Periodontitis and the Elderly: An Overview of the Disease and its Impact on an Aging Population

Nicole Weissenfluh

A Senior Thesis submitted in partial fulfillment
of the requirements for graduation
in the Honors Program
Liberty University
Spring 2019

Acceptance of Senior Honors Thesis

This Senior Honors Thesis is accepted in partial fulfillment of the requirements for graduation from the Honors Program of Liberty University.

_____

Randall Hubbard, Ph.D.
Thesis Chair

_____

Kimberly Mitchell, Ph.D.
Committee Member

_____

David Dinsmore, Ed.D.
Committee Member

_____

Cynthia Goodrich, Ed.D.
Assistant Honors Director

_____

Date

Table of Contents

Abstract

Periodontitis affects millions of Americans each year, and is especially prevalent among the elderly. Since periodontitis is a chronic, progressive condition, uninterrupted disease progression leads to irreversible oral damage; therefore, periodontitis often reduces the oral health-related quality of life. Furthermore, research strongly suggests a correlation between periodontitis and other systemic diseases (e.g., cardiovascular disease and diabetes mellitus), highlighting the importance of understanding, treating, and preventing periodontitis. This thesis explores the pathology and etiology of periodontitis, with special focus given to the prevalence and impact of the disease in the elderly population. Additionally, the connection between periodontitis and other systemic diseases common to the elderly will be explored. Finally, treatment and prevention strategies for periodontitis in the elderly will be considered.

Periodontitis and the Elderly: An Overview of the Disease and its Impact on an Aging Population

Periodontitis is a severe infection of the gums that adversely affects the oral and systemic health of millions of people each year. Periodontitis is usually preceded by a less severe condition known as gingivitis. Gingivitis is an inflammation of the gums caused by bacterial plaque that can be reversed through nonsurgical therapy and proper oral hygiene practices. However, untreated gingivitis often progresses to periodontitis. In periodontitis, the gums begin to pull away from the teeth, forming small pockets that allow for the accumulation of plaque between the tooth and gum. The subsequent immune response to bacterial plaque leads to a local inflammatory state, which, in conjunction with bacterial toxins, causes the gradual, irreversible destruction of the supporting structures of the teeth.

Left untreated, periodontitis will lead to tooth mobility, tooth loss, and potentially other local and systemic complications. The practice of proper oral hygiene, along with regular dental cleanings and healthy diet and lifestyle choices, is sufficient to prevent the development of periodontitis in many cases. Even in mild to moderate cases of periodontitis, nonsurgical procedures coupled with hygiene modifications and/or antibiotics have been proven to be widely successful in the treatment of the disease [1]. However, periodontitis is a chronic inflammatory disease that increases in severity the longer it is left untreated, and once the more serious effects of the disease, such as degradation of supporting tissue, have taken place, it is difficult to correct without more invasive surgical procedures.

Periodontitis is a common disease that has been estimated to affect nearly half of the adult population 30 years and older in the United States [2]. The incidence of periodontitis increases among the elderly population, defined as those 65 years of age and older. As the population of elderly adults grows, it becomes more important to understand the causes, impact, treatment, and prevention of periodontitis on this age group in order to improve oral health. Additionally, recent research has suggested a connection between periodontitis and other systemic conditions common to the elderly, including cardiovascular disease, Alzheimer's disease, and diabetes mellitus. This correlation of periodontitis with overall systemic health carries implications for the overall quality of life of the elderly, and is an important area of periodontitis research. Difficulty in recovering from surgical intervention and impeded access to treatment are also factors of particular concern for the elderly, and another prominent focus of periodontitis research has been to develop less invasive, more cost-effective treatment options for combating advanced periodontitis.

Prevalence

Worldwide, periodontitis ranks as the sixth most common chronic health condition [3]. Based on data collected from the 2009 and 2010 National Health and Nutrition Examination Survey it has been estimated that 47.2% of American adults 30 years and older suffer from some form of periodontitis [2]. Of these cases, mild, moderate, and severe periodontitis constituted 8.7%, 30.0%, and 8.5%, respectively [4]. Based on these numbers, it is clear that periodontitis is widespread in the United States adult population, and ought to be regarded as a major oral health concern. The prevalence of periodontitis is even higher in the elderly adult population: it has been approximated that

roughly two-thirds of Americans 65 years of age and older have moderate to severe periodontitis [3, 5]. These numbers are expected to keep rising, as Americans are living longer – although not necessarily healthier – lives and preserving more of their natural dentition than in years past [5].

Normal Physiology

In order to understand the physiological effects of periodontitis, it is important to be familiar with the normal physiology of the periodontium (i.e., the soft and hard tissues surrounding and supporting the teeth). The primary structures involved in periodontitis are the gingiva (or gums), the soft tissue that visibly surrounds the teeth; the alveolar bone, the part of the jaw bone that provides support to the teeth; and the periodontal ligament, which attaches the teeth to the alveolar bone [6]. In a healthy mouth, the gums are pink, firm, and attached to the teeth at the point where the crown meets the root, known as the cervical margin. The roots of the teeth are encased by the alveolar bone, and the periodontal ligament securely anchors the teeth to the alveolar bone. This structure facilitates the proper functioning of the teeth in activities such as breaking down food and speaking clearly [7].

Etiology

Periodontitis is a chronic, severe form of periodontal disease characterized by the gradual recession of the gingiva, breakdown of the periodontal ligament, and resorption of the alveolar bone as a result of chronic inflammation in response to bacterial infection. The onset and progression of periodontitis are complex processes influenced by a number of factors and pathogenic mechanisms.

Risk Factors

An individual's susceptibility to periodontitis is not easy to determine, as the individual immune response to the same pathogenic microbes varies from person to person [8]. However, there are a variety of risk factors associated with the development of periodontitis, falling into both modifiable and non-modifiable categories. The former category consists of factors that can be effectively controlled or managed, while the latter category is comprised of factors that cannot. The modifiable risk factor that has been most strongly associated with periodontitis is smoking, with both current and former smokers demonstrating an increased likelihood of developing the disease and worsened treatment outcomes [8]. Other modifiable risk factors include diabetes mellitus, low socioeconomic status, poor oral hygiene practices and/or lack of access to regular dental care, psychological stress, and calcium, vitamin D, and vitamin C deficiencies [8, 9]. Non-modifiable risk factors associated with periodontitis include genetic predisposition, tooth abnormalities, osteoporosis, and the aging process [8, 9].

