic conditions that commonly affect the elderly. Numerous cross sectional studies address the oral health status of individuals with AD and dementia.²⁻¹³ Overall, evidence indicates that Alzheimer's patients exhibit poor oral health, including increased plaque, bleeding, and calculus than age- and gender-matched controls.¹⁰ While it is true that Alzheimer's patients may be unable to adequately perform oral hygiene measures, thereby facilitating the development of periodontal disease,¹⁴ a potential exists for a bi-directional relationship.¹⁵⁻¹⁷ Researchers are now investigating the role of poor oral health and periodontal disease in development of AD. In this paper we provide an overview of AD, review the epidemiology of periodontal disease, and outline biologically plausible mechanisms underlying the relationship between periodontal disease and AD.

Alzheimer's Disease: An Overview

Alzheimer's disease is the leading cause of dementia in the US elderly population. Other dementias include vascular dementia, dementia accompanied by Lewy bodies, frontotemporal dementia, Creutzfeldt-Jakob disease, and Parkinson's disease. AD is a progressive dementia characterized by early short-term memory impairment. The incidence of AD within the aging population is significant and disturbing: currently, an estimated 4.5 million Americans have AD, and it is estimated that 14 million will be afflicted by 2050. Approximately 1% of the population between 65 and 69 years of age has been diagnosed with AD, and the incidence increases logarithmically with age, with 5% of individuals at 75 years of age and 22% of individuals at age 85. The clinical course of AD from the first identifiable symptoms averages 8-10 years but may continue as long as 20 years.¹⁸ The annual cost in the US for care, lost productivity, and resource loss involving individuals with AD is approximately \$100 billion.¹⁹

A clinical diagnosis of AD is based upon cognitive assessment tools, including the Mini Mental State Examination (MMSE)²⁰ and the Clinical Dementia Rating scale (CDR).^{21,22} While the primary symptoms of AD are learning impairment and delayed recall, multiple aspects of cognitive deterioration often occur in the course of decline. These include inability to concentrate, confusion, decline in verbal skills, spatial disorientation, depression and other personality changes, limb rigidity and incontinence. As the disease progresses, every cognitive function becomes impaired and an individual scores zero on all tests.²³ A cognitively normal elderly individual can have a MMSE score of 26-30 while an individual with mild AD usually has a score < 23. The expected decline in individuals with AD is about 3 points per year. A CDR score of 1.0 or higher is an indication of AD.

The major pathological hallmarks of AD, first described by Alois Alzheimer in 1907,²⁴ are the presence of neurofibrillary tangles (NFT), neuropil threads (NT), and beta-amyloid plaques, often referred to as senile plaques (SP). While the presence or absence of these pathological structures does not necessarily indicate that an individual is afflicted with AD, a final diagnosis must include observation of some of these hallmarks. The abundance of NFT in the cerebral cortex is positively correlated with disease progression.^{25,26} Although the severity of dementia also correlates with the cortical density and distribution of both NFT and SP, several studies have observed these lesions in cognitively intact elderly individuals,²⁷⁻³¹ suggesting they occur in the course of normal aging as well. More recent reports observe significant loss of synapses in the hippocampus and neocortex^{32,33} coupled with significant neuronal loss.³⁴⁻³⁷ It is still controversial which neuronal loss plays the most significant role in AD and whether or not the loss of larger neurons is more important than the site at which they are lost.

Currently there are no effective therapies for AD although numerous laboratories are working on preventive strategies. One of the problems associated with developing an effective therapy is that the etiologies of the disease are unknown. The greatest risk factor for AD is increasing

age and a family history of the disease. But why these individuals are at high risk factors and what happens to engage the neuropathological cascade of AD are unknown. Increasing evidence supports the involvement of oxidative stress, in which free radical levels exceed antioxidant defenses, as a major cause of AD.^{38,39} Progressive oxidative modification of proteins is a normal consequence of aging and appears to underlie accumulation of amyloid- β protein (A β).⁴⁰⁻⁴² The amyloid hypothesis of AD states that the formation of A β initially triggers AD.⁴³ Amyloid peptides are also potent activators of microglial cells in the brain.^{44,45} Numerous studies have shown an inflammatory response associated with the presence of neuritic amyloid plaques involving microglia and astrocytes. Coupled with this activation is an upregulation of inflammatory cytokines and chemokines, which could potentially damage synapses and neurons leading to further microglial activation and astrogliosis.⁴⁶ While it is currently being actively debated whether inflammatory mechanisms cause CNS damage in AD, an inflammatory response certainly coincides with the neuropathology of the disease. Epidemiological studies provide intriguing evidence in support of use of non-steroidal anti-inflammatory drugs (NSAIDs) for several chronic inflammatory diseases, including AD.⁴⁶⁻⁵⁰ NSAIDs, such as aspirin, ibuprofen, naproxen, COX-2 inhibitors, and other medications, may lower the risk of AD.

Epidemiology of Periodontitis and Systemic Disease Association

The prevalence of a disease is defined as the proportion of cases in a specific population at a given point. The prevalence of severe, generalized periodontitis ranges from 5-15%.⁵¹ Estimates are higher for mild periodontitis (21.8%) in the US.⁵² Estimating periodontal disease trends is challenging and not without controversy. Borrell and colleagues have reported decreases in periodontitis prevalence from NHANES III to NHANES 1999-2000.⁵³ Others estimate that the number of adults over age 25 with some form of periodontitis will increase through 2010.⁵⁴

Periodontal infections are the direct result of an interaction between a tooth-associated microbial biofilm and host defenses. A mature biofilm is comprised of large numbers of gram-negative anaerobes that stimulate a host response.⁵⁵ Neutrophils and other cells are recruited resulting from a host response and produce a variety of inflammatory mediators, including cytokines and prostaglandins.⁵⁶ The chronicity of the local lesion is important, as it is the continued generation of inflammatory mediators and subsequent interactions derived from the host response that leads to destruction of alveolar bone and connective tissue.^{57,58} Research efforts have focused on this chronic inflammatory process and have defined mechanisms enabling specific bacterial cell invasion and the role of pathogens in the local destruction of oral tissues.⁵⁹ The impact of this process extends beyond the oral cavity, as is illustrated by examples of periodontopathogenic processes believed to initiate or exacerbate systemic disease.

Genco and colleagues reviewed the epidemiology and possible mechanisms involved in periodontal and cardiovascular disease (CVD).⁶⁰ They reported that some investigators find a direct effect of oral bacteria such as *Porphyromonas gingivalis* and *Streptococcus sanguis* on induction of platelet activation and aggregation, which may contribute to atheroma formation and thrombosis. In their review they describe human studies identifying oral periodontopathogens in atherosclerotic plaque, along with animal studies implicating *P. gingivalis* in activating the acute-phase response.⁶⁰ It is believed that acute-phase activation promotes lipemia and formation of atheromas. Mechanistic models for *P. gingivalis*-accelerated atherosclerosis, including microbial invasion, immunological sounding, pathogen trafficking and autoimmunity, have been proposed by Gibson and colleagues.⁶¹ Genco and colleagues also reported several case-control and cross-sectional studies evaluating coronary heart disease and poor oral health.⁶⁰ One study evaluated NHANES III data and found that the odds of having a heart attack increased with the severity of periodontitis, while another supported the association of specific periodontal pathogens and myocardial infarction. Most longitudinal studies reporting such an association found that the level or burden of periodontal disease was important.

Investigations of linkages of preterm birth and diabetes to periodontal disease have increased because of the enormous economical and social burden caused by these health problems. Offenbacher and colleagues report that mothers with significant periodontal disease had a 7.5 fold increase in the risk of having a preterm, low birth weight baby.⁶² A recent study by Pitiphat and colleagues report 65% higher levels of C-reactive protein (CRP) among pregnant women with periodontitis compared with periodontally healthy women.⁶³ Clinical intervention trials are being conducted to investigate if non-surgical periodontal intervention therapy reduces the incidence of preterm birth and low birth weight babies. In addition, there appears to be a bi-directional relationship between periodontal disease and diabetes, with improved metabolic control seen in poorly controlled diabetics following periodontal therapy.⁶⁴⁻⁶⁶

P. gingivalis has also been linked pathogenetically to rheumatoid arthritis (RA) through the enzyme peptidylarginine deiminase (PAD). Rosenstein and colleagues hypothesize that individuals predisposed to periodontal disease exhibit autoimmune responses, such as production of rheumatoid factor.⁶⁷ PAD enzyme breaks down fibrin in the periodontal pocket and parallels intra-articular breakdown of fibrin and other proteins. The authors note that several RA treatments, such as treatment with nonsteroidal anti-inflammatory drugs, ameliorate periodontal disease. Golub and colleagues propose a "two-hit" model of chronic destructive periodontitis.⁶⁸ They cite several animal and human studies supporting their model that a subgingival biofilm (the first hit) is followed by a disease (the second hit, such as rheumatoid arthritis), which in turn increases levels of circulating inflammatory biomarkers. The second hit also results in increased alveolar bone loss. Therefore, defining mechanisms mediating systemic induction of periodontal disease may provide improved treatment strategies for chronic local and systemic diseases.

When evaluating epidemiological studies of periodontal disease it is important to consider differences in the definition of case severity, populations sampled, sites selected and sampling procedures used in a particular study.⁶⁹ Dietrich and Garcia note that randomized control trials are needed to assess periodontal treatment efficacy in reducing CVD and stroke, but that such an approach may not be sufficient to determine the etiology of periodontal disease in these conditions.⁷⁰ Therefore they stress the need for further well-designed observational studies to facilitate understanding of disease relationships.

Plausible Links Between Periodontal Disease and AD

It is clear that periodontal disease is associated with numerous systemic diseases, although it is too soon to tell if we can add AD to the list. Investigators are currently asking whether poor oral health promotes development of AD and dementia. Thus we outline below plausible biological mechanisms linking periodontitis and AD.

Metastatic Spread of Gram-negative Bacteria from the Oral Cavity to the Brain via Transient Bacteremia or Neuronal Pathways

For years it has been known that oral bacteria can disseminate to distant sites within the body.⁷²⁻⁷⁵ Elderly⁷⁶ and immunocompromised patients, such as those suffering from cancer, diabetes, or rheumatoid arthritis, may be especially vulnerable to systemic oral pathogens.⁷⁷ Any dental procedure that causes bleeding can produce transient bacteremia.⁷⁸ It is well documented that certain dental procedures, such as extractions, periodontal surgery, periodontal scaling and root planing, induce hematogenous seeding.⁷⁹⁻⁸⁴ The American Heart Association provides guidelines to prevent infections of the joints, cardiac valves, and endocardium caused by oral bacteria.⁷⁸ Could oral pathogens also infect the brain with subsequent neuropathological consequences? Additionally, could the bacteremia responsible for this neuropathology be the result of chronic periodontal disease?

