# Impact of Tobacco Use on Periodontal Status

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Abstract: This article reviews the effects of smoked and smokeless tobacco on periodontal status, including the impact of smoking on periodontal therapy and potential mechanisms for the adverse effects of tobacco on the periodontium. Approximately half of periodontitis cases have been attributed to either current or former smoking. Both cigar and cigarette smokers have significantly greater loss of bone height than nonsmokers, and there is a trend for pipe smokers to have more bone loss than nonsmokers. Unlike smokers, who experience widespread periodontal destruction, the most prevalent effects of smokeless tobacco are localized to the site of placement, in the form of gingival recession and white mucosal lesions. Smoking has an adverse effect on all forms of periodontal therapy, and up to 90 percent of refractory periodontitis patients are smokers. The pathogenesis of smoking-related periodontal destruction has been attributed to alterations in the microflora and/or host response. Some data indicates that smoking may increase levels of certain periodontal pathogens, but there is more evidence that smoking has a negative effect on host response, such as neutrophil function and antibody production. An encouraging finding is that periodontal disease progression slows in patients who quit smoking and that these individuals have a similar response to periodontal therapy as nonsmokers. The facts presented in this paper will assist dental health professionals in treatment-planning decisions and provide them with important information to share with patients who use tobacco products.

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For many years, smoking has been linked to lung disease, cancer, cardiovascular disease, and poor pregnancy outcomes, such as miscarriage and low birth weight.[1] Over the past two decades, it has also been recognized that smoking is associated with periodontal disease. As early as the 1940s, Pindborg[2,3] noted that acute necrotizing ulcerative gingivitis was associated with smoking in the Danish Royal Marines. However, for other forms of periodontal disease, the prevailing opinion for many years was that if smokers did have more periodontal disease, it was probably due to differences in levels of plaque and calculus. Beginning in the 1980s, numerous epidemiological studies that have controlled for confounding variables, such as age, plaque, calculus, gender, and socioeconomic status, have provided strong evidence that smoking is a risk factor for periodontitis.

## Smoking and Periodontitis

Results from the first United States National Health and Nutrition Examination Survey (NHANES I) demonstrated that, even though current smokers had higher levels of plaque and calculus, after adjusting for oral hygiene and other confounding variables, they still had greater periodontal destruction than former, or never, smokers.[4] More recently, based on data from the NHANES III study, which included 12,329 subjects eighteen years and older, Tomar and Asma[5] concluded that approximately half of periodontitis cases were attributable to either current (41.9 percent) smoking or former (10.9 percent) smoking. Current smokers were about four times as likely as never smokers to have periodontitis, after adjusting for age, gender, race, education, and income. Former smokers were 1.68 times more likely to have periodontitis.

The Erie County study, which included 1,426 adults aged twenty-five to seventy-four years, found an association between smoking and attachment loss after correcting for confounding factors such as age, plaque and calculus, gender, income, education, and socioeconomic status.[6] The odds for greater attachment loss in smokers as compared to nonsmokers ranged from 2.05 in light smokers up to 4.75 in heavy smokers. This study also examined the risk for bone loss in 1,361 of the study participants. The risk of bone loss in smokers was even greater than that for attachment loss, with smokers having odds ranging from 3.25 for light smokers to 7.28 for heavy smokers. A strong dose response was noted between smoking and bone loss.[7] Collectively, these epidemiological studies show that, after correcting for plaque and other confounding variables, smokers have at least

three times the odds of having severe periodontitis than nonsmokers.[8]

Only a few prospective studies have evaluated the longitudinal effects of smoking on periodontal health.[9-15] The most recent of these investigated the effect of smoking exposure on periodontal status over a ten-year period.[13] That study found that the rate of bone loss in smokers was almost four times greater than that of nonsmokers.