Pathogenesis

The direct cause of periodontitis is the growth of microbial dental plaque, which triggers an inflammatory immune response. The mouth is inhabited by a wide variety of endogenous periodontal bacteria, many of which are beneficial in preventing the colonization of potentially harmful transient microorganisms [10]. However, an overabundance of periodontal bacteria results in microbial plaque formation on and between the teeth. Regular dental cleanings and good hygiene techniques are normally sufficient to remove much of this plaque. However, if proper oral hygiene, such as daily brushing and flossing, is not performed, and regular dental cleanings are not observed,

this harmful plaque hardens into tartar (or calculus) beneath the gum line. If it is not removed by a professional cleaning, this tartar leads to inflammation or swelling of the gums, known as gingivitis. This condition generally precedes the development of periodontitis, and can be reversed by professional cleanings and good oral hygiene practices.

If gingivitis is not treated, and inflammation is allowed to persist, periodontitis may develop. In periodontitis, the inflammatory response occurring in response to subgingival tartar causes the gums to pull away from the teeth, resulting in the development of pockets between the teeth and gums. These pockets then become filled with a host of bacteria and tartar, which lead to the disruption of host homeostasis and cause infection [10]. This infection, along with the resultant chronic inflammatory response, gradually leads to the breakdown of the supportive structures of the tooth, including connective tissue and alveolar bone. Ultimately, untreated periodontitis leads to loose teeth, tooth loss, and potentially other systemic conditions that will be discussed later in this paper.

It is important to note that the bacteria that make up the subgingival tartar are not sufficient to cause periodontitis by themselves; the inflammatory response to the microbial environment is the primary cause of the breakdown of the supportive structures of the tooth [11]. The microbial communities involved in periodontitis are highly resistant to host defense mechanisms such as inflammation, and can even take advantage of the inflammatory response to become more abundant [11]. Classifying the specific periodontal bacteria that make up plaque and their contribution to the progression of periodontitis has been a primary aim of periodontitis researchers. One group of bacteria implicated in the

formation of dental plaque is known as the “red complex” bacterial group, which includes *Porphyromonas gingivalis, Tannerella forsythia* and *Treponema denticola* [10]. Other bacteria that have been identified as probable risk indicators of periodontitis, including *Prevotella intermedia* and *Fusobacterium nucleatum* [8].

Studies have suggested that the type and composition of bacteria in the biofilm plays a role in the nature and severity of periodontitis [12, 13]. For instance, of the red complex bacteria, which are the most studied and well-understood of the periodontal plaque-associated bacteria, *T. forsythia* has been linked to an increased severity of periodontitis, as indicated by an increase in the depth of subgingival pockets, while *T. denticola* has been linked to more severe bleeding on probing [12]. *P. gingivalis*, while low in abundance in the microbial community associated with periodontitis, has been identified as a keystone bacteria that instigates the inflammatory response seen in periodontal disease [11]. The presence of the bacterium *Actinobacillus actinomycetemcomitans* is also suspected to be an important etiologic agent necessary for the development of periodontitis [8].

Because there is such a strong microbial component to periodontitis, researchers have sought for years to determine the various types of bacteria that constitute dental plaque and understand how their interaction contributes to the pathogenesis and progression of periodontitis. While the connection of certain classes of bacteria to the development and progression of periodontitis has been established, the microbial interactions contributing to the inflammatory response of periodontitis are highly complex and incompletely understood. In addition to this uncertainty, researchers are still discovering new classes of bacteria that may be associated with periodontitis, and it

will take time to understand if and how the interplay of these bacteria contributes to the disease.

Etiology in the Elderly

The elderly are particularly susceptible to developing periodontitis. There are several potential reasons for this susceptibility, including systemic changes inherent to the aging process itself, dietary changes, and a greater likelihood of existing chronic systemic disease. First, the risk for developing periodontitis rises due to the very nature of the aging process. The process of aging is characterized by an increase in systemic, low-grade inflammation, which contributes to the formation and progression of many chronic diseases, including periodontitis. Aging is also accompanied by a decrease in immune regulation and an increase in autoimmunity, which can exacerbate the inflammatory response to periodontitis-associated pathogens [5]. This immune senescence may help to explain some of the observed changes in periodontitis progression in the elderly, including attachment loss resulting from pronounced gingival recession as opposed to increased pocket depth [7]. Dietary changes may also influence the development of periodontitis in the elderly. The traditional menu selection offered at assisted living facilities often includes an abundance of refined sugars, which have been associated with increased inflammation and poor oral health [5]. Another important factor that may influence the development of periodontitis in the elderly is the presence of existing chronic systemic diseases.

Common Diseases in the Elderly Correlated with Periodontitis

The link between oral health and systemic health has garnered a great deal of attention in the past few decades. This link is especially evident when it comes to

periodontitis and its relationship to systemic health, as emerging evidence has suggested a connection between periodontitis and a wide variety of other chronic systemic diseases. In periodontitis, bacteria and bacterial toxins are able to pass from the gingival pockets into the bloodstream, along with locally produced inflammatory markers [14]. These periodontal disease products can then be disseminated throughout the body, contributing to a systemic inflammatory state. This state of systemic inflammation is suspected of being a potential exacerbating factor for other chronic inflammatory diseases. Some of the systemic complications common in the elderly population that have been associated with periodontitis include cardiovascular disease, respiratory diseases, cognitive impairment and Alzheimer's disease, osteoporosis, and diabetes mellitus [15].

Cardiovascular Disease

Cardiovascular disease is one of the leading causes of death in the United States, and it is the primary cause of death in both American men and women ≥65 years of age [16]. The overall prevalence of cardiovascular disease in the elderly population is significant. Over two-thirds of American adults 60-79 suffer from cardiovascular disease; for those aged 80 years and older, the prevalence of cardiovascular disease increases to about 85% [16]. Numerous researchers have examined the possible correlation between chronic periodontitis and cardiovascular conditions including atherosclerosis, hypertension, and coronary heart disease [17-19].

Atherosclerosis is a cardiovascular condition that occurs when arterial plaques build up in the walls of arteries, causing the arteries to become hardened and narrow [20]. These plaques have the potential to obstruct blood flow or to burst, leading to a blood clot. A variety of epidemiological evidence has been discovered that supports an

association between periodontitis and atherosclerosis: increased arterial wall stiffness has been correlated with periodontitis, and patients with periodontitis demonstrate an increased arterial wall thickness [20, 21]. Furthermore, periodontal pathogens implicated in periodontitis, including *Bacteroides fosythus, Prevotella intermedia,* and *Porphyromonas gingivalis,* have been discovered in atherosclerotic plaques [20]. Coronary heart disease, an atherosclerosis-related disease occurring when plaques build up in the coronary arteries, has also been shown to have a statistically significant relationship with periodontitis. The authors of one meta-analysis found that patients with periodontitis had at least a 1.14 times higher risk of developing coronary heart disease, pointing to periodontitis as a risk factor for coronary heart disease [18].