In individuals with good oral hygiene the number of oral pathogenic bacteria reaching the systemic circulation is small. However, this number increases twofold to tenfold in persons with periodontal disease.⁸⁵ High levels of pathogenic bacteria, coupled with the edematous state of the infected periodontal pocket, leads to ongoing, chronic dissemination of periodontal bacteria into the bloodstream. One study demonstrated positive cultures of oral bacteria in arterial blood in 55% of patients with severe periodontal disease.⁸⁶

As early as 1891, it was suggested that oral bacteria could “lodge in some weak point in the brain” and result in brain infection and abscess.⁷⁵ Indeed, there are numerous reports of brain infection testing positive for oral bacteria, with most cases specifically linked to periodontal pathogens.⁸⁷⁻⁹⁸ Brain infection by one such bacteria, *Actinobacillus actinomycetemcomitans*, is associated with coagulative necrosis of cortical cells and white matter.⁹⁵

The flora of periodontal disease consists largely of gram-negative bacteria. Current research has identified brain receptors specific for gram-negative bacteria.⁹⁹ Brain infections by gram-negative bacteria have been linked to Alzheimer's etiology, specifically late-onset sporadic AD.¹⁰⁰ A recent histologic study demonstrated the presence of gram-negative *Chlamydia pneumoniae* in cells of affected brain regions in 17 of 19 post mortem Alzheimer's brains, while brains of controls were not infected.¹⁰¹ In another post mortem study, oral *Treponema* was found in the cortex of 14 of 16 Alzheimer's brains compared with only 4 of 18 control brains. *Treponema* was detected in cells of the trigeminal ganglion, suggesting that bacteria may reach the brain through branches of the trigeminal nerve.¹⁰²

Overall these studies indicate that it is biologically feasible for pathogenic oral bacteria to disseminate through the bloodstream, reach the brain and either initiate or exacerbate existing lesions.

Injury to Brain Tissue from Systemic Inflammatory Mediators Produced in Response to Periodontal Pathogens

It is also possible that pathogenic periodontal bacteria do not “infect” the brain but rather induce a systemic inflammatory response leading to injury of brain tissue. Since host responses to periodontal disease, such as upregulation of proinflammatory mediators, show significant positive correlation with coronary artery disease and premature birth, neuropathological responses may also be induced.

Inflammation is a recurrent theme among investigations of oral and systemic diseases.¹⁰³⁻¹⁰⁵ The cascade of inflammatory events associated with periodontal disease begins with endotoxin, a high molecular weight lipopolysaccharide found in the cell wall of gram-negative periodontal bacteria.¹⁰⁶⁻¹⁰⁸ Endotoxin initiates inflammation locally in the periodontal pocket by stimulating inflammatory cells such as monocytes, macrophages, fibroblasts and T cells to produce cytokines and prostaglandins (PGE₂).^{105,109-111} Cytokines transmit information from cell to cell at very low levels, in the nanomolar to picomolar range.¹⁰⁸ Some of the most important inflammatory cytokines associated with periodontal disease are interleukin-1 (IL-1), interleukin-6 (IL-6), interleukin-8 (IL-8), and tissue necrotizing factor-alpha (TNF- α). IL-1 and TNF- α signal hepatic cells to produce several Type 1 acute phase proteins, among them CRP.¹¹²

Studies have shown increased levels of proinflammatory cytokines in inflamed gingival tissues compared with healthy tissue¹¹³ and in the gingival crevicular fluid in patients with active periodontal disease.^{114,115} Elevated levels of acute phase proteins, including CRP, have also been demonstrated in the gingival crevicular fluid.¹¹⁶⁻¹¹⁸ It is suggested that inflammatory mediators produced locally may “spill over” into the systemic circulation, producing increased serum levels of cytokines and acute phase reactants.^{103,108,110} In addition, daily bacteremias, or chronic “trickling” of pathogenic periodontal bacteria into the circulation, could initiate a systemic cascade of inflammatory events resulting in a sustained elevation of inflammatory products.¹¹⁹

Indeed investigators have found markers of systemic inflammation when analyzing the serum of individuals with periodontal infections. A study by Ebersole and colleagues showed that levels of endotoxin detectable in the blood increase with the level of oral disease.¹¹² Periodontal

pathogens have been shown to elicit a circulating antibody response.¹²⁰⁻¹²² Abnormally elevated serum levels of PGE2¹²³ and CRP¹²⁴⁻¹²⁹ have been found in people with periodontitis. In one study of an elderly population, Bretz and colleagues found significantly higher levels of IL-6 in the blood of those with extensive periodontal disease compared with controls.¹³⁰ This finding is noteworthy because IL-6 is associated with local production of amyloid proteins,¹¹² and in the Alzheimer's brain it may regulate production of amyloid proteins found in neuritic plaques, which are shown in Figure 1.¹³¹

Cytokines have been implicated in the pathophysiology of several psychiatric disorders, including AD, because of their ability to stimulate neurochemical, neuroendocrine, and neuroimmune changes in the brain.¹³² As noted, inflammatory mediators can damage synapses and neurons and activate microglia and the inflammatory cascade. IL-1 is particularly relevant to the pathogenesis of AD since it is overexpressed in neuritic plaques.¹³³ In addition, IL-1 increases synthesis of beta-amyloid precursor protein and activates astrocytes.¹³⁴

Given the evidence for the role of chronic inflammation in AD,¹³³ it is reasonable to suggest that long-term systemic exposure to periodontal pathogens and their subsequent chronic production of inflammatory mediators may precipitate neuropathological changes.

Periodontal Disease Increases the Risk of Cerebrovascular Injury to Brain

Stroke, or cerebrovascular accident, affects the blood supply to the brain. There are two types of stroke: hemorrhagic, in which an artery supplying oxygen-rich blood to the brain ruptures, and ischemic, when a blood vessel supplying the brain is blocked by a local thrombus or an aggregation of bacteria and fibrin from a distant source.⁷⁷ Although stroke is not considered a major risk factor for AD,¹³⁵ stroke has been related to the severity of clinical symptoms in Alzheimer's patients,¹³⁶ and individuals with a history of stroke demonstrate more rapid decline in memory performance than do healthy individuals.¹³⁷ Stroke is a significant risk factor for dementia.¹³⁵ In fact, the risk of dementia increases ninefold in subjects experiencing ischemic stroke.¹³⁹ The relationship between stroke and periodontal disease thus merits discussion.

Recent findings suggest that periodontal disease is an important risk factor for stroke.¹⁴⁰ Beck and colleagues found that persons with severe periodontal bone loss at baseline had nearly 3 times the chance of experiencing a cerebrovascular accident (CVA) compared with those with minimal bone loss or no periodontal disease.¹⁴⁰ Elter and colleagues examined 9,415 dentate and 1,491 edentulous adults and found stroke associated with both edentulism and clinical attachment loss of 3 millimeters or greater.¹⁴¹ Findings from similar studies by Grau and colleagues indicate that subjects with severe periodontal disease, as defined by clinical attachment loss of 6 mm or greater, had from 4.3¹⁴² to 7.4¹⁴³ times greater risk of cerebral ischemia than control subjects or subjects with mild periodontal disease. In an investigation of plaque index scores and oral hygiene practices of 401 US veterans, it was shown to have a significant association with stroke.¹⁴⁴ Examining subjects under the age of 50, Syrjänen and colleagues found a greater risk of ischemic cerebrovascular disease in males with severe dental infections combined with other bacterial infections.¹⁴⁵ In a case control study, patients with acute cerebrovascular ischemia were found to have more severe periodontal disease when compared with age and sex-matched nonstroke patient controls.¹⁴³ In addition, men who have 24 or fewer teeth have been shown to have a greater risk of stroke.¹⁴⁶

What mechanism underlies the association between periodontal disease and stroke? Li suggests that in individuals with periodontal disease bacteria and cytokines disseminating into the systemic circulation contribute to stroke by altering platelet function and promoting atherosclerosis and blood coagulation, a hypothesis supported in the literature.⁷⁷ Proinflammatory mediators (IL-1, TNF- α , PGE2, and IL-6) produced in response to the bacterial challenge of periodontal disease induce the release of platelet activating factor (PAF).¹⁰⁸ Platelet aggregation-associated protein expressed on the periodontal pathogen *P. gingivalis* has been found to induce platelet aggregation, potentially increasing the chance of acute thromboembolic events.¹⁴⁷⁻¹⁴⁹ In addition, *P. gingivalis* can activate endothelial cells.¹⁵⁰ Individuals with periodontitis have been found to have significantly higher levels of serum fibrinogen.¹⁵¹ As noted, periodontal pathogens have been found in human atheromas. Haraszthy and colleagues found that 44% of human atheromas removed during carotid endarterectomies tested positive for at least one of the following periodontal pathogens: *A. actinomycetemcomitans*, *Bacteroides forsythus*, *P. gingivalis*, or *Prevotella intermedia*.¹⁵² In a similar study by Zambon and colleagues, periodontal pathogens were found in over half of the atheromas examined.¹⁵³

Data from recent studies thus indicates that periodontal disease affects platelets and blood coagulation, influences thrombus formation, and activates endothelial cells, all of which contribute to the onset of stroke and could potentially result in the types of neuropathology associated with cognitive impairment.

Genetics: Polymorphisms in the Interleukin 1 Gene Family

Inflammation is a lifesaving defense mechanism against bacterial and viral pathogens. However, if unchecked, it can become chronic and play a role in numerous pathologic processes, including periodontal disease and AD.^{108,133} Genetic factors may predispose one to a high risk phenotype favoring chronic inflammation because of a hyper-responsive immune system.¹⁵⁴

Investigations of the genetics of both AD and periodontal disease show polymorphisms (variations) in the interleukin 1 gene family associated with the disease. Human chromosome 2 (2q13) contains 3 IL-1 genes in a cluster.¹⁵⁵ Two encode the proteins IL-1A and IL-1B, which produce the proinflammatory mediators IL-1 α and IL-1 β , respectively. The third gene encodes a protein that binds IL-1 receptor sites functioning as a receptor antagonist.¹⁵⁶

Periodontal research suggests that specific polymorphisms in the IL-1 gene cluster constitute a risk factor for chronic periodontitis.¹⁵⁷ The risk

appears to increase when a particular polymorphism is combined with smoking.¹⁵⁸⁻¹⁶² Studies show a significant association between the severity of adult periodontitis and specific IL-1 polymorphisms.^{156,159} Individuals with this “periodontitis-associated genotype” exhibit significantly elevated levels of IL-1B in gingival crevicular fluid that remain high even after treatment.¹⁶³ In a related study by Poicut, an IL-1 polymorphism related to periodontal disease was found to correlate with a twofold to fourfold increase in IL-1 β production.¹⁶⁴ These studies offer explanations for individual differences in susceptibility to and variations in clinical expression of periodontitis demonstrated in previous studies.¹⁶⁵⁻¹⁶⁷

Genetic studies in AD have also identified risk alleles in the coding regions of IL-1 α (IL-1 α -889)¹⁶⁸⁻¹⁷⁰ and IL-1 β (IL-1B-511) genes.¹⁷¹ These genotypes are associated with overexpression of IL-1 in brain tissue, plaque formation, overgrowth of dystrophic neuritis, and elevated neuronal acetylcholinesterase.¹⁷² Yucsoy and colleagues found a significant association between genetic variations in the IL-1 gene family and AD and suggested that such variations increased the risk for AD.¹⁷¹ Other investigators studying Italian and American subjects demonstrated the IL-1 α -889 allele may be a risk factor for sporadic AD.¹⁷³ Bosco and colleagues also showed that individuals with particular variations in the IL-1 gene cluster were at increased risk of developing AD (odds ratio 4.8).¹⁷⁴ The results of a meta analysis of all studies investigating potential association of IL-1 genes and AD showed a strong association in persons with early onset AD.¹⁷⁵ A related study by Grimaldi found a significant association between specific polymorphisms in the cluster, primarily in the gene encoding IL-1A, and AD onset before 65 years of age.¹⁶⁹ Nicol found that of 232 confirmed Alzheimer’s cases, 12.9% possessed the IL-1A 2,2 genotype, while only 6.6% of the controls showed this variation.¹⁷⁵ A similar study demonstrated an IL-1A polymorphism known as allele 2 in 46% of individuals clinically diagnosed with AD compared with 34% in the control population.¹⁶⁸

Genetic studies of both AD and periodontal disease therefore indicate a common theme of variants in the IL-1 gene family. Individuals with particular polymorphisms produce significantly elevated IL-1, which could promote increased inflammatory responses and a predisposition to diseases related to chronic inflammation. Further investigation of genetic factors underlying both AD and periodontal disease should provide insights into the pathogenesis of both processes.