Many clinicians have noted a high prevalence of smoking among young patients with aggressive periodontitis. Haber and coworkers estimated that as much as 51 percent of periodontitis in nineteen- to thirty-year-olds is associated with smoking[16]; the prevalence of periodontitis was almost four times higher in smokers than nonsmokers in that age group.[17] Other studies have also demonstrated that, despite similar plaque levels, smokers in their twenties and thirties have deeper probing depths and more attachment loss.[18,19] The generalized form of aggressive periodontitis (formerly referred to as "generalized early-onset periodontitis") is more associated with smoking than the localized form of aggressive periodontitis (formerly referred to as "localized juvenile periodontitis").[20,21]

In general, calculus deposits are also greater in smokers,[18,22,23] although amounts of plaque are variable.[18,22,24,25] The effects of smoking on gingival inflammation are equivocal,[25-30] although the trend is towards decreased inflammation. Smokers have a higher prevalence of furcation involvement as assessed by radiographic evidence of bone loss,[31,32] and clinical evaluation demonstrates both a higher prevalence and severity of furcation attachment loss.[32] Furthermore, smokers experience greater tooth loss than nonsmokers.[32-36]

As smokers have a higher prevalence and severity of periodontitis, it is not surprising that one study reported that 75 percent of patients referred to a periodontist were either current or past smokers, as compared to 54 percent of patients in general practices.[37] In fact, Haber and Kent[37] reported that patients with moderate to advanced periodontitis who were referred to a periodontal practice had 2.6 times the odds of a smoking history compared to patients in the general practice who had no history of periodontitis.

## Response to Periodontal Therapy in Smokers

Several studies have found that up to 90 percent of refractory periodontitis patients are smokers.[38-40] In a six-year longitudinal study, most of the patients with a high incidence of breakdown were smokers.[41] Among maintenance patients who were followed for five to eight years in a private periodontal practice setting, patients who smoked were more than twice as likely to lose teeth as nonsmokers.[33] Collectively, these studies clearly demonstrate that smoking impairs the response to periodontal therapy.

A number of clinical studies have compared the response of smokers and nonsmokers to various types of periodontal therapy, including nonsurgical and surgical therapy.[42-53] Most of these studies show significantly less improvement in clinical parameters among smokers than nonsmokers. In a six-year longitudinal study, smokers had approximately 50 percent less improvement in probing depth and clinical attachment levels than nonsmokers.[42]

Smoking has a strong negative impact on regenerative therapy, including osseous grafting,[54] guided tissue regeneration,[55,56] or a combination of these treatments.[57] After correcting for plaque and original defects, at one year smokers had significantly less attachment gain (2.1 + 1.2 mm) following guided tissue regeneration in infrabony defects as compared to nonsmokers (5.2 + 1.9 mm).[58] Poor oral hygiene, smoking, and lack of recall compliance were associated with breakdown over a five-year period following guided tissue regeneration or scaling and root planing.[59]

The majority of studies show that gingival grafting for root coverage is less successful in smokers than nonsmokers.[60-62] Some clinicians believe that smoking is a relative contraindication to dental implant therapy. Early failures, before loading, in the maxilla were higher in smokers (9 percent) than nonsmokers (2 percent).[63] Over an average of a thirty-eight-month follow-up, Bain and Moy[64] reported that implant failure rates were more than twice as high in smokers (11.28 percent) as nonsmokers (4.76 percent). Effects were most pronounced in the maxil-

lary arch, where the failure rate for smokers was 16.82 percent in the anterior region as compared to 3.60 percent in nonsmokers. In a fifteen-year longitudinal study of implants supporting mandibular fixed prostheses, only 1 percent of implants were lost, but smokers demonstrated significantly more bone loss than former or never smokers.[65]

# Other Forms of Tobacco and Periodontal Status

In the United States, cigar consumption declined by 66 percent from 1964 until 1993. However, between 1993 and 1997, overall cigar consumption increased almost 50 percent.[66] This increase has been attributed to cigar smoking among young adults who tend to smoke specialty cigars.[67] Data from the Veterans Administration Dental Longitudinal Study,[12] which was begun in 1968, demonstrated that both cigar and cigarette smokers had significantly more bone loss than nonsmokers ($p<0.01$), and there was a trend for pipe smokers to have even more bone loss than nonsmokers ($p=0.17$). As compared to nonsmokers, the relative risk of tooth loss in pipe and cigarette smokers was 1.6 as compared to 1.3 in cigar smokers. This study included 690 subjects, 50 of whom were cigar smokers, 32 pipe smokers, 141 cigarette smokers, and 477 nonsmokers. Therefore, the number of cigar and pipe smokers was relatively small.