While the exact mechanism connecting periodontitis and heart disease is not known, it has been hypothesized that the relationship may be due to the activity of specific periodontal pathogens and elevated levels of inflammatory markers, such as C-reactive protein [15, 17]. Periodontitis triggers the release of bacteria, bacterial endotoxins, and inflammatory cytokines into the bloodstream, resulting in an increase in systemic levels of the inflammatory marker C-reactive protein. This increase in systemic inflammatory activity influences the development or propagation of atherosclerotic lesions, thereby contributing to the development and progression of atherosclerosis [18]. This process seems to provide a mechanistic link between periodontitis and atherosclerosis; however, a definitive causal relationship has not been established, and there are a lack of studies examining what effect, if any, periodontal treatment has on atherosclerosis outcomes.

High blood pressure, or hypertension, is another cardiovascular disease condition that is especially prevalent in the elderly. Around two-thirds of American adults 65-74 years of age are hypertensive, and that percentage increases to nearly 80% of the ≥75-year-old cohort [16]. Many studies that have been conducted on the relationship between periodontitis and hypertension have reported a statistically significant association between the two conditions, and it should be noted based on these studies that this association becomes stronger as the severity of periodontitis increases [22]. It is uncertain whether this connection can be explained by common risk factors for both conditions, or by underlying inflammatory mechanisms akin to those implicated in the connection between periodontitis and atherosclerosis.

Respiratory Diseases

Respiratory diseases can pose a serious threat to the elderly; two common respiratory concerns in this population are chronic obstructive pulmonary disease (COPD) and pneumonia.

Chronic obstructive pulmonary disease.

The term COPD is used to describe a group of progressive lung diseases, the most common of which are chronic bronchitis and emphysema [23]. In COPD, an overactive inflammatory response results in obstruction of the airways, making breathing difficult. Over time, the condition results in irreversible lung damage, and is one of the leading causes of mortality in the United States [24, 25]. A wide variety of conditions have been speculated to be associated with COPD, including periodontitis. A study based on data from the United States National Health and Nutrition Examination Survey found that patients with preexisting COPD displayed greater attachment loss (indicating

periodontitis) than patients without COPD; furthermore, the presence of periodontitis (indicated by increased attachment loss) was associated with an increased risk of COPD and a decrease in lung function [23]. Conversely, periodontal treatment may improve outcomes for patients with COPD. The results of a research study demonstrated both a lower incidence of adverse respiratory events (i.e., acute exacerbation, pneumonia, and acute respiratory failure), along with a 37% decrease in all-cause mortality in COPD patients who received periodontal treatment for periodontal disease compared to COPD patients without periodontal disease [26].

Since both periodontitis and COPD are chronic, inflammatory conditions that result in the destruction of tissue, it has been hypothesized they may share similar pathophysiological mechanisms, and that these mechanisms may play a role in the onset and progression of both diseases [25, 27]. One proposed mechanism of association between periodontitis and COPD is the aspiration of pathogenic periodontal bacteria from the oral cavity into the lower respiratory tract. In healthy persons, aspirated bacteria are often cleared by the immune system; however, in patients with COPD, aspirated pathogens are more likely to avoid clearance and promote pulmonary infection and the exacerbation of inflammation [23]. The oral cavity also has the potential to be colonized by and serve as a repository for pathogenic respiratory bacteria, which then cause the same respiratory complications mentioned previously when aspirated [25].

Other mechanisms that have been proposed to explain the possible relationship between periodontitis and COPD relate to the state of chronic inflammation common to both conditions. One hypothesis suggests that the dissemination of periodontal pathogens into the bloodstream triggers the upregulation of adhesion receptors on the surface of the

respiratory mucosa, resulting in increased colonization by respiratory pathogens [25]. The spillover of inflammatory cytokines (arising from the local inflammatory response to periodontal pathogens) into the systemic circulation is another mechanism that may result in respiratory pathogen colonization of the airways via adhesion receptors [26]. In terms of the impact of COPD on periodontitis, it has been proposed that the expectoration of bronchial secretions containing bacteria and by-products of inflammation into the oral cavity contributes to an increase in periodontal inflammation [25].

While there is some evidence to support a pathophysiological correlation between periodontitis and COPD, it is important to take into consideration the fact that there are also several shared risk factors between the two conditions that could potentially explain their concurrence. Smoking is the primary risk factor for both periodontitis and COPD, and smoking status (current, former, or never smoker) appears to have some impact on the strength of the correlation between the two diseases [28]. Furthermore, age and low socioeconomic status are common risk factors for both periodontitis and COPD, both of which commonly correlate with poor dental hygiene habits [25]. While common risk factors certainly do not preclude a pathophysiological correlation between periodontitis and COPD, more research is needed in this area to differentiate any pathophysiological connection from potential confounding factors.

Pneumonia.

Bacterial pneumonia is a common infection caused by the colonization and multiplication of pathogenic bacteria in the lungs [29]. Unlike many of the diseases suspected to be related to periodontitis, pneumonia is an acute condition, and one that can pose a significant, immediate threat to at-risk groups, including the elderly [24]. Elderly

patients admitted to intensive care units are particularly susceptible to contracting nosocomial (hospital-acquired) pneumonia, a severe form of the disease responsible for 15% of hospital-acquired infections [24]. A subset of nosocomial pneumonia, ventilator-associated pneumonia (VAP), can occur after intubation due to the mechanical transfer of bacteria from the oral cavity to the lower respiratory tract by the endotracheal tube, and is associated with especially high mortality rates in hospitalized patients [24, 28].

Periodontitis and pneumonia are thought to be connected by some of the same pathophysiological mechanisms proposed to link periodontitis and COPD. The most commonly-cited of these mechanisms is the colonization of dental plaque by pulmonary pathogens (e.g., *Staphylococcus aureus* and *Pseudomonas aeruginosa*), which can then be aspirated into the respiratory tract and promote infection in at-risk patients [24, 28]. The presence of periodontitis, which is characterized by a large accumulation of dental plaque, may promote the accumulation of these and other pathogenic bacteria, thereby increasing the likelihood of aspirational pneumonia [28].