Weight Loss and Wasting Associated with Periodontal Disease May Contribute to Cognitive Decline

Periodontal disease contributes to general wasting of body tissues in two ways. First, it often results in tooth loss, which often leads to problems with chewing, swallowing and food selection.¹⁰ Individuals also poorly absorb nutrients from food when it is not well masticated.⁷⁷ Evidence from several studies indicates a deterioration in nutritional status in individuals missing teeth.¹⁷⁷⁻¹⁷⁹

Current research suggests a connection between tooth loss and AD. In a recent twin study examining several potentially modifiable risk factors for dementia, tooth loss before the age of 35 was shown to be strongly associated with AD.¹⁵ Data from a study by Kondo and colleagues also suggest tooth loss is an AD risk factor.¹⁶ A six year prospective cohort study found subjects with fewer teeth at baseline showed a greater probability of developing mental impairment.¹⁷

To interpret these findings, it must be acknowledged that tooth loss could mark prior inflammation and that chronic exposure to inflammatory products may mediate an increased AD risk. However, in an animal study of the effect of extracted molar teeth, defects in cholinergic neurotransmission and impaired spatial memory were observed.¹⁸⁰ These observations suggest that something more than inflammation plays a role in this outcome, and a logical choice would be impaired chewing and the nutritional deficiencies that follow.

Periodontal disease also contributes to weight loss and wasting through the effects of bacterial products and proinflammatory mediators. Lipopolysaccharide found in the cell wall of gram-negative periodontal pathogens has been shown to induce metabolic wasting.¹⁰⁸ Inflammatory cytokines associated with periodontal disease including IL-1 and TNF- α are implicated in weight loss and wasting in the elderly. TNF- α regulates cachectin, a cytokine responsible for inducing cachexia, a syndrome which includes anorexia, weight loss and protein wasting.¹⁸¹ IL-1 has also been shown to induce significant anorexia.^{182,183} In addition, IL-1 and TNF- α contribute to sarcopenia, or loss of muscle mass in the elderly,^{183,184} and individuals with higher serum levels of TNF- α exhibit lower body cell mass and less appendicular skeletal muscle mass.¹⁸⁵ These findings are significant because declining body mass index is associated with cognitive decline and increased risk of AD.¹⁸⁶

In summary, both tooth loss and inflammation related to periodontal disease may accelerate unintentional weight loss and muscle wasting, which in turn may accelerate neurodegeneration.

Conclusion

Recently much research has examined potential associations between oral and systemic diseases, but few studies have investigated a potential link between oral disease and AD or dementia. AD is a significant health problem that will likely become even greater as the population ages. It is established that AD contributes to deterioration in oral health.¹⁰ Some studies suggest that oral disease contributes to AD or cognitive impairment.^{15-17,71} However, data supporting a bi-directional association is limited, and it is currently unclear which occurs first, oral disease or AD. It is possible that the lines are blurred and that each disease contributes to the pathogenesis of the other.

Several biologically plausible mechanisms are proposed for a potential association between the two diseases and summarized in Figure 2. It

should be noted, as well as the etiology of AD is complex and multi-factorial, it is unlikely that any one mechanism is purely causal but instead may "tip the balance" in favor of dementia in an individual otherwise at risk.

It is important that research continue to investigate more fully what role oral disease plays in the pathogenesis of AD. Though costly and time consuming, large prospective randomized clinical studies and interventional studies are needed to clarify the interrelationship of these two diseases and should encourage design of more effective intervention strategies.¹⁰³ Although some risk factors are immutable for AD (family history and age), oral disease is one that can be prevented.

Whether poor oral health contributes to or is the product of dementia, the clinical implications are similar. Early preventive care must be established and a program put into place to maintain oral health.¹⁸⁷ For individuals with AD, as cognitive and physical abilities decline, oral hygiene measures will likely suffer and dental visits become less frequent. This lack of care may result in a vicious cycle producing increased inflammation, exacerbating both periodontal disease and AD, and resulting in further decline of oral health measures.

We cannot tolerate that poor oral health is often accepted as a normal part of aging. There is adequate data to indicate that untreated oral disease leads to significant morbidity, mortality, and avoidable healthcare costs.⁷⁶ It is critical that relationships between elderly patients and their caregivers be established with dentists, dental hygienists, physicians, nursing staff and other care providers.¹⁰ When everyone participating in the health care of a patient is convinced of the importance of maintaining oral health, more positive overall health outcomes will be achieved. Furthermore, those in charge of distribution of healthcare resources must be educated about the role oral disease plays in systemic diseases, in the hope that they will realize that the increased expense of oral health care is far less than the cost of ignoring it.

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The promise of transdisciplinary Nurse-dental hygienist collaboration In achieving health-related quality of life for elderly nursing home residents

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Introduction

The multi-dimensional concept of Health-Related Quality of Life (HRQL)¹ has been widely used to describe certain domains of physical and psychosocial functioning, as well as perceptions of health and opportunity. These domains have been used to quantify an elderly person's experiences, beliefs, expectations and perception of quality of life. Similarly, Oral Health-Related Quality of Life (OHRQL) is a concept that was introduced in 1998 by a group of dental hygiene faculty members who sought to define a model of care that emphasized the multidimensional nature of oral problems.² The concept of OHRQL was designed to help dental hygienists better plan and assess dental hygiene care with respect to an individual's perceptions of and reactions to their own oral health status, as modified by impairments, functional states, perceptions, and social opportunities.² There currently exists sufficient evidence of oral-systemic relationships such that meaningful distinctions between HRQL and OHRQL cannot be rendered. In fact, considering these concepts in isolation contributes to the historical schism between medicine and dentistry. In short, oral health-related issues can no longer be viewed as separate from those relating to somatic health because oral diseases and conditions seriously compromise the quality of life of older people. A new model of care focusing on comprehensive chronic disease management for the elderly must be developed in order to advance quality of life for this population.

As tragic statistics on NH care are reported, we cannot pretend that the care many elderly persons receive in NHs meets minimal standards. Coupled with mounting evidence to support oral-systemic relationships and the fact that oral health is an essential component of an elderly person's physical and social well-being, we must begin a dialogue on the significance of oral health as a determinant of HRQL in NH residents. Furthermore, rather than resigning ourselves to the belief that suffering from multifactorial chronic disease states is a natural progression of age and nonmodifiable, we must advocate for a model of successful aging for geriatric dentistry in the 21st century.³ Research suggests that prevention or treatment of periodontal disease diminishes the overall inflammatory burden systemically and therefore should be part of a best practice approach to disease management for older adults.

Indeed, the time is now to look for sustainable models of NH care that can fulfill the following criteria:

1. Improve NH residents' access to progressive management of interrelated chronic disease states, such as periodontal disease, diabetes, atherosclerosis-induced conditions, pulmonary diseases, insulin resistance, rheumatoid arthritis, osteoporosis, and even neurodegenerative diseases like Alzheimer's and Parkinson's.
2. Promote sustainable clinical outcomes leading to oral and systemic health.
3. Provide intervention strategies that are economically viable.
4. Provide satisfying professional experiences for persons providing care in NHs.

In this article we propose a model of care that fulfills the above criteria by relying on transdisciplinary collaboration between professional nurses and dental hygienists to achieve oral health and HRQL for NH residents. In support of this new model, we present background information providing a rationale for proposed changes. Although this discussion focuses more on periodontal disease as it relates to increasing the risk for systemic sequelae in the elderly, it must be noted that other oral conditions such as caries, xerostomia, impaired mastication from dysfunctional occlusion, burning mouth syndrome, and candidiasis infection, among others, also impact the overall health of the elderly.

The Aging Population and Chronic Disease Trends

The size of the older population will likely double over the next 30 years. By 2030, almost 1 in 5 Americans - 72 million - will be 65 years or older.⁴ The age group 85 and older (the "oldest old") is now the fastest growing segment of the US population. This group is projected to

double from 4.7 million in 2003 to 9.6 million in 2030, and double again to 20.9 million by 2050.⁴ As a group, this population has experienced greater longevity, but they have an increased likelihood of experiencing lasting damage resulting from chronic inflammatory diseases or conditions. The most common chronic conditions among elderly NH residents are cerebrovascular disease and cardiovascular disease (CVD) (e.g., hypertension, stroke), cognitive and musculoskeletal disorders (e.g., arthritis), and endocrine disorders (e.g., diabetes).⁵ The added burden of periodontal disease likely increases risk of systemic inflammation and exacerbates already existing chronic diseases in the elderly. As an example, approximately 1 in 5 skilled nursing facility residents over 55 have diabetes in addition to other multiple, chronic comorbidities.⁶ This condition is accompanied by increased risk of periodontal disease and associated infection and increased risk for diabetic complications. If healthcare providers in NHs can begin to view periodontal disease as a risk factor for chronic inflammatory systemic conditions and initiate appropriate treatment, this outcome may have a positive impact on co-existing chronic diseases in at-risk residents.

The Profile of a Typical NH Resident

In 1997, 1.6 million elderly lived in NHs,⁷ and this number is expected to triple over the next 30 years. Most NH residents need assistance with at least 3 activities of daily living: bathing and showering, including oral care; dressing; and eating. Most also suffer significant sensory, visual and orthopedic impairments, and rely on Medicaid as their primary source of payment.⁸ At least 50-80% of NH residents have some form of dementia.⁹ Because of water and dentifrice fluoridation, the large “baby boomer” population will comprise the first cohort group composed of elderly individuals who are dentate.^{3,10} Epidemiologic trends in chronic inflammatory periodontal disease indicate that 44% to 81% of adults 55 years and older have some level of periodontal disease,¹¹ most of which is undiagnosed. Consequently, it is reasonable to predict that most individuals entering NHs will have undiagnosed and untreated periodontal disease. These new residents may be at greater risk for systemic sequelae related to inflammation of oral origin, including increasing risk for atherosclerosis-induced diseases, aspiration pneumonia, and complications of diabetes and rheumatoid arthritis.

The burden of oral disease in elderly individuals is well documented.¹² In a comprehensive review of oral health studies of institutionalized elderly published between 1970 and 1989, Berkey and colleagues¹³ describe the compromised oral health status of NH elderly. Most had unmet oral needs, including high rates of edentulism, dental caries, poor oral hygiene, periodontal disease, and soft tissue lesions. Similarly, poor oral hygiene was reported for most NH residents with natural teeth in a study of 1,063 residents residing in 31 different NHs.¹⁴ In a recent observational study of oral care in US NHs, 81% of the resident sample had poor oral hygiene.¹⁵ Furthermore, using data from the 1995 US National Nursing Home Survey, Gift and colleagues¹⁶ reported that only 15% of the residents could be described as having excellent or very good oral health. With declining rates of edentulism and the cumulative effects of chronic, disabling illnesses, the likelihood of risk for dental and periodontal disease is extended into a time characterized by increasing self-care deficits.¹⁷ Thus daily oral hygiene, early diagnosis of oral diseases and conditions, definitive treatment, and professionally rendered maintenance procedures are required for elderly NH residents to enjoy normal oral function and to achieve optimal oral health.

The Relationship between Oral Health, Whole Body Health, Quality of Life and Mortality

Much has been written about the importance of oral health for older adults. The US Surgeon General's Report, Oral Health in America,¹⁸ emphasized that oral health is integral to general health. The report documented oral health disparities in the very old population, and described a “silent epidemic” characterizing the gap between an epidemic of oral disease and silence from those who need oral health care. In its Futures Initiative, the Centers for Disease Control issued a health impact goal aimed at increasing the average lifespan of older adults (50 and over) by 2 years of healthy life.¹⁹ The present system of healthcare delivery in NHs seems to undermine the national health goals stated for older adults.¹⁸ Achieving the goals set forth by these agencies requires comprehension of the relationship between oral health, whole body health, quality of life, and mortality.