In 1991, 5.3 million (2.9 percent) of U.S. adults were current smokeless tobacco users. Regional differences exist in usage, with smokeless tobacco use most popular in the southern United States and in rural areas. Data from 1997 showed differences in prevalence of more than sixfold, from 1.4 percent in Arizona to 8.8 percent in West Virginia.[68] In men the prevalence of use is greatest among young males aged eighteen to twenty-four years and for women among those aged over seventy-five years.[69] However, these figures do not include individuals under eighteen years, and this is where the greatest increase in use has been seen. Advertising targets young males, associating smokeless tobacco use with virility, athletics, and the great outdoors. Approximately 16 percent of high school male students report use of smokeless tobacco in the past thirty days. Among young females use remains low at 1.5 percent.[70]

Unlike cigarette smokers, who experience widespread periodontal destruction, the oral effects of smokeless tobacco are localized to the site of placement. The primary periodontal alteration in smokeless tobacco users is localized gingival recession. In general, gingival recession occurs in 25-30 percent of these users, and white mucosal lesions occur in 50-60 percent of users.[71-73] The higher prevalence of mucosal lesions as compared to gingival lesions is probably due to the closer proximity of the tobacco to the mucosal tissues.

Although the severity of white mucosal lesions is related to the amount and duration of smokeless tobacco use,[74] it is noteworthy that these alterations are seen in teens that have used tobacco for short periods of two to three years. In one study, 56 percent of smokeless tobacco users developed white lesions within seven days of placement of smokeless tobacco at a new site.[75] Inflammatory mediators, such as prostaglandin E2 (PGE2) and interleukin–1 (IL-1) are elevated in these developing sites,[75] and IL-1 remains elevated in the established lesion.[76] In the developing lesion, the pro-inflammatory effects of these mediators likely contribute to the observed erythema. In addition, both PGE2 and IL-1 influence keratinocyte proliferation,[77,78] which has implications for development of the hyperplastic epithelial lesion. Exposure of keratinocytes[79] and monocytes[80] to aqueous extracts of smokeless tobacco increases production of these mediators and increases keratinocyte proliferation.[81]

The majority of the white mucosal lesions regress when the smokeless tobacco habit is discontinued. Martin and coworkers[82] reported that among healthy, male Air Force basic trainees, 97 percent of smokeless tobacco-induced lesions resolved within six weeks of tobacco cessation. In another study, 22 percent of lesions resolved one week after tobacco exposure ceased.[75] The clinician can use this information to guide decisions regarding the timing of biopsies in smokeless tobacco users.

# Pathogenesis of Smoking-Related Periodontal Destruction

## Microbial Effects

The increased prevalence and severity of periodontitis in smokers cannot be explained by differ-

ences in the amount of plaque between smokers and nonsmokers.[6,13,18,24,35,83,84] Another possible explanation is that smoking may alter the quality of the flora. The oxygen tension in the periodontal pocket is lower in smokers, which may favor anaerobic species.[85] Several studies indicate that the types of bacteria in smokers and nonsmokers did not vary significantly,[86-89] but data from the Erie County Study[90] demonstrated that current smokers were 3.1 times more likely to exhibit Actinobacillus actinomycetemcomitans infection and 2.3 times more likely to be infected with Bacteroides forsythus than former or never smokers. In another study, smokers were eleven times more likely to have a positive BANA reaction than nonsmokers.[91] A positive BANA reaction indicates the presence of Porphyromonas gingivalis, Trepenema denticola, or B forsythus, which hydrolyze the trypsin substrate.[92] One explanation for these findings is that pathogens may be more difficult to eliminate in smokers. After scaling and root planing, fewer current smokers were negative for P. gingivalis and B. forsythus ($p < 0.008$), compared to never smokers and former smokers.[45] Renvert and coworkers[48] also reported that A. actimomycetemcomitans was more difficult to eliminate in smokers.