Several studies have examined the efficacy of taking measures to improve oral health as a way to reduce the incidence of nosocomial pneumonia in at-risk patients. Such oral interventions include mechanically removing dental plaque through professional dental cleanings, disinfecting the area through the use of topical antiseptics, and administrating antibiotics [28]. A systematic review of the literature found that making interventions like those listed above to improve oral hygiene reduced the occurrence of nosocomial pneumonia by an average of 40% [27]. In keeping with this finding, another systematic research review concluded there was good evidence to support the improvement of oral hygiene and the reception of frequent professional dental care as

effective means to reduce the risk of contracting nosocomial pneumonia in at-risk elderly individuals [24].

Cognitive Impairment and Alzheimer's Disease

As the population of elderly adults continues to expand in the United States and worldwide, rates of Alzheimer's disease, the most common form of dementia, continue to increase. It is estimated that approximately 5.6 million Americans ≥65 years of age suffer from Alzheimer's disease, and this number is expected to almost triple by the year 2050 owing largely to an aging population and longer life spans [30]. While significant and aggressive efforts have been made to develop an effective drug (or drugs) for the treatment for Alzheimer's disease, there remains no cure for the disease. As a result, researchers are currently aiming to better understand the mechanisms and potential modifiable risk factors involved in the onset and progression of Alzheimer's disease.

Alzheimer's disease is a neurodegenerative disorder characterized by progressive synaptic loss and the formation of neurofibrillary tangles and amyloid-ß (Aß) plaques in the frontal neocortex and limbic systems of the brain [31]. While a definitive mechanism has not yet been determined, inflammation, both local and systemic, is thought to be heavily involved in the pathogenesis of Alzheimer's disease. The brain's innate inflammatory immune response to the accumulation of Aß plaques, characterized by the activation of microglia (immune cells of the brain), is currently thought to be a primary contributor to the pathogenesis of Alzheimer's disease. This neuroinflammatory response is thought to begin when the excessive formation of Aß plaques stimulates microglia. The activated microglia then release pro-inflammatory mediators (i.e.,

cytokines), which in turn activate more microglia; this interaction sets up a positive reinforcement cycle that contributes to the neurodegenerative process [31, 32].

Emerging research has also lent support to the hypothesis that systemic (peripheral) inflammation has an aggravating effect on the brain's innate inflammatory response. Two of the mechanisms that may explain how peripheral inflammation contributes to the neurodegenerative process include through systemic circulation and/or neural pathways [33]. The former mechanism involves the passage of pro-inflammatory mediators from the systemic circulation into the central nervous system either through areas that lack a blood-brain barrier, or through the blood-brain barrier itself, where they may either indirectly stimulate additional microglia to produce more pro-inflammatory cytokines or directly increase the local level of pro-inflammatory cytokines [34]. Alternatively, the neural pathway mechanism involves the stimulation of the afferent fibers of peripheral nerves by peripheral pro-inflammatory cytokines, leading to the production of local pro-inflammatory cytokines [34]. Peripheral pro-inflammatory cytokines may also take advantage of peripheral nerve-associated channels or compartments to enter the brain [33].

While the body of research into the association between periodontitis and Alzheimer's disease is relatively recent, preliminary results seem to support a bidirectional relationship between the two diseases. Alzheimer's disease often corresponds with poor oral hygiene as a result of reduced manual dexterity and/or the inability to receive regular professional dental care; this lack of proper dental care may result in periodontitis and tooth loss [31]. Correspondingly, clinical research studies have demonstrated that periodontal disease markers, including tooth loss and the presence of

serum antibodies to periodontal pathogens, are associated with increased cognitive impairment in elderly individuals [35-37]. The state of systemic inflammation caused by periodontitis has been proposed as a possible mechanistic explanation for how periodontitis may contribute to the onset and progression of Alzheimer's disease.

According to this mechanism, periodontal bacteria and the subsequent immune response cause an increase in the levels of local pro-inflammatory cytokines. Some of these cytokines are then disseminated throughout the body via systemic circulation, resulting in a state of peripheral inflammation. Once this state of peripheral inflammation has been established, pro-inflammatory mediators may be capable of passing into the brain by way of the systemic circulation mechanism described previously [33, 34]. Another mechanism suggested to explain the contribution of periodontitis to Alzheimer's disease involves the colonization of the brain by periodontal bacteria originating in dental plaque. These bacteria are thought to enter the brain either through the bloodstream or through peripheral nerve-associated channels or compartments, where they then elicit an inflammatory response that contributes to the neurodegenerative process [33]. This hypothesis is supported by the fact that *P. gingivalis*, a keystone pathogen in periodontitis, along with periodontal pathogens *T. denticola* and *T. forsythia*, have been found in the brain tissue of Alzheimer's disease patients [38, 39].

While a great deal of emerging evidence appears to support a bidirectional relationship between periodontitis and Alzheimer's disease, further studies, especially longitudinal studies, are needed in order to determine whether this relationship is causal or simply correlational. If causal, this would have important implications for the treatment and even prevention of Alzheimer's disease, as periodontitis is treatable and

therefore could be considered a modifiable risk factor [34]. In light of this, an additional focus of periodontitis-Alzheimer's disease research that warrants further study is determining what impact, if any, periodontal treatment has on the onset and progression of Alzheimer's disease.

Osteoporosis

Osteoporosis is a condition in which the bones become brittle due to a loss of density, resulting in proneness to fractures. The elderly, especially elderly postmenopausal women, are most commonly affected by osteoporosis; it has been estimated over half of adults ≥50 years of age suffer from osteoporosis and low bone mass [40]. Bone resorption is a key characteristic of both osteoporosis and periodontitis, and the two conditions share common risk factors including aging, smoking, calcium and vitamin D deficiency, and diabetes [41, 42]. Although osteoporosis is a common disease amongst elderly men and women, most studies assessing the correlation between periodontitis and osteoporosis have been conducted within a population of elderly postmenopausal women, as they are most commonly afflicted with osteoporosis. The results of these studies indicate a positive correlation between the two diseases [41-43].

Osteoporosis is responsible for systemic loss of bone density, including from the alveolar bone, which in turn is suspected to enhance the progression of alveolar bone loss in periodontitis [43]. This fact has led many to consider osteoporosis as a modifiable risk factor for periodontitis. Conversely, periodontitis has been hypothesized to be a risk factor for osteoporosis [42]. The results of recent research seem to lend support to this hypothesis. The presence of periodontitis, as indicated by clinical attachment loss, has been found to be associated with decreased bone mineral density in postmenopausal

women [43]. In addition, women ≥50 who suffer from periodontitis have been found to experience a higher incidence of osteoporosis than their counterparts without periodontitis [42]. Periodontitis may also increase the likelihood of skeletal fractures: one study found that the risk of skeletal fractures over 3 years increased fourfold for patients who also suffered from diagnosed periodontitis [44].