HRQL represents the functional impact of an illness, disability or condition and its treatment on an individual, as perceived by the individual.²⁰ The major domains of HRQL include the physical and the psychosocial. An individual's oral health status (e.g., periodontal disease) can affect both the physical and psychosocial health domains, and thus it is important for clinicians to monitor the impact of oral health on health outcomes. Using periodontal infection as an example, Figure 1 illustrates how oral health status can specifically alter an individual's physical and psychosocial functioning. Healthcare providers involved in geriatric medicine have been slow to recognize the impact of specific oral pathological processes on overall health and in doing so have missed opportunities to eliminate or modify risk factors for both physiological and psychosocial health.

Oral-Systemic Health Considerations of the Elderly

Common systemic diseases in the elderly population have important oral sequelae and can detract from successful aging.²¹ For example, diabetes increases susceptibility to periodontal disease, which progresses more rapidly in diabetic individuals than in nondiabetic subjects and worsens the diabetic state. Controlling periodontal infection increases glycemic control and enables better management of diabetes.²²⁻²⁷ In addition to increased susceptibility to periodontal disease, other oral complications of diabetes include angular cheilitis, candidiasis, glossitis, tooth mobility and caries. The potential for these complications in NH residents has important consequences for disease management by health professionals.⁶ Neurological diseases (e.g., Alzheimer's disease or stroke) impair motor, sensory and cognitive function in a way that can increase the risk of developing gingivitis, periodontitis and dental caries. Conversely, recent literature indicates that periodontal disease may actually be linked to development of Alzheimer's disease (see Stein, Scheff & Dawson on pages 14-24).

Partial or complete loss of teeth likely complicates medical conditions by affecting diet selection and the ability to chew, swallow, and enjoy food, with resulting adverse impact on nutritional status.^{28,29} Most elderly NH residents receive an average of 7 routine prescription

medications per day and 2.7 additional medications on an “as needed” basis to control chronic conditions.^{30,31} Many of these drugs have side effects (e.g., xerostomia, gingival hyperplasia, lichenoid reactions) that adversely affect oral tissue.³²

Older people are also susceptible to infections caused by periodontal pathogens, which have been known to translocate to tissues distant from the oral cavity. Empirical evidence consistently indicates that conditions of poor oral hygiene, dental plaque accumulation, and impaired host defenses provide conditions favorable for proliferation and aspiration of oral pathogens that cause nursing home-acquired pneumonia.³³⁻³⁶ At its 2003 consensus development conference, the American Academy of Periodontology concluded that “patients and healthcare providers should be informed that periodontal intervention may prevent the onset or progression of atherosclerosis-induced diseases”.³⁷

Similarly, several studies show that individuals with poor oral hygiene and periodontal disease are more likely to develop CVD than individuals without periodontal infection,³⁸ and one study suggests that the risk of fatal heart disease doubles for persons with severe periodontal disease.³⁹ There is compelling evidence that tooth loss is a marker of past periodontal disease, and that periodontal disease may actually accelerate the development of atherosclerosis-induced diseases, such as heart disease and stroke.^{40,41} These findings suggest that oral infections, specifically periodontal pathogens, contribute to the incidence of CVD. Thus, many older adults may be at increased risk for myocardial infarctions or strokes because of undiagnosed and asymptomatic atherosclerosis potentially accelerated by chronic periodontal infections. By treating periodontal disease, the development of vascular diseases may be prevented or controlled, thereby decreasing risk for myocardial infarction and stroke. Similarly, preventive interventions, particularly improvements in oral hygiene, could lower the risk of aspiration pneumonia in older adults.⁴²⁻⁴⁴

Oral Health and Quality of Life

Oral and pharyngeal problems accompanied by oral-facial pain, infections, edentulousness, and tooth loss negatively impact an older adult’s quality of life.²⁹ Clearly, partial or complete edentulism has negative esthetic and functional (speech, chewing/eating, swallowing, and nutritional) consequences, and the emotional impact of total tooth loss can be profound.⁴⁵ The literature shows that for individuals with dementia, the pain of dental etiology is under-detected and under-treated by health professionals.⁴⁶ Furthermore, tooth and mouth problems can affect facial appearance and the ability to eat, communicate, and interact socially. While important at all ages, these activities have an especially vital connection for older NH residents who are at risk for malnutrition, are experiencing a shrinking social world and are increasingly susceptible to infection.^{29,47} Thus, good oral health for older adults means eliminating pain and discomfort and maintaining function so that quality of life can be optimized.

Barriers to Preserving Oral Health in Nursing Homes

Despite its importance, a low priority is placed on oral health in a NH setting. Several factors contribute to this situation and to oral health disparities experienced by the vulnerable elderly population, who rely on caregivers for at least part of their oral hygiene care.

Self-Care Deficits and Lack of Capacity

Oral health care is complicated by functional and behavioral factors associated with increased frailty. Self-care deficits related to sensation (e.g., vision), cognition (e.g., dementia), mobility (e.g., manual dexterity and range of motion), and endurance and motivation are endemic among the NH elderly. Both positioning and gaining adequate access to the mouth and encountering complex dentitions, such as fixed or removable prostheses or missing, chipped or rotated teeth, present enormous challenges for certified nursing assistants (CNAs) responsible for daily oral care. These professionals often have insufficient knowledge, skill, time or appreciation of the importance of oral health.^{48,49} In addition, competing tasks and priorities influence the degree and quality of oral care provided.⁵⁰

Cognitive and behavioral problems are common among NH residents, and care-resistant or disruptive behaviors during personal care are reported by nursing staff to be the most difficult aspect of providing care.⁵¹ CNAs report that attempts to assist with oral care are often met with hostile and uncooperative behaviors, such as residents refusing to open their mouth, biting on toothbrushes, and hitting.⁴⁸⁻⁵⁰ Oral care can be an unpleasant experience for both the CNA and resident, and administering procedures that invoke fear or meets resistance may discourage CNAs from providing adequate care. The quality of care and care interactions during mouth care provided by CNAs has been recently described.¹⁵ Findings indicate that most residents who need assistance do not receive oral care. Residents are commonly resistant when oral care is provided, but behaviors seem to be related to how care is provided. Common approaches by CNAs administering oral hygiene care included wearing unclean gloves, inserting implements into the mouth without telling residents first, positioning residents supine or in other non-functional positions, and resorting to physical restraints. Time spent brushing teeth by CNAs assisting residents was observed to be an average of 16.2 seconds (range 10-22 seconds), which is inconsistent with clinical practice standards. For most residents, basic supplies (toothbrush, toothpaste, mouthwash or toothette) were lacking. Thus, direct-care providers need practical strategies and on-going organizational support to provide oral care in a humane and efficacious manner.

Knowledge and Perceptions of Nursing Home Staff

CNAs have limited formal knowledge^{52,53} or training in oral health care.⁴⁹ Similarly, only one-half hour of professional nursing curricula is devoted to geriatric oral health.⁵⁴ As a result, recognizing oral problems such as lesions or oral sequelae of chronic systemic conditions, appreciating the effects of medications on oral tissue,⁵⁵ and planning appropriate care is often overlooked.⁵⁵ Few registered nurses are confident in their ability to recognize signs of periodontal disease or lesions that might require referral for treatment.^{53,56} Mouth care practices

in nursing have remained relatively unchanged over the past 120 years.⁵⁷ Negative perceptions held by CNAs (who are responsible for most daily oral care) regarding mouth care are numerous, including expressions of fear and disgust, and descriptors including burdensome, unrewarding, problematic, unpleasant, repulsive and trivial.^{48,58-62} Furthermore, few physicians caring for NH residents view oral health as important,⁶³ and the accuracy of physicians' oral assessments has been reported to be unacceptably low, with a high incidence of inappropriate treatment and referral decisions.⁶⁴

Lack of staff, supervision and limited accountability also influence how well the oral care needs of residents in NHs will be met. Oral care is a care activity identified by CNAs as easily eliminated when staffing problems occur,⁶⁵ and NHs are rarely sanctioned for failing to provide such care.

Limitations of Current Regulatory Policy

There is evidence that oral health assessment and treatment needs of elderly residents are only partially met by currently mandated regulatory formulas in NHs. Federal regulations require that all long-term care facilities with Medicare and Medicaid reimbursement complete a comprehensive health assessment for each resident (known as the Minimum Data Set [MDS 2.0]), which includes oral health. Registered nurses are required to complete sections K and L of the MDS, which are comprised of only two queries pertaining directly to oral health. The goal is to indicate oral health problems and "triggers" requiring intervention and plan for care. Recent studies, however, suggest that use of the MDS to detect oral health concerns is limited, since nurses identify few oral health or hygiene problems via the MDS.⁶⁶⁻⁶⁸ Moreover, when the problems are identified, rarely does dental treatment occur. Consequently, the MDS, as currently structured for the oral health component, does not provide regulatory support for good clinical practice. The American Dental Association and Special Care Dentistry have asserted that the oral/dental content of the MDS reflects an incomplete appraisal of the oral health of individuals when used by NH staff, and recently recommended a revised version.⁶⁹ Although this recent recommendation is a step in the right direction relative to providing a more complete oral assessment, these authors recommend an additional revision which focuses on comprehensive periodontal evaluation.

Limitations in Financial Policy

Few NH residents can pay for dental care. On average, 67% of NH residents have their overall health care paid for through the Medicaid program, while 9% are covered by the federally funded health insurance program for older adults, Medicare, and 24% are covered by other payers or pay for care themselves.⁷⁰ Most elderly lack private dental insurance, and Medicare does not provide any dental benefits. Dental care under Medicaid is an optional benefit that varies state-by-state, and many states' Medicaid programs do not provide dental coverage for adults. In states with adult dental benefits, dental services vital for NH elderly are frequently not covered, and 27 states have failed to meet even the most minimal standards of care.⁷¹ Thus, older adults must pay for dental care as an out-of-pocket expense,⁷² at a time when their oral health needs are perhaps the greatest.

State Medicaid programs reimburse dentists for basic services at rates significantly below customary fees, resulting in low levels of dental provider participation in the program. In addition to low reimbursement levels, dentists often refuse to care for NH residents because of lack of geriatric training, interest, or adequate treatment facilities.⁷³ Recent research demonstrates that treatment of periodontal disease may decrease healthcare costs related to diabetes and CVD.⁷⁴ Accordingly, there is some marginal movement within the private insurance industry to cover costs associated with nonsurgical periodontal treatment in recognition of the fact that providing coverage for this type of care may lower future costs of providing care for chronic conditions such as diabetes and CVD.⁷⁵

If private insurers can demonstrate that treating periodontal disease equates to cost savings from future complications of chronic disease, perhaps the federal government may follow suit to cover the cost of treatment of periodontal disease in the NH setting.

Rationale for Moving to Transdisciplinary Collaboration

The current "unidisciplinary" approach to oral health care in NHs, wherein each individual performs his/her job within a formal scope of practice, is unsuccessful. Interventions improving delivery of oral care in NHs have met limited success. Prior approaches relied predominantly on oral health education programs (OHEPs) for CNAs.⁷⁶⁻⁸⁰ Historically, OHEP programs have been narrowly focused, usually containing content on the importance of oral health, oral diseases common among older adults, oral assessment and preventative oral care. Length of training varies from single, one hour sessions to sessions conducted over several weeks. The programs have produced some short-term gains in CNA knowledge and attitudes^{78,81} but show inconsistent evidence of health gain for the resident,^{77,80} and sustainability is problematic. A change in practice responsive to the needs of an aging population is now needed. Given the growth of the aging population, their dentate status, the impact of chronic medical conditions and treatments on oral health, and the suggested relationship of oral disease and general health, the "myth of the omnipotence of the independent practitioner" must be challenged, as evidence accumulates that collaboration works when health professionals function well as a team.^{82,83} However, before real collaboration can occur, healthcare providers must fully appreciate oral-systemic relationships. Specifically, members of the medical community must move beyond thinking of oral infection as pathology confined to the mouth without systemic consequence.