## Impact of Smoking on Host Response

The primary etiology of periodontal disease is bacteria; however, the host response determines a patient's susceptibility to disease. There is strong evidence that smoking affects the innate and immune host responses.[93] The findings of decreased inflammation[26,27,94] and reduced gingival crevicular fluid volumes in smokers as compared to nonsmokers[95] suggest that smoking impairs gingival blood flow. However, studies examining the effects of nicotine or smoking on gingival blood flow have shown conflicting results.[96] These varied results are likely related to the dose of tobacco components, timing of measurements, and methodology employed to assess blood flow. Smoking impairs revascularization of bone[97] and soft tissues,[98] which could have a major impact on wound healing, particularly as it relates to regenerative and periodontal and implant therapies.

Neutrophils are the first line of defense against bacterial infection, and although smokers actually have significantly higher numbers of neutrophils in the peripheral circulation,[99] their function is impaired. Neutrophils from smokers have shown decreased chemotaxis,[100] phagocytosis,[38,101] and adherence.[38] In vitro nicotine or smoke treatment can inhibit production of superoxide and hydrogen peroxide by stimulated neutrophils,[102,103] which may inhibit microbial killing mechanisms and thus impair the host's ability to combat periodontal infection. On the other hand, smoke exposure of unstimulated neutrophils has been shown to elevate the oxidative burst,[103] which could enhance tissue destruction through direct and indirect toxic effects. These various effects of smoking on neutrophil function may exacerbate smoking-related periodontal disease.

Antibody production is another protective host mechanism that is altered by smoking. It is a fairly consistent finding that smoking decreases serum IgG concentrations.[104,105] Serum IgG antibodies to certain periodontal pathogens have been reported to be reduced in smokers,[16,106] and patients with aggressive periodontitis have decreased IgG2.[107,108] One of the mechanisms to explain this finding is that smoking decreases the proliferative capacity of T-cells, which affects B-cell function and antibody generation.[93]

Another factor to consider is that many of the tobacco components may be toxic to cells. In vitro nicotine treatment of root surfaces impairs fibroblast attachment.[109,110] Volatile components of cigarette smoke (acrolein and acetaldehyde) have also been shown to inhibit gingival fibroblast attachment and proliferation.[111] Fibroblasts exposed to nicotine produce less fibronectin and collagen, whereas collagenase production was increased.[112] These deleterious effects on fibroblast functions could impact wound healing and periodontitis progression.

Smoking also has negative effects on bone metabolism. By the time they reach menopause, women who smoke one pack of cigarettes a day throughout their adult lives will have an average deficit in bone density of 5-8 percent.[113] Recent reports suggest that the combination of smoking and low systemic bone density negatively affects alveolar bone height1[14] and density in postmenopausal females.[115]

Smoking may influence osteoporosis and periodontitis by similar mechanisms. Of relevance to female smokers is that estrogen metabolism is altered by smoking.[116] Estrogen deficiency is associated with elevations in IL-1, interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-alpha),[117,118] which may affect both alveolar and systemic bone status. Tobacco components have also been shown to have direct effects on certain bone resorptive mediators. The

combination of nicotine and bacterial lipopolysaccharide (LPS) increased PGE2 secretion by peripheral monocytes.[119] Nicotine treatment increased IL-6 production by cultured murine osteoblasts.[120] In human smokers, Tappia et al.[121] reported that smokers exposed to LPS had significantly higher plasma levels of TNF alpha and IL-6 than nonsmokers. Elevated levels of TNF-alpha have been found in gingival crevicular fluid (GCF) of smokers.[122]However, no difference in GCF IL-1 beta or IL-1 receptor antagonist was identified between smokers and nonsmokers.[123] Although nicotine increases IL-1 alpha and beta production by keratinocytes,[124] it does not affect IL-1 beta secretion by peripheral monocytes or gingival mononuclear cells.[119,125] In fact, the combination of nicotine and LPS