The mechanistic link between periodontitis and osteoporosis is far from fully understood. Two of the more well-supported explanations for the apparent relationship include estrogen deficiency and low bone mineral density [42]. Estrogen deficiency has been identified as a major risk factor for osteoporosis, in part because it inhibits the absorption and promotes the excretion of calcium and disrupts homeostasis in bone tissue [41]. Recent research has also indicated estrogen may play a role in the process of inflammation, suggesting that estrogen deficiency may exacerbate periodontitis [41]. Inflammation may also play a role in osteoporosis: Patients with osteoporosis exhibit higher levels of systemic pro-inflammatory cytokines, and cytokine levels have been found to be associated with decreased bone mineral density and increased risk of skeletal fractures [45-47]. Based on these findings, inflammation seems to be a likely candidate for the mechanism underlying the apparent connection between periodontitis and osteoporosis.

Important therapeutic implications exist in light of the relationship between periodontitis and osteoporosis. Since the progression of osteoporosis is linked to enhanced resorption of the alveolar bone, and emerging evidence suggests elderly women with periodontitis are at an increased risk for developing osteoporosis, early diagnosis and treatment of either condition may also help to improve outcomes for the other. For

example, the addition of calcium and vitamin D supplements in the diet seems to be beneficial in the management of both periodontitis and osteoporosis [41]. While more research is needed in order to be able to fully assess the therapeutic connection between periodontitis and osteoporosis, preliminary evidence of such a connection should be considered in order to effectively manage both conditions.

Diabetes Mellitus

The disease that researchers have consistently shown to be most closely associated with periodontitis is diabetes mellitus. Diabetes mellitus is a common disease in the United States, and has shown a substantial increase in prevalence over the past few decades; as recently as 2016, the prevalence of diabetes among American adults ≥65 years of age was nearly 40% [48]. Diabetes can have a severe detrimental impact on quality of life for elderly patients, especially if it is not managed well. When it comes to the association between periodontitis and type 2 diabetes mellitus, researchers have demonstrated that periodontitis adversely effects diabetes patients' glycemic control, leading to worsened diabetes management; conversely, the treatment of periodontitis is directly associated with moderate improvements in glycemic control for both insulin dependent diabetes mellitus and insulin resistant diabetes patients [14].

A growing body of evidence substantiates that the relationship between periodontitis and diabetes mellitus is bidirectional. It has been established that diabetes (type 1 and type 2) is a major risk factor for periodontitis: patients with poorly managed diabetes mellitus are up to three times more likely to develop periodontitis, and the patient's level of glycemic control is directly associated with increased risk [6, 49]. The progression of periodontitis is more rapid and severe in patients who have poorly

managed diabetes [49]. Additionally, the results of some studies show that periodontitis increases blood glucose levels in those without diabetes and even promotes the development of type 2 diabetes [20, 50]. For patients with existing diabetes, evidence suggests that periodontitis increases the risk of poor glycemic control and other complications of diabetes, e.g., renal failure and cardiovascular mortality [6, 49].

The authors of recent studies and reviews have placed a large amount of focus on elucidating the mechanism or mechanisms at play behind the connection between the two diseases. Available evidence suggests that diabetes leads to the modification of periodontal tissue, resulting in immunological and structural dysfunction [49]. The hyperglycemic state common in diabetes also seems to promote a hyper-inflammatory response to periodontal microbiota, resulting in greater destruction of the periodontal tissue and potentially explaining the increased prevalence and severity of periodontitis in the diabetic population [49]. In turn, periodontitis is suspected to adversely impact diabetes outcomes by increasing the levels of pro-inflammatory regulators, which in turn compounds insulin resistance [14].

Diagnosis

Clinical Presentation

While gingivitis, the precursor to gum disease, is often painless and hard to detect, the development and progression of periodontitis is more likely to cause symptoms that result in discomfort for the patient. Depending on the severity of a patient's periodontitis, these symptoms may include bad breath, tooth or gum pain, inflamed gums, gums that bleed easily, pus between the teeth and gums, gum recession, tooth mobility, and tooth loss [51]. Along with taking into consideration the clinical presentation of periodontitis, a

comprehensive periodontal examination can provide the definitive information on which to base a diagnosis, e.g., quantifiable factors such as probing depth and clinical attachment loss.

Periodontal Examination

The periodontal examination includes a variety of evaluative and assessment procedures. The extent of gingival inflammation, plaque accumulation, and tooth mobility are important diagnostic indicators that can be determined during the periodontal examination. Bleeding on probing, while not a quantitative measurement, is another common indicator used by dental practitioners to diagnose periodontitis [52]. Periodontitis is most commonly diagnosed based on a probe measurement of pocket depth (the distance from the gingival margin – the highest point the gum rises on the tooth – to the base of the pocket) and gum recession (the degree to which the gums have receded from around the affected teeth, exposing the tooth root) [53]. Pocket depths deeper than 4 mm are indicative of early stage periodontitis, while pocket depths deeper than 6 mm indicate moderate to advanced periodontitis [4]. Using probing depth and gingival recession measurements, clinical attachment loss can be measured to assess the presence and progression of periodontitis. The degree of clinical attachment loss is calculated by adding the degree of gingival recession to the pocket depth [54]. A clinical attachment loss greater than 3 mm is indicative of periodontal disease, and increasing values indicate increased severity of the disease [54].

Treatment

Effectively treating a chronic condition such as periodontitis is a complex task that necessitates coordinated efforts by primary dental care teams, dental and potentially

medical specialists, and the patient. Since the destruction that occurs as a result of periodontitis is largely irreversible, identifying and implementing the correct treatment option to mitigate further damage is a priority. The traditional approach to the treatment of mild to moderate periodontitis is often overseen by general dental practitioners, and involves patient education and the removal of existing plaque through the use of nonsurgical approaches. If the disease is more advanced (as in severe periodontitis) or if the desired outcome is not achieved through nonsurgical intervention, specialists may have to become involved, and more invasive surgical procedures may need be utilized.

Patient education and the establishment of a treatment plan should be the first step in the dental practitioner's approach to treating periodontitis. Possible treatment options for periodontitis depend heavily upon how advanced the disease is and how much supporting tissue destruction has occurred; therefore, developing a case-specific treatment plan is important in achieving the best outcome for the patient. The goals of the treatment plan should include improving patient health through diet and lifestyle modification, managing the progression of the disease through non-surgical or surgical professional intervention, and preserving the natural dentition [53]. Once periodontitis has been diagnosed, the focus of treatment centers on mechanical debridement of the tooth root surface to remove the tartar below the gum line [52].