Interdisciplinary Collaboration Works: Impact on Patients and Clinicians

There are impressive outcomes from collaborative models of interdisciplinary care.⁸⁴⁻⁸⁶ Most of the focus on interdisciplinary collaborative care has been between a narrow range of health professionals, primarily nurses and physicians in hospital settings. Evidence indicates that the presence or absence of interdisciplinary collaborative care affects the work environment and quality of patient care. In an early study

physicians and nurses was associated with higher than expected death rates. Shortell and colleagues⁸⁷ found that poor communication between caregivers was associated with a shorter length of stay in the intensive care unit (ICU), lower nurse turnover, better quality of care, and greater ability to meet family member needs. Schmitt and colleagues⁸⁹ reviewed 11 studies conducted on the effectiveness of geriatric interprofessional teams and found that team care was more effective for the outcomes examined, including mortality, functional status, hospital use (e.g., length of stay and readmission), referrals and cost. In a recent study conducted in three proprietary NHs, Krichbaum and colleagues⁹⁰ showed that forming collaborative problem-solving teams between CNAs and advance practice nurses (APNs) improved the quality of care and resulted in significant improvement in resident outcomes, including decreased incidence of depression and incontinence.

Collaboration also results in greater personal and professional satisfaction and a healthier work environment.⁸⁵ Studies demonstrate significant associations between physician-nurse collaboration and nurse satisfaction, self-esteem, and staff perceptions of uncoordinated, unsafe care.⁸⁴ In short, there is ample evidence that collaborative practice is essential for good health care. Collaboration is a valuable “best practice” approach to improve the quality of oral health care in the NH setting.

Beyond Interdisciplinary Care: Moving to Transdisciplinary Collaboration

Nursing and dental hygiene do not share a tradition of collaborative practice. Their respective practices have not been integrated to any great degree, and both professions have worked in “splendid isolation”. But a potential for synergy between the two exists in the NH. First, in this setting, there is opportunity for interdisciplinary work in healthcare teams that have informal clinical and administrative structure. Second, as noted, there is an unmet need to promote oral health and prevent disease in a growing elderly population with multiple chronic diseases. Nurses must become advocates for good oral health and hygienists need to become more aware of disease management affecting oral health. Third, members of both professions share common goals in terms of scope of practice, conceptual approach to practice, and professional competencies. Nursing’s scope of practice focuses on the patient and family and consists of providing direct care, coordinating care, and collaborating with other health professionals; both prevention and treatment of disease are encompassed in this practice.⁹⁰ The practices of both nurses and dental hygienists are guided by standards by their respective professional organizations, and those standards delineate a well-accepted systematic approach to care, which includes assessment, diagnosis and planning, implementation and evaluation, with scope of practice for dental hygiene focusing on oral health promotion and disease prevention, facilitating self-care, treatment, and collaboration.⁹¹⁻⁹³ A recent analysis revealed major areas of overlap between dental core competencies and nurse practitioner competencies.⁹⁴

The authors contend that movement to a transdisciplinary perspective is vital to implement oral-systemic medicine because incorporation of this science into medical and nursing practice has been slow to evolve and limited to the “tooth level”. Moreover, we must apply this model because of the historic failure to value oral health⁹⁵ at both institutional and regulatory levels, a failure reflected by failure to nurture good clinical practice and establish regulatory oversight. A transdisciplinary model utilizes the disciplinary perspectives and the expertise of nurses, dental hygienists, and other members of the healthcare team. In such a practice model, members collaborate, build consensus, and institute regular and open communication across discipline boundaries in order to provide integrated services.⁹⁶ One distinction between an interdisciplinary and transdisciplinary approach is that in the latter, members of different disciplines are responsible for educating one another on the significance of a clinical problem or treatment. Thus, practice becomes a synthesis of knowledge and practice. Each contributor maintains the integrity of self, but the learning and plan of care is “owned” by all. There is no turf, because the goal of quality care transcends it.⁸⁵ This framework will provide a foundation for a best practice approach to the delivery of excellent geriatric oral health care.

The single instance in the literature of transdisciplinary collaboration between nursing and dental hygienists was reported by Pelligrini and colleagues⁹⁷ and related to joint care of patients admitted to an ICU. Traditionally, the ICU has not been an arena for maintenance of oral health or a place where dental hygienists work with nurses. In fact, the clinical relevance of the observations and the hygienists’ unique perspective to patient management were incidental to the planned study, although the nature of the collaboration was critical to staff and patient outcomes. Pelligrini and colleagues described a joint project in which nurses working with dental hygienists learned to conduct oral health assessments for mechanically ventilated ICU patients. Nurses were trained by hygienists to assess the oral status of ICU patients (including components such as dental plaque, inflammation, salivary flow, bleeding, caries, and candidiasis), and the dental hygienist was able to envision a unique role, bringing clinical expertise to research and clinical practice. This study showed that trans-collaborative interactions with dental hygienists improve nurses’ knowledge and abilities related to oral care.

Unleashing the Potential of Nurse-Dental Hygienist Transdisciplinary Care within Nursing Home Facilities

A transdisciplinary collaborative care management model is shown in Figure 2. This model provides a collaborative practice arrangement between Nurse Practitioners (NPs) and Advanced Dental Hygiene Practitioners (ADHPs), a professional role that is currently being developed by the American Dental Hygienists’ Association. The ADHP has garnered federal support with legislation signed by the President that includes language encouraging the Health Resources and Services Administration (HRSA) to explore creation of the ADHP to improve access to oral health care services.⁹⁸

The model is grounded conceptually in commonalities between both professions in the scope of and approach to practice (i.e., assessment, diagnosis, planning, implementation and evaluation). The model sees NPs and ADHPs with geriatric expertise as collaborators in revising the MDS to 1) provide a more comprehensive evaluation, 2) conduct joint screening and diagnostic procedures, and 3) develop care plans addressing short- and long-term care needs, taking into consideration pharmacologic, nutritional, neurologic and physiologic co-factors with oral health needs.

The salient features of the model include integrated evaluation and transdisciplinary interventions. Residents admitted to a NH would be

assessed by both NPs and ADHPs. Based on history and physical examination findings, diagnoses would be generated consistent with each professional's scope of practice. The goal of collaboration at this juncture would be to evaluate the necessity and risk of therapeutic intervention, including the nature and severity of co-morbidities, the cognitive/emotional state of the resident, advance directives, and invasiveness of proposed treatment.⁹⁹ Individualized prevention and treatment care plans would be co-developed utilizing each profession's expertise. Three broad-based joint treatment plans are envisioned: a chronic disease management plan, an episodic care plan and a palliative care plan. A chronic disease management plan is consistent with the level of chronic disease burden of NH residents, and would be suited for most residents. Some frail individuals may not be appropriate for this level of intervention and would be more suited to a palliative plan of care. Consistent with real-world practice, residents could "cycle" from one care plan to the next, so the model must remain dynamic and not be rigidly applied. Similarly, residents may develop acute conditions requiring appropriate triage to a medical or dental provider for definitive treatment, returning to their baseline treatment trajectory. Interventions requiring transdisciplinary care would include education and support of staff responsible for daily oral care, consultation regarding behavioral problems that interfere with routine care, performance of periodic screenings to measure residents' oral health needs, coordination of dental services with area dentists, development of policy to comply with regulatory requirements, and monitoring of clinical outcomes.

In addition, the NP and ADHP could collaborate on grantsmanship opportunities to secure funding to restructure the NH setting so that on-site oral health care is viable. For example, an oral health center providing a dental operatory within the NH could be established enabling visiting dentists to provide therapeutic care to clients. Educational experiences could be coordinated among local dental, dental hygiene, dental assisting and nursing schools so that students are provided greater experiences in geriatric centers. Further, registered dental hygienists (RDHs) could be hired as staff members of NH facilities to provide routine oral health care to the residents and administer preventive and therapeutic dental hygiene care as established in the care plans. RDHs would be ideal for this role as they have the skills and knowledge both to provide these services and oversee CNAs in providing daily oral health care to residents. It is conceivable that one RDH could be assigned to 50 beds, ensuring that clients receive oral health care twice daily. RDHs would be supervised by ADHPs.

In addition, this model provides opportunities for research to evaluate its merits. Research questions to be addressed might include: To what extent has access to collaborative care management been improved using the transdisciplinary model for NH residents? Has the transdisciplinary model improved the quality of life for NH residents and, if so, how? Has the oral health of NH residents changed using the transdisciplinary model of practice? Has the nutrition status and diet of NH residents changed since the transdisciplinary model of practice has been implemented? To what extent has insurance coverage for oral health care changed since the transdisciplinary model has been implemented in NH settings? How has the transdisciplinary model affected the professional status and prestige of nurses and dental hygienists?

Conclusion

Can HRQL, promoted through comprehensive chronic disease management addressing oral health as a key component, become a real world standard? Some would argue that given the size of the aging population and the competition for shrinking resources for the delivery of geriatric care, this model of care is a "pie in the sky" notion best reserved for ivory tower discussions. However, with the flood of baby boomers entering nursing homes, public opinion may begin to favor implementation of comprehensive chronic disease management strategies for the elderly. Nowhere could this model of care provide greater relief than in the 18,000 nursing homes across the US. Because of their profound dependency, elderly residents in a NH setting constitute a special population requiring the attention and consideration of society and governmental policymakers.

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Maintaining Oral Health in the Aging Population: The Importance of the Periodontal-Systemic Connection in the Elderly

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Introduction

The number of elderly Americans surpassed 35 million in 2000, and by 2030 twenty percent of Americans will be 65 or older.¹ Rapid growth of this population will dramatically impact dentistry, since in this era, increased numbers of older adults retain their teeth.^{2,3} Additionally, ethnic/cultural minorities account for a larger percentage of the elderly population, and individuals aged 85 and older are the fastest growing segment of the elderly population.¹ Thus, the diversity and number of frail/functionally-dependent elderly persons requiring care in nontraditional or institutionalized settings is increasing. The landmark 2000 report on oral health by the US Surgeon General documented profound disparities in the oral health status of older Americans.⁴ Over 25% of people aged 65-74 have severe periodontal disease, and at any given time 5% of Americans aged 65 and older (currently approximately 1.7 million people) live in a long-term care facility where dental care is inadequate. In 2003, Oral Health America released its national grading report emphasizing that the oral health of older Americans is in a "state of decay".⁵ Every state received failing or near failing grades in all categories of dental services for older adults, especially preventive and periodontal care.^{6,7}

Adequate numbers of properly trained dental professionals are needed to ensure quality oral health care for older adults. These professionals must play a greater collaborative role with healthcare management teams as the community practice environment moves to a transdisciplinary care model.² For the dental profession to participate in this dynamic practice environment, practitioners must be prepared to address specific geriatric issues related to access, risk assessment, prevention, cultural diversity, confounding medical conditions, and psychosocial influences, in addition to primary dental care.^{8,9} Access is particularly important as low-income, minority, and institutionalized/homebound elderly are at high risk for oral disease but are the least likely to receive services.¹⁰ A recent study by the Centers for Disease Control (CDC) reported that only 15% of these elderly had satisfactory oral health.¹¹