The treatment of periodontitis in the elderly, while mostly similar to the treatment of periodontitis in younger age groups, involves a few special considerations [7]. When it comes to developing a treatment plan for elderly patients, it is important that the patient and any caregivers understand the goals of the treatment and their own responsibility in maintaining proper oral hygiene practices. This understanding is imperative; regardless

of how advanced the case of periodontitis may be and what professional treatment option is selected, patient cooperation and compliance with periodontal health maintenance plans is absolutely essential to the long-term success of the treatment plan [53]. In cases where the patient is not able to adequately maintain oral hygiene on his or her own, the use of topical disinfectants and more frequent dental visits may be warranted [55]. Furthermore, dentists should be aware of any existing medical conditions and/or medications taken by the patient; this often requires communication between the dental care team and medical care teams [7].

Nonsurgical Intervention

Nonsurgical treatment options for periodontitis include scaling and root planing of the affected area, which may be accompanied by the prescription of antibiotics [56]. Scaling and root planing is the most common and widely-used approach to treating mild, moderate, and even advanced periodontitis. Scaling involves the removal of plaque and tartar from the subgingival surface, and root planing smooths the tooth root to promote reattachment of the gums to the teeth [57]. The impact of scaling and root planing on mild to moderate cases of periodontitis is highly beneficial. In most cases, scaling and root planing leads to a significant reduction in inflammation, a decrease in bleeding upon probing, and can even lead to a reduction in tooth loss. Therefore, dental practitioners regard scaling and root planing as the 'gold standard' in the treatment of periodontitis [57].

Some dental professionals use antibiotics in conjunction with scaling and root planing, an approach that has been demonstrated to be moderately beneficial in improving the outcome for patients suffering from periodontitis [58]. As discussed previously, the modification of oral hygiene habits on the part of the patient, in addition

to professional intervention, is critical to improving long-term outcomes of moderate periodontitis. In more advanced cases of periodontitis, when the pocket between the tooth and gum is deeper than 7 mm, the possibility of completely removing tartar through scaling becomes far more remote. Scaling and root planing have still shown positive benefits in treating more advanced cases of periodontitis, but in many of these cases patients will require the work of dental and/or medical specialists and the use of more invasive surgical options.

Surgical Intervention

There are several surgical procedures that have been used over the years to treat advanced periodontitis. These are often used after or alongside the initial nonsurgical treatment approach of scaling and root planing. The majority of the common surgical approaches to the treatment of periodontitis, in order of increasing invasiveness, can be categorized as soft tissue procedures, osseous procedures, and dental tissue procedures [53]. Soft tissue procedures are those that primarily involve the gingiva; these include gingivectomy, gingivoplasty, flap debridement, gingival curettage and excisional new attachment procedure, and laser-assisted new attachment procedure [53]. Each of these procedures involves the excision of some of the inflamed soft tissue to access the tooth root for cleaning, and each is performed with the primary goal of re-establishing the gingiva in a way that complements patient efforts to maintain periodontal health [59].

Osseous procedures are performed on the bone, and are generally more invasive than soft tissue procedures; these include ostectomy, the removal of bone, and osteoplasty, the reshaping of bone. Dental tissue procedures include root resection, tooth hemisection, and odontoplasty [53]. In addition to the preceding surgical approaches, less

common and more radical reconstructive procedures (i.e., replacement grafts and periodontal plastic surgery) may be required in advanced cases of periodontitis. While the preservation of the natural dentition is one of the primary goals of periodontal treatment, in the most severe cases of periodontitis, tooth extraction may be the only option available to dental practitioners to control the disease [53].

Experimental Treatments

The success of current periodontitis treatments to a great extent depends upon patient cooperation and the progression of the disease. Therefore, consistent efforts have been made over the past several years to improve existing treatment options and pioneer simpler, less invasive, and more cost-effective ways to treat the disease. These efforts can be largely attributed to the advancements in dental technology made in the past decade, along with the fact that more patients with periodontitis are initially receiving treatment from general dentists as opposed to specialists. Some of the more promising experimental treatments for periodontitis include laser therapy and the use of antibiotics, which are intended be used alongside traditional treatments.

The use of laser therapy in conjunction with nonsurgical treatment has shown some promise for improving patient outcomes in certain studies [60, 61]. However, these results are by no means conclusive, and more research is needed to determine the efficacy of laser therapy as an adjunct or alternative to traditional periodontitis treatments [62]. Another option that has been examined for its effectiveness in the treatment of periodontitis is the administration of systemic antibiotics in conjunction with the conventional approach of scaling and root planing. The results of some studies have shown the use of antibiotics in combination with nonsurgical procedures such as scaling

and root planing to provide more positive patient outcomes than the use of nonsurgical procedures or antibiotics alone [63]. However, these benefits are modest and must be evaluated against the potential risks, especially when it comes to treating elderly patients who are more likely to suffer from other chronic medical conditions and/or be on multiple medications.

Prevention

In many cases, periodontitis is an entirely preventable disease if proper oral care (i.e., tooth brushing and flossing and regular dental visits) is observed throughout one's life. However, taking these preventive measures may become difficult for elderly adults facing such obstacles as decreased manual dexterity and mobility, cognitive decline, and impeded access to care. These barriers to oral health maintenance ought to be taken into consideration by elderly adults, caregivers, and dental care teams. Ideally, these groups ought to work together to proactively develop care plans that adapt to individual disabilities while addressing any potential areas of oral health concern, such as smoking or poor hygiene habits.

Furthermore, as discussed earlier, the presence of chronic systemic disease(s) that contribute to a state of systemic inflammation (many of which are commonly suffered by the elderly) increases the risk of developing periodontitis. In light of this, early detection and treatment of conditions such as diabetes mellitus and osteoporosis is important to help prevent the development of periodontitis. Dietary changes, namely an increase in refined sugar consumption, may also put the elderly at an increased risk for developing periodontitis. Receiving proper nutritional guidance, along with limiting the

consumption of refined sugar, may be an effective way for the elderly to prevent the onset and progression of periodontitis [5].