The current state of geriatric dental expertise in the US is woefully inadequate.^{8,12,13} Clinicians competent in geriatric issues are not being trained in numbers sufficient enough to meet projected workforce needs.¹⁰ A recent report by the Institute of Medicine (IOM) criticized the lack of geriatric dental expertise, stating that "linkages between dentistry and medicine are insufficient to prepare practitioners for patients with complex medical problems".¹⁴ Additionally, it noted that "the traditional isolation of dentistry from the rest of the healthcare team has been detrimental to the profession".¹⁴ Transdisciplinary practice is a vital component of geriatric dental expertise because it exposes dental professionals to contributions of other health disciplines and fosters communication.^{8,10} Other healthcare professionals must also develop appreciation for the abilities of dental personnel to manage oral health needs of the elderly. Such a transdisciplinary team management approach improves the prognosis of the elderly. In fact, studies demonstrate that elderly individuals whose comprehensive management includes dental care develop fewer co-morbid conditions and require less expenditure of healthcare dollars.¹⁰

The transdisciplinary concept has long been supported by the Health Resource Services Administration - Bureau of Health Professions (HRSA-BHPr), as noted in their white papers for health professions education.¹⁵ Yet, inclusion of other healthcare disciplines in geriatric dental practice or oral health education for non-dental health professions is inadequate and lacks uniformity.^{10,15} Dental professionals must be able to provide education and training for other healthcare practitioners and caregivers regarding 1) the relationship of oral health to general health, 2) the importance of daily oral care, 3) the means to provide basic oral care, and 4) the referral to a dental professional when necessary.^{8,11,12}

Achieving an optimal level of transdisciplinary practice required for the elderly requires cooperation of like-minded healthcare professionals in community-based study clubs emphasizing transdisciplinary approaches. Involving dental professionals with these groups would provide comprehensive exposure to attitudes and skills required to provide dental care to older adults. As patients become disabled or experience cognitive dysfunction, dental teams will also need to address ethical issues relevant to dental diagnosis, treatment planning, and how care is provided.^{8,11,12} In geriatric treatment planning, the focus should be on identifying an optimal level of care for the patient (ranging from none to very extensive). In other words, optimal care should not by definition be highest level technically possible. Rather, it should be to establish a level of care appropriate to maintain oral and general health. Other issues that should be considered within this framework are alternative treatment procedures or techniques, expanding the oral care team to include other health professionals or paraprofessionals, and the potential interactions of oral disease with systemic conditions in the elderly.

The field of geriatric practice will evolve as research is applied to patient care. Thus, dental professionals need lifelong education in using health technology/informatics resources to update their skills.^{16,17} Currently dental professionals need to be better acquainted with diagnosis/management of complex transdisciplinary cases and function more like oral physicians.¹⁸ The shift toward prevention-oriented models must continue so that the traditional "repair" approach to dental care is transformed to one of early diagnosis and prevention. For the elderly population, professionals must familiarize themselves with evidence-based decision making and understand transdisciplinary management of complex cases in addition to acquiring expertise in restorative procedures and fabrication of dental appliances.^{8,12,18} The most accessible and comprehensive transdisciplinary Web-based resource providing guidelines relevant to oral health in the elderly is currently available through the Wisconsin Geriatric Education Center and Marquette University School of Dentistry.¹⁹

Importance of the Periodontal-Systemic Connection in the Elderly

Recently the concept of a periodontal-systemic connection linking periodontal disease to systemic effects has emerged.²⁰ The implications of this connection, however, for the aging population have not been considered in depth.²¹ In terms of public health impact, there is no doubt that poor oral health negatively impacts general health, particularly in the elderly.²² Most chronic inflammatory diseases and conditions, including periodontal disease, are cumulative and thus manifested later in life. Decades of oral neglect contribute to additional health problems in the elderly population, which already consumes the majority of healthcare dollars nationwide, an outcome that places a significant burden on the healthcare system.^{10,11} Given that periodontal disease has already been linked to development or exacerbation of systemic disease, maintaining optimal periodontal health in midlife may do more to reduce healthcare expenditures in one's remaining lifespan than any other public health measure. Thus, optimal oral health cannot be reserved only for those who can afford basic care, but it must be a national priority to improve the overall health of all citizens.²²

Physiological/Biochemical Linkage of Periodontal and Systemic Diseases

Many chronic inflammatory conditions share some common physiological and biochemical elements with periodontal disease (periodontitis).²³ Periodontitis is more than a localized oral infection. Recent data indicate that periodontitis may initiate changes in systemic physiology and biochemistry that alter immune function, serum cytokine/lipid levels, and tissue homeostasis.²³⁻²⁵

Periodontal Disease, Diabetes, and Insulin Resistance

The interrelationship of periodontitis and diabetes is the most obvious example of a systemic disease predisposing one to oral infection, and once that infection is established, it may in turn exacerbate the disease.²⁵⁻²⁷ However, in this case, an oral infection might also predispose otherwise healthy patients to systemic disease.²³⁻²⁵ Common cellular/molecular mechanisms underlie the reciprocity of diabetes and periodontitis and likely synergize when the conditions coexist. The proposed mechanistic link involves the broad axis of inflammation and includes activities of immune cells (polymorphonuclear leukocytes, monocytes, macrophages), serum lipid levels (low density lipoprotein cholesterol and triglycerides (LDL/TRG)), and tissue homeostasis.²³⁻³⁰

As a result of metabolic and enzymatic deficiencies, diabetic patients are prone to elevated serum LDL/TRG, even when blood glucose levels are controlled.³¹⁻³⁴ Elevated lipid levels alter immune cell function, producing an inflammatory immune cell phenotype (upregulation of pro-inflammatory cytokines from monocytes/polymorphonuclear leukocytes and downregulation of growth factors secreted from macrophages).^{28-30,35-38} This occurrence predisposes an individual to chronic inflammation and progressive tissue breakdown and diminishes tissue repair capacity. Periodontal tissues are frequently affected because they are constantly wounded by substances emanating from bacterial biofilms. Thus much clinical and epidemiological evidence supports the idea that individuals with diabetes (both type I and type II) show higher incidence of severe or rapidly progressing forms of periodontitis than non-diabetics.³⁹⁻⁴⁵

Periodontitis-induced bacteremia/endotoxemia also elevates levels of serum pro-inflammatory cytokines such as interleukin-1 beta (IL-1 β) and tumor necrosis factor-alpha (TNF- α).⁴⁶⁻⁴⁸ The activities of both cytokines alters lipid metabolism and leads to hyperlipidemia similar to that observed in diabetes. Additionally, these factors can produce an insulin resistance syndrome similar to that observed in pre-diabetes and may initiate destruction of pancreatic β -cells, leading to diabetes. Elevated IL-1 β levels play a role in the development of type I diabetes through destruction of pancreatic β -cells.⁴⁹⁻⁵² TNF- α has also been implicated as a causative factor in insulin resistance and type II diabetes, as elevated TNF- α levels alter intracellular signaling stimulated by insulin, reduce synthesis of the insulin-responsive glucose transporter, and mediate macrophage-dependent cytotoxicity in pancreatic islets.⁵³⁻⁵⁷ Infection-induced insulin resistance syndromes, if long-standing or chronic, are precursors of active diabetes because of the pancreatic β -cell destruction resulting from sustained elevation in IL-1 β /TNF- α .^{51,53,57} In fact, a pro-inflammatory imbalance created by excess IL-1 β /TNF- α may be one of the most critical determinants of β -cell loss in diabetes.⁵⁸ Thus, periodontitis may potentially exacerbate conditions associated with diabetes.

Recent clinical studies provide strong support for such a hypothesis, particularly with regard to insulin resistance.⁵⁹ The degree of insulin resistance has been shown to be directly related to the severity of periodontitis⁶⁰, and some investigators have demonstrated a relationship between pre-diabetes and periodontitis in non-diabetic patients.⁶¹ Such reciprocity is further illustrated by recent studies demonstrating the effect of either periodontal disease or successful treatment of such disease on diabetes-induced hyperglycemia.⁶²⁻⁶⁴ Periodontal treatment actually improved glycemic status, especially in type II diabetes, where controlled trials have shown improvement of glycemic control after periodontal therapy.⁶⁵ In another study, effective treatment of periodontal infection and reduction of periodontal inflammation were associated with lower levels of glycated hemoglobin.⁶⁶ Thus, chronic untreated periodontitis may induce diabetes.

Periodontal Disease and Atherosclerosis-induced Diseases

Investigators have hypothesized that periodontitis-induced elevations of IL-1 β and TNF- α and subsequent elevation of serum LDL/TRG levels trigger development of other systemic conditions that disproportionately affect the elderly, particularly cardiovascular disease (CVD), cerebrovascular disease (CBVD), rheumatoid arthritis (RA), and dementia.^{23,24,67-71} In fact, recent studies suggest that in advanced periodontitis, serum levels of IL-1 β , TNF- α , and other inflammatory mediators/biomarkers are sufficiently elevated to be considered a significant systemic health risk, even in the absence of overt clinical symptoms of disease.^{46,72,73} Even at low levels, these cytokines can initiate significant systemic responses, including inflammatory tissue and organ damage. Interestingly, chronic periodontitis is one of the strongest and most reliable elevators of serum pro-inflammatory cytokine/lipid levels, and treatment of periodontitis has been shown to significantly reduce serum levels of these factors.^{23-27,48,67,74,75}

The impact of periodontal disease on CVD and CBVD is closely tied to mechanisms underlying initiation and progression of atherosclerosis. This effect involves a combination of a systemic inflammatory state and dysregulation of lipid metabolism plus direct interaction of periodontal pathogens with vascular walls. Increasing evidence confirms that periodontitis facilitates atheroma formation.⁶⁷ The contribution of systemic inflammation and elevated serum LDL/TRG to atherosclerosis has been thoroughly described.⁷⁶ Periodontitis-induced elevation of serum pro-inflammatory cytokines, inflammatory biomarkers, and serum LDL/TRG has also been well documented.^{23-27,67,72-74,77-81} Other studies demonstrate that periodontal pathogens interact with vascular endothelial cells (either directly or through inflammatory responses to antibodies directed against periodontal pathogens) and colonize developing atheromas, contributing to thickening of arterial walls and atheroma formation.^{67,82-89} Thus, there is likely more than a casual relationship between periodontitis and pathogenic mechanisms underlying atherosclerosis. In the presence of systemic periodontal pathogens and antibody-mediated reactions to those pathogens, periodontitis-induced elevated serum LDL/TRG and pro-inflammatory cytokines may damage vascular endothelial cells, leading to recruitment of macrophages or foam cell formation and development of atheromatous plaques.

Periodontal Disease and Rheumatoid Arthritis

Periodontitis and RA share common pathogenic mechanisms and immunological/pathological outcomes. Patients with severe periodontitis or RA exhibit similar blood cytokine profiles distinct from disease-free individuals.⁶⁸ Recent evidence suggests a strong correlation between the extent and severity of periodontal disease and RA. Individuals with advanced RA will likely experience more significant periodontal problems than normal individuals and vice-versa.⁶⁹ Thus these conditions could be closely related through the systemic inflammatory state previously described, as accumulating evidence supports the notion that elevated pro-inflammatory cytokines and reduced tissue repair capacity are manifested in both conditions.⁶⁹ Additionally, some periodontal pathogens expressing the enzyme peptidylarginine deaminase (PAD) may generate antigens capable of stimulating production of rheumatoid factor-containing immune complexes and initiating inflammation in the synovium.⁹⁰ Of the pathologies previously described, evidence for this relationship is preliminary. Nonetheless, the immediate clinical lesson is that the periodontal status of patients with RA should be carefully monitored.