Conclusion

As lifespans lengthen and the number of elderly people continues to expand around the world, it is important to consider how quality – not just quantity – of life may be improved for this population. Recent research indicates oral health exerts influence on and is influenced by systemic health; therefore, it is important to take oral complications into account when assessing health improvement measures for the elderly. Periodontitis is a particularly prevalent oral concern among the elderly. This condition is induced and promoted by an inflammatory response to a local infection of pathogenic plaque-associated bacteria that, along with the release of bacterial toxins, causes the gradual destruction of the supporting structures of the teeth. Beyond reducing the oral health-related quality of life in and of itself, periodontitis has also been connected to a variety of systemic diseases common in the elderly, including cardiovascular disease, respiratory diseases, osteoporosis, cognitive impairment and Alzheimer's disease, and diabetes mellitus. These connections are still being researched, but evidence suggests a bidirectional relationship between periodontitis and many of these conditions that may have important implications for their management and prevention in the future.

While effective treatment and management options for periodontitis are available, their efficacy depends greatly upon patient cooperation and lifestyle modification, which can be difficult for the elderly individual to accomplish. Therefore, cooperation between the patient and all health care professionals, along with the development of a personalized treatment plan, is vital to ensure good outcomes for patients with periodontitis. Finally,

in light of the potential local and systemic health complications and reduction of quality of life, developing strategies to prevent the onset of periodontitis in this age group ought to be a priority for health care practitioners at all levels.

References

1. Turani D, Bissett SM, Preshaw PM. Techniques for effective management of periodontitis. Dent Update 2013;40(3):181-4, 87-90, 93.
2. Eke PI, Dye BA, Wei L, et al. Update on Prevalence of periodontitis in adults in the United States: NHANES 2009 to 2012. J Periodontol 2015;86(5):611-22.
3. Eke PI, Wei L, Borgnakke WS, et al. Periodontitis prevalence in adults >/= 65 years of age, in the USA. Periodontol 2000 2016;72(1):76-95.
4. Eke PI, Dye BA, Wei L, et al. Prevalence of periodontitis in adults in the United States: 2009 and 2010. J Dent Res 2012;91(10):914-20.
5. Persson GR. Dental geriatrics and periodontitis. Periodontol 2000 2017;74(1):102-15.
6. Preshaw PM, Bissett SM. Periodontitis: oral complication of diabetes. Endocrinol Metab Clin North Am 2013;42(4):849-67.
7. Boehm TK, Scannapieco FA. The epidemiology, consequences and management of periodontal disease in older adults. J Am Dent Assoc 2007;138 Suppl:26S-33S.
8. Van Dyke TE, Sheilesh D. Risk factors for periodontitis. J Int Acad Periodontol 2005;7(1):3-7.
9. Nunn ME. Understanding the etiology of periodontitis: an overview of periodontal risk factors. Periodontol 2000 2003;32:11-23.
10. Darveau RP. Periodontitis: a polymicrobial disruption of host homeostasis. Nat Rev Microbiol 2010;8(7):481-90.
11. Hajishengallis G. Immunomicrobial pathogenesis of periodontitis: keystones, pathobionts, and host response. Trends Immunol 2014;35(1):3-11.
12. Lanza E, Magan-Fernandez A, Bermejo B, et al. Complementary clinical effects of red complex bacteria on generalized periodontitis in a caucasian population. Oral Dis 2016;22(5):430-7.
13. Kageyama S, Takeshita T, Asakawa M, et al. Relative abundance of total subgingival plaque-specific bacteria in salivary microbiota reflects the overall periodontal condition in patients with periodontitis. PLoS One 2017;12(4):e0174782.
14. Lalla E, Papapanou PN. Diabetes mellitus and periodontitis: a tale of two common interrelated diseases. Nat Rev Endocrinol 2011;7(12):738-48.
15. Cardoso EM, Reis C, Manzanares-Cespedes MC. Chronic periodontitis, inflammatory cytokines, and interrelationship with other chronic diseases. Postgrad Med 2017:1-7.
16. Mozaffarian D, Benjamin EJ, Go AS, et al. Heart Disease and Stroke Statistics - 2016 Update. Circulation 2016;133(4):e38-e360.
17. Almeida A, Fagundes NCF, Maia LC, Lima RR. Is there an association between periodontitis and atherosclerosis in adults? A systematic review. Curr Vasc Pharmacol 2018;16(6):569-82.
18. Bahekar AA, Singh S, Saha S, Molnar J, Arora R. The prevalence and incidence of coronary heart disease is significantly increased in periodontitis: a meta-analysis. Am Heart J 2007;154(5):830-7.
19. Arowojolu MO, Oladapo O, Opeodu OI, Nwhator SO. An evaluation of the possible relationship between chronic periodontitis and hypertension. J West Afr Coll Surg 2016;6(2):20-38.
20. Borgnakke WS, Glick M, Genco RJ. Periodontitis: the canary in the coal mine. J Am Dent Assoc 2013;144(7):764-6.

21. Nicolosi LN, Lewin PG, Rudzinski JJ, et al. Relation between periodontal disease and arterial stiffness. J Periodontal Res 2017;52(1):122-26.
22. Martin-Cabezas R, Seelam N, Petit C, et al. Association between periodontitis and arterial hypertension: a systematic review and meta-analysis. Am Heart J 2016;180:98-112.
23. Scannapieco FA, Ho AW. Potential associations between chronic respiratory disease and periodontal disease: analysis of National Health and Nutrition Examination Survey III. J Periodontol 2001;72(1):50-6.
24. Azarpazhooh A, Leake JL. Systematic review of the association between respiratory diseases and oral health. J Periodontol 2006;77(9):1465-82.
25. Hobbins S, Chapple IL, Sapey E, Stockley RA. Is periodontitis a comorbidity of COPD or can associations be explained by shared risk factors/behaviors? Int J Chron Obstruct Pulmon Dis 2017;12:1339-49.
26. Shen TC, Chang PY, Lin CL, et al. Periodontal treatment reduces risk of adverse respiratory events in patients with chronic obstructive pulmonary disease: a propensity-matched cohort study. Medicine (Baltimore) 2016;95(20):e3735.
27. Scannapieco FA, Bush RB, Paju S. Associations between periodontal disease and risk for nosocomial bacterial pneumonia and chronic obstructive pulmonary disease. A systematic review. Ann Periodontol 2003;8(1):54-69.
28. Linden GJ, Lyons A, Scannapieco FA. Periodontal systemic associations: review of the evidence. J Periodontol 2013;84(4 Suppl):S8-S19.
29. Scannapieco FA, Mylotte JM. Relationships between periodontal disease and bacterial pneumonia. J Periodontol 1996;67 Suppl 10S:1114-22.
30. Hebert LE, Weuve J, Scherr PA, Evans DA. Alzheimer disease in the United States (2010-2050) estimated using the 2010 census. Neurology 2013;80(19):1778-83.
31. Gaur S, Agnihotri R. Alzheimer's disease and chronic periodontitis: is there an association? Geriatr Gerontol Int 2015;15(4):391-404.
32. Teixeira FB, Saito MT, Matheus FC, et al. Periodontitis and Alzheimer's Disease: a possible comorbidity between oral chronic inflammatory condition and neuroinflammation. Front Aging Neurosci 2017;9:327.
33. Abbayya K, Puthanakar NY, Naduwinmani S, Chidambar YS. Association between periodontitis and Alzheimer's Disease. N Am J Med Sci 2015;7(6):241-6.
34. Kamer AR, Craig RG, Dasanayake AP, et al. Inflammation and Alzheimer's disease: possible role of periodontal diseases. Alzheimers Dement 2008;4(4):242-50.
35. Kamer AR, Craig RG, Pirraglia E, et al. TNF-alpha and antibodies to periodontal bacteria discriminate between Alzheimer's disease patients and normal subjects. J Neuroimmunol 2009;216(1-2):92-7.
36. Noble JM, Borrell LN, Papapanou PN, et al. Periodontitis is associated with cognitive impairment among older adults: analysis of NHANES-III. J Neurol Neurosurg Psychiatry 2009;80(11):1206-11.
37. Sparks Stein P, Steffen MJ, Smith C, et al. Serum antibodies to periodontal pathogens are a risk factor for Alzheimer's disease. Alzheimers Dement 2012;8(3):196-203.
38. Poole S, Singhrao SK, Kesavalu L, Curtis MA, Crean S. Determining the presence of periodontopathic virulence factors in short-term postmortem Alzheimer's disease brain tissue. J Alzheimers Dis 2013;36(4):665-77.

39. Dominy SS, Lynch C, Ermini F, et al. *Porphyromonas gingivalis* in Alzheimer's disease brains: evidence for disease causation and treatment with small-molecule inhibitors. Science Advances 2019;5(1):eaau3333.
40. Wright NC, Looker AC, Saag KG, et al. The recent prevalence of osteoporosis and low bone mass in the United States based on bone mineral density at the femoral neck or lumbar spine. J Bone Miner Res 2014;29(11):2520-6.
41. Wang CJ, McCauley LK. Osteoporosis and periodontitis. Curr Osteoporos Rep 2016;14(6):284-91.
42. Choi JK, Kim YT, Kweon HI, et al. Effect of periodontitis on the development of osteoporosis: results from a nationwide population-based cohort study (2003-2013). BMC Womens Health 2017;17(1):77.
43. Goyal L, Goyal T, Gupta ND. Osteoporosis and periodontitis in postmenopausal women: A systematic review. J Midlife Health 2017;8(4):151-58.
44. Persson GR, Berglund J, Persson RE, Renvert S. Prediction of hip and hand fractures in older persons with or without a diagnosis of periodontitis. Bone 2011;48(3):552-6.
45. Brincat SD, Borg M, Camilleri G, Calleja-Agius J. The role of cytokines in postmenopausal osteoporosis. Minerva Ginecol 2014;66(4):391-407.
46. Scheidt-Nave C, Bismar H, Leidig-Bruckner G, et al. Serum interleukin 6 is a major predictor of bone loss in women specific to the first decade past menopause. J Clin Endocrinol Metab 2001;86(5):2032-42.
47. Barbour KE, Lui LY, Ensrud KE, et al. Inflammatory markers and risk of hip fracture in older white women: the study of osteoporotic fractures. J Bone Miner Res 2014;29(9):2057-64.
48. Fang M. Trends in the prevalence of diabetes among U.S. adults: 1999-2016. Am J Prev Med 2018;55(4):497-505.
49. Sima C, Glogauer M. Diabetes mellitus and periodontal diseases. Curr Diab Rep 2013;13(3):445-52.
50. Ziukaite L, Slot DE, Van der Weijden FA. Prevalence of diabetes mellitus in people clinically diagnosed with periodontitis: a systematic review and meta-analysis of epidemiologic studies. J Clin Periodontol 2017.
51. Papapanou PN, Susin C. Periodontitis epidemiology: is periodontitis under-recognized, over-diagnosed, or both? Periodontol 2000 2017;75(1):45-51.
52. Sanz I, Alonso B, Carasol M, Herrera D, Sanz M. Nonsurgical treatment of periodontitis. J Evid Based Dent Pract 2012;12(3 Suppl):76-86.
53. American Academy of Periodontology. Comprehensive periodontal therapy: a statement by the American Academy of Periodontology. J Periodontol 2011;82(7):943-9.
54. Van der Velden U. Diagnosis of periodontitis. J Clin Periodontol 2000;27(12):960-1.
55. Renvert S, Persson GR. Treatment of periodontal disease in older adults. Periodontol 2000 2016;72(1):108-19.
56. Cionca N. Editorial: Use and misuse of systemic antibiotics in periodontitis treatment. Oral Health Prev Dent 2017;15(4):305-06.
57. Smiley CJ, Tracy SL, Abt E, et al. Evidence-based clinical practice guideline on the nonsurgical treatment of chronic periodontitis by means of scaling and root planing with or without adjuncts. J Am Dent Assoc 2015;146(7):525-35.
58. Preshaw PM. Antibiotics in the treatment of periodontitis. Dent Update 2004;31(8):448-50, 53-4, 56.

59. Deas DE, Moritz AJ, Sagun RS, Jr., Gruwell SF, Powell CA. Scaling and root planing vs. conservative surgery in the treatment of chronic periodontitis. Periodontol 2000 2016;71(1):128-39.
60. Sanz-Sanchez I, Ortiz-Vigon A, Matos R, Herrera D, Sanz M. Clinical efficacy of subgingival debridement with adjunctive erbium:yttrium-aluminum-garnet laser treatment in patients with chronic periodontitis: a randomized clinical trial. J Periodontol 2015;86(4):527-35.
61. Zhao Y, Yin Y, Tao L, et al. Er:YAG laser versus scaling and root planing as alternative or adjuvant for chronic periodontitis treatment: a systematic review. J Clin Periodontol 2014;41(11):1069-79.
62. Sgolastra F, Petrucci A, Gatto R, Monaco A. Efficacy of Er:YAG laser in the treatment of chronic periodontitis: systematic review and meta-analysis. Lasers Med Sci 2012;27(3):661-73.
63. Garcia Canas P, Khouly I, Sanz J, Loomer PM. Effectiveness of systemic antimicrobial therapy in combination with scaling and root planing in the treatment of periodontitis: a systematic review. J Am Dent Assoc 2015;146(3):150-63.