Periodontal Disease and Neurodegenerative Diseases

The inflammatory hypothesis of neurodegenerative diseases such as Alzheimer's and Parkinson's (the most common neurodegenerative disorders leading to dementia in the elderly) has moved from medical speculation to mainstream thinking.^{70,71} Brain mononuclear phagocytes, particularly microglia (brain resident macrophages), protect the nervous system by acting as debris scavengers, killers of microbial pathogens, and regulators of immune responses. Microglia are activated by numerous environmental stimuli including pro-inflammatory cytokines and bacterial lipopolysaccharides, initiating a cascade of neuroinflammatory events.⁷⁰ Systemic inflammation is associated with signals transferred from blood to brain via perivascular macrophages and microglia.⁹¹ Resultant neuroinflammatory responses include secretion of neurotoxic factors mediating neuronal cell injury and death. Over time a slow, smoldering inflammation in the brain may destroy sufficient neurons to cause clinical manifestations of Alzheimer's or Parkinson's dementia. Indeed, a recent population-based prospective cohort study showed that serum C-reactive protein and pro-inflammatory cytokine levels are increased prior to the clinical onset of dementia.⁹² These interactions suggest that systemic infections, or indeed any challenge promoting a systemic inflammatory response, may contribute to the progression of chronic neurodegenerative disease and provide a potential link between early periodontitis-induced bacteremia/endotoxemia and subsequent neuronal injury.

Memory can be impacted by insulin activity. Insulin resistance is associated with age-related memory impairment and Alzheimer's disease.⁹³ Thus, the previously described periodontitis-induced insulin resistance may contribute to pathologic mechanisms underlying neurodegeneration, as might the described links between periodontitis and vascular disease. Increasing evidence indicates that several pathogenic mechanisms promoting atherosclerosis also function in neurodegenerative diseases.⁹⁴ Vascular disease and Alzheimer's disease share some biological mechanisms and risk factors, such as lipid metabolism dysregulation and systemic inflammation. Although the evidence for such a relationship is preliminary, atherosclerosis may be another important mechanistic link between periodontitis and neurodegeneration affecting the elderly.

Periodontal Disease and Respiratory Diseases

Periodontal disease may be connected more directly to respiratory disease. Although some studies of chronic obstructive pulmonary disease describe significant associations with periodontal disease and propose systemic mechanisms relating to inflammation and/or physiologic linkages, this data requires further support.⁹⁵⁻⁹⁸ A stronger case has been made that bacterial components of dental plaque are a major cause of respiratory infections in older adults, especially those in institutions.⁹⁹⁻¹⁰² Up to 48% of infections seen in nursing homes result from

aspiration pneumonia, and the cost to treat patients developing pneumonia in these institutions has increased dramatically.⁹⁹ Aspiration pneumonia is a significant cause of morbidity, hospitalization, and mortality in the nursing home population.¹⁰⁰

When host defense mechanisms are compromised because of disease, aging, poor nutrition, or other conditions associated with elderly patients in nursing homes, the aspiration of a large pathogenic inoculum from periodontally involved teeth overwhelms normal flora and significantly increases the risk of respiratory infection.¹⁰³ Bacteria constitute approximately 70% to 80% of solid plaque material and 1 mm³ of plaque contains more than 106 bacteria of 300 different aerobic and anaerobic species.⁹⁹ Aspiration of plaque bacteria by older patients often leads to lower respiratory tract infections, such as aspiration pneumonia or pneumonitis, and recent evidence links anaerobic bacteria from periodontopathic biofilms with aspiration pneumonia in elderly persons.^{103,104} Thus, poor periodontal health and accumulation of dental plaque is a major contributory factor in respiratory infections.^{99,100,105} Furthermore, addressing periodontal health in nursing home patients is critical not only because older adults are now more likely to retain their teeth but because younger persons are being admitted to such facilities.^{101,102}

Effect of Aging on the Periodontal-Systemic Connection

Age may also predispose individuals to the periodontal-systemic connection. It is well known that the incidence of periodontitis and the severity of untreated periodontal disease increase with age.¹⁰⁶⁻¹⁰⁸ Secretion of pro-inflammatory cytokines from monocytes/macrophages and levels of soluble TNF- α receptor normally increase with age.^{109,110} Thus, further increases in serum cytokines induced by periodontitis would not only be cumulative but could create a more destructive scenario through enhanced receptor interactions. Serum lipid levels also increase with age, particularly LDL.^{111,112} Similar to the pro-inflammatory cytokines, periodontitis-induced LDL/TRG elevation could be more damaging in this context and further increase pathological lipid levels.

Aging is associated with increased insulin resistance.^{113,114} Likewise, the incidence and severity of diabetes also increases with age.^{115,116} These conditions may result from loss of an individual's capacity to respond to environmental challenges.¹¹⁵ Some investigators attribute this association to an imbalance of important intracellular divalent cations such as calcium and magnesium that make cells vulnerable to ionic disturbances.¹¹⁶ Many other systemic diseases/conditions associated with chronic inflammation also demonstrate increased incidence and severity with advancing age.^{117,118} The specific mechanisms by which advanced age promotes chronic inflammation are not yet understood. Nonetheless, age-related increases in pro-inflammatory cytokine/cytokine receptor expression and oxidative stress, along with decreased bioavailability of free radical scavenging systems, likely exacerbate the systemic inflammatory state in the elderly and promote development of chronic inflammatory diseases.^{118,119}

Thus, with advancing age, factors mediating the periodontal-systemic connection are positioned to act synergistically, putting even healthy patients at risk to develop periodontitis. An overview of the link between periodontitis and systemic diseases/conditions predominantly affecting the elderly is shown in Figure 1 (previous page). Of perhaps greater significance relative to morbidity/mortality, elderly patients with chronic periodontitis also may be at risk for developing any systemic disease or condition associated with elevated pro-inflammatory cytokines/serum lipids. Future clinical studies are required to validate this premise.

Masticatory Function and Nutrition in Older Adults

Although recent discussions of the periodontal-systemic connection have focused on systemic diseases/conditions, there is significant evidence associating dietary imbalance with systemic illnesses. Oral health significantly influences dietary intake, particularly aspects of oral health related to masticatory function and edentulism.¹²²⁻¹²⁹

Mastication is the first step in digestion and is absolutely essential to optimize dietary intake. Masticatory function in older individuals is influenced by two variables: the number and health of natural teeth and the functional status of dental prostheses. Older people tend to have fewer natural teeth and there are higher rates of edentulism with increasing age. That pattern is, however, changing with a projected reduction in edentulism over the next 20 years.^{2,3} Nevertheless, many older people rely on dentures for oral function, and even those who are dentate may require either partial dentures or a full denture in one jaw opposed by some natural teeth. Masticatory function in this group is often not much better than that seen in individuals who rely on full dentures.^{124,127} Additionally, over 25% of those aged 65-74 have severe periodontal disease likely accompanied by varying levels of pain or dysfunction.⁴ Compromised masticatory function causes variation in food choice to foods that an individual with impaired chewing can tolerate.¹²²⁻¹²⁹ Thus, poor oral health, especially poor periodontal health and edentulism, may negatively impact systemic health by disturbing nutritional intake.

Tooth loss is correlated with changes in diet that may contribute to increased risk of developing chronic diseases.¹² Losing natural teeth and/or pain associated with oral infection impairs masticatory function.¹²⁴ This outcome is particularly relevant to people residing in institutional settings where mastication may not be monitored. Furthermore, the use of dental prostheses may not always restore full masticatory function, resulting in significant dietary changes through altered food choices or food preparation methods.¹²³ Indeed, denture wearers are often not aware of gradual adjustments made in food choice. As masticatory efficiency declines, people report increasing difficulty chewing foods and may choose not to eat foods difficult to chew, such as beef or steak, raw vegetables, or dry solid food like crusty bread. People handicapped by their dentition consequently suffer impaired intake of fruits, vegetables, and some key nutrients. Decreased intake of total calories, proteins, non-starch polysaccharides (dietary fiber) and vitamins is often accompanied by increased consumption of sugars and fats. These dietary links are supported by evidence by several large cross-sectional and longitudinal studies in Europe and the US linking oral health status to biochemical analyte levels of key micronutrients.¹³⁰ These studies (the National Diet and Nutrition Surveys in the UK and the National Health and Nutrition Examination Surveys in the US) cited significant reductions in some micronutrients (vitamin C, retinol, folate and β carotene) in

edentulous subjects with those with natural teeth. The outcomes were independent of effects of age, gender, regional variation within a country and socioeconomic group.

The negative impact of masticatory dysfunction is likely compounded by food preparation. Fresh foods can be over-prepared (by removing skin from fruits and vegetables) or over-cooked by or for a person with reduced chewing efficiency and nutrients are consequently lost. Those nutrients might prevent or antagonize disease and facilitate cellular defenses and combat aging (anti-oxidant vitamins C and E).^{131,132} Reduction in dietary fiber (non-starch polysaccharides or dietary fiber) and in fruit and vegetable consumption is associated with increased risk of CVD and certain cancers (breast, prostate, cervical, pancreatic, gastric and colorectal), most likely because of the lipid-lowering capabilities of soluble fiber and the beneficial effects of anti-oxidants in fruits and vegetables.¹³¹⁻¹³⁹ Many dietary components that form an essential part of the cellular defenses against oxidative damage to DNA may be lost because of over-cooked meals. They include the trace elements selenium, zinc and manganese, vitamins A, C and E and other plant-derived micronutrients (β carotene, luteine, lycopene and plant flavenoids).^{131,132} The role of these factors in maintaining homeostasis is becoming increasingly apparent. Links have been demonstrated between deficiencies of these micronutrients, tissue breakdown, and cardio-vascular disease and stroke in the elderly.¹³⁵⁻¹³⁸

Recent studies confirm a direct relationship between compromised masticatory function and malnutrition in both community-dwelling and institutionalized older adults.¹²⁵⁻¹²⁹ Elderly people with persistent untreated periodontal disease and/or dysfunctional prostheses had lower Healthy Eating Index (HEI) scores and significantly lower intake of vitamins A and B6.¹²⁵ Poor nutritional status demonstrated by the Mini Nutritional Assessment (MNA) and a questionnaire on eating problems was significantly associated with periodontal problems, edentulism, and dysfunctional prostheses.¹²⁶ These findings emphasize the importance of tools such as the MNA or HEI to assess nutrition along with dental evaluation for oral problems in a comprehensive care plan. Poorly fitting prostheses or chronic periodontitis as well as the potential for associated lesions and pain are of concern for individuals suffering from dementia or conditions that prevent them from articulating the cause for difficulty in chewing food.¹⁴⁰⁻¹⁴³ Often, institutionalized elderly patients undergo rapid weight loss after being fitted for new dentures that are not monitored for comfort and functional efficiency.^{141,142} Most often, poorly fitting dentures can be confirmed through the presence of lesions at the borders of the prostheses such as tissue overgrowth (epulis fissuratum) or ulcerations (denture ulcers).

Restoration of masticatory function by dental intervention alone will not necessarily lead to improved nutritional intake. Dental services should always be complemented by nutritional counsel, as has been confirmed in a recent clinical study where impaired chewing ability caused avoidance of hard and fibrous foods including fruits, vegetables and whole grains leading to a very low intake of non-starch polysaccharides and micronutrients.¹²³ In this case, provision of prostheses did not improve the diet. However, individualized dietary advice provided at the time of denture insertion resulted in increased consumption of fruits and vegetables and improved intake of non-starch polysaccharides. It is important to note that an individual's ability to respond to nutritional advice will be moderated by their oral health status. For example, an edentulous patient who has had a stroke resulting in paresis of the facial musculature will have considerable difficulty chewing foods because their ability to stabilize a complete denture during function will be impaired. The dental professional will need to work with the comprehensive care team to encourage a diverse and healthy dietary pattern. This could be accomplished in part while the patient receives instructions for use of complete dentures by challenging the patient to explore new foods and chewing methods. Dietary support and advice should always be given to patients being converted to edentulism for the first time, since using complete dentures as a masticatory tool is a challenge that will often be met by the blender unless positive support and advice is forthcoming from the dental team. It is widely recognized that a significant proportion of elderly people admitted to hospitals suffer from nutritional deficiencies and that adequate nutrient intake is an important determinant of recovery from illness.¹⁴⁴⁻¹⁴⁷ Specific plans for nutritional support may be required for edentulous subjects during such recovery, and professional dental help may be required to help such patients cope with poorly fitting dentures.

Two case studies shown below, (Figures 2 and 3), provide strong support for the importance of maintaining oral and periodontal health in aging patients.

Relevant Medical and Social History:

- 80-year-old male, suffered a severe stroke affecting the right side of his body resulting in dense right-sided hemiparesis of the arm and leg with facial paresis and impaired speech (he is able to swallow)
- History of hypertension with arrhythmia and adult onset (type II) diabetes mellitus
- Approximately 6 months after the stroke, hypertension and diabetes worsened and are now difficult to control
- Smokes 20 cigarettes per day and imbibes the equivalent of 20 alcoholic drinks each week
- Fiercely independent widower living alone with pets
- Children live 150 miles away and cannot provide consistent monitoring and care

Relevant Dental History:

- Has not seen a dentist for over 20 years
- Had no complaints prior to the stroke but grandchildren commented about his missing front teeth
- Reports being able to chew all varieties of food prior to his stroke, but his daughter reveals that his diet is limited in terms of variety since the stroke and that he often cooks his food very thoroughly to facilitate chewing

Clinical Findings/Problems:

- Functional contacts between only 2 pairs of natural teeth (he can no longer manipulate a food bolus with his tongue so that it can be chewed by these contacts)
- Poor oral hygiene as a consequence of the hemiparesis

- Mandibular cervical caries, severe wear and pulpal exposure of maxillary molars
- Collapsed vertical dimension of occlusion
- Has never worn a prosthesis
- Altered neuromuscular control and coordination as a consequence of the stroke

Treatment Considerations:

- Severely compromised masticatory function from dental neglect and stroke
- Had been able to function prior to the stroke because he could manipulate foods between his remaining tooth contacts
- Since the stroke, has no control over a food bolus because of loss of tongue function and has changed his diet and modified food preparation to facilitate chewing
- Recent exacerbation of existing systemic disease may be because of nutritional imbalances caused by changes in diet and food preparation
- Without masticatory rehabilitation, he can no longer function independently

Treatment Options:

- Provide basic periodontal care, restore mandibular carious lesions, perform endodontics and restorations for maxillary molars, modify diet to processed food combinations that are nutritionally balanced; the latter would require supervision by caregivers or personal care workers
- In addition to dental services listed, provide dentures to increase functional contacts and maximize masticatory efficiency (a significant challenge for this patient to learn to tolerate and use) along with nutritional counseling

Treatment Provided:

- Phase I periodontal therapy
- Restoration of mandibular cervical caries using a glass ionomer
- Single visit endodontics for maxillary molars
- Restoration of maxillary molars using composite resin
- Acrylic maxillary partial denture using zest anchors and increasing the vertical dimension
- Personalized oral hygiene plan for this patient including use of a daily fluoride mouth rinse and application of fluoride varnish to the overdenture abutment on a weekly basis
- Nutritional counseling in consultation with family physician and children for occasional monitoring and reinforcement

Follow-Up:

This treatment approach gave this patient a reasonably stable upper denture that improved his appearance and masticatory function. In most cases, use of maxillary zest anchors would not have been contemplated given his poor oral hygiene; however, it was more important to ensure adequate retention for the removable partial denture. The oral hygiene program was successful in maintaining the zest anchors. This patient adjusted to the denture and was compliant with nutritional advice. His systemic health significantly improved within six months of denture insertion. This patient survived another 10 years before dying from a second stroke.

Relevant Medical and Social History:

- 82-year-old widow, living in a nursing home for the past six years
- Prior to admission, history of RA since age 60 with little change in condition
- Approximately six months after admission, she began to experience states of confusion and, after two years, a primary diagnosis of Alzheimer's-type dementia was recorded (currently being treated with amitriptyline)
- During the past three years, she has suffered from re-peated occurrences of lobar pneumonia that did not respond well to antimicrobial therapy and were slow to resolve
- During the past two years, there has been significant progression of the arthritis with marked deformity of the right wrist and fingers
- During the past year, has had significant weight loss of unknown origin

Relevant Dental History:

- Had seen her general dentist regularly for many years but had not had any dental examination or dental care since entering the nursing home (the facility did not have an oral healthcare policy and most residents were edentulous with the exception of this patient)
- Previous dental records indicated that she had 20 natural teeth remaining when she was last seen by her general dentist; half of her teeth had been restored but the periodontal condition was good and there was no evidence of active caries
- Had not brushed her teeth since the day of her admission to the nursing home and the facility staff were not aware she had her own teeth rather than dentures
- After six years in residence, she was referred for a dental consult by one of the visiting medical staff who was concerned that she might have a problem with her teeth?

Clinical Findings/Problems:

- Facility had a free access kitchen area providing drinks and readily available snacks, such as bread and jelly
- This patient had a habit of getting cups of tea/coffee for other residents throughout the day and making a drink for herself each time using 2 teaspoons of sugar (estimated frequency of sugar intake was 16-18 sugar-laden drinks per day); the cariogenic effect of the sugar was compounded by the xerostomic effects of amitryp-tiline
- Rampant cervical caries involving all teeth in maxillary and mandibular arches (the mandibular central and lateral incisors were amputated below the crown)
- Poor oral hygiene and severe generalized periodontal disease

Treatment Considerations:

- Progression of dementia and arthritis along with frequent pneumonia appear temporally related to cessation of oral hygiene and development of rampant caries/periodontal disease
- Weight loss may be related to oral pain and discomfort and/or decreased masticatory function associated with decline of oral health and subsequent nutritional imbalance
- Treatment may need to be limited as a consequence of the extent of her oral disease, caries risk, and ability to tolerate dental procedures

Treatment Options:

- Removal of all remaining teeth and provision of immediate dentures
- Removal of grossly carious roots followed by transitional partial dentures planning for a phased movement to total edentulousness over the next 12-18 months
- Rigorous prevention program to overcome problems with xerostomia/caries and the addition of a partial denture (includes regular use of fluoride rinse, education of facility caregivers in appropriate oral hygiene techniques and the use of a mechanical brush)

Treatment Provided:

- Mandibular lateral and central incisor roots were extracted
- Phase I periodontal therapy
- Carious lesions were restored using chemo-mechanical caries removal with Aldarai followed by restoration using glass ionomer cement
- Nutritional counseling for facility caregivers
- Prevention program consisted of regular use of a fluoride rinse and education of facility caregivers in appropriate oral hygiene techniques including use of an automated toothbrush

Follow-Up:

This patient lived an additional 6 years. During that time, her remaining teeth were caries free and she did not develop any additional pneumonias. Her dementia and arthritis did not progress further. Her eating habits improved and she regained her normal weight.

Conclusions

A periodontal-systemic connection, although not fully understood on a molecular level, is relevant to the aging population and supported by ample literature. Evidence for such a connection is sufficient to base patient management approaches on paradigms including comprehensive transdisciplinary care. This is especially important for older patients susceptible to exacerbation of systemic diseases or to development of comorbid conditions if periodontal health is not maintained. In the future, comprehensive care models must integrate dental and medical professionals with other health professionals to manage periodontitis and systemic disease. Dental professionals should appreciate the periodontal-systemic connection and stress the importance of regular periodontal maintenance to patients and other health professionals. Finally, insurers and policy makers must be convinced that investing in preventive periodontal management will pay huge dividends as the population ages with regard to reducing potential systemic complications, such as chronic inflammatory diseases/conditions.

The relationship between periodontitis, systemic disease, and the systemic inflammatory state as defined by serum pro-inflammatory cytokine and lipid levels not only offers intriguing therapeutic possibilities but suggests that notions of adequate preventive patient management need revision. Lipid-lowering therapies or dietary interventions used to treat periodontitis in older patients may also counteract chronic inflammatory systemic diseases linked to periodontitis. Recent clinical studies have established a positive correlation between high LDL/TRG levels and periodontitis.^{23-27,61,120,121} In fact, recent data demonstrate that high-fat diets and/or diets rich in omega-6 fatty acids produce a systemic inflammatory state associated with development of periodontitis.¹⁴⁸ Low fat diets, lipid-lowering drugs, and diets rich in omega-3 fatty acids appear to have the opposite effect and may be useful in preventive approaches or in patients with refractory periodontitis.^{23-27,149,150}

There are significant interactions between oral health and nutrition. In the presence of dysfunctional dentition and/or oral disease, dietary alterations likely occur resulting in nutritional imbalance. Such deficiencies could exacerbate systemic disease and result in increased systemic illness. Appropriate care strategies to cope with this issue are not yet fully defined, but simple nutrient supplementation is unlikely to be effective without nutritional counseling from a comprehensive care team. Thus, elderly patients should be evaluated for masticatory function, and rapid weight loss without apparent systemic cause should trigger an oral assessment or a dental referral.

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Grand Rounds Inspires the Future

Lyle Hoyt

By Lyle Hoyt †

On July 25th, Casey Hein, Chief Editor of Grand Rounds in Oral-Systemic Medicine™, testified before the United States Department of Health and Human Services (DHHS) Advisory Board for Interdisciplinary Community-Based Linkages regarding the connection between oral health and systemic health. This advisory board is comprised of professionals representing medicine, dentistry, nursing, dental hygiene, and other allied health disciplines. Expert testimony is used to provide recommendations to the DHHS Secretary and Congress related to appropriations, guidelines, and best practices for federally supported interdisciplinary community-based education/training programs involving all health and allied health professions. Hein's presentation highlighted the important data supporting the suspected relationship between periodontal disease and systemic diseases, the need for all health professions to embrace transdisciplinary models for prevention/comprehensive patient management, and the role of Grand Rounds in Oral-Systemic Medicine™ in providing information to practitioners bridging the gap between the latest information and clinical care. Hein was assisted in her presentation by Dr. Joanne Gurenlian, who discussed a new interdisciplinary nursing/hygienist model for preventive dental care in nursing home settings that has been described for the first time by Coleman, Hein and Gurenlian in this issue of Grand Rounds. Additionally, Hein was able to secure the participation of Tom Meyers, of America's Health Insurance Plans, to deliver a follow-up presentation which discussed how some insurance companies have begun to change their approach to reimbursement for preventive dental care. These new reimbursement considerations are based on recent data indicating that periodontal treatment and maintenance may reduce overall healthcare expenditures associated with chronic inflammatory diseases such as diabetes and cardiovascular/cerebrovascular disease. New models for preventive dental coverage also extend to high-risk groups that include pregnancy. The DHHS advisory board was impressed with the presentations and is currently considering recommendations that may lead to federal support of interdisciplinary education/training programs that address the periodontal-systemic connection and demonstration projects that provide innovative models for comprehensive preventive care or data regarding healthcare economics impact.

The significance of this event for the dental profession cannot be overemphasized. The potential availability of federal funds to support development of education/training programs and pilot projects is certainly a desirable outcome. More importantly however, the invitation for Hein to testify before this advisory board provides necessary exposure to validate the periodontal-systemic connection. The federal government and the insurance industry are now beginning to recognize the importance of the periodontal-systemic connection. The acceptance of Grand Rounds in Oral-Systemic Medicine™ by other health and allied health professionals provides important visibility for the role of the dental profession in overall health and quality of life. The dental profession must be ready and able to respond to the almost certain demand for increased collaboration that will characterize future community-based transdisciplinary/comprehensive care models.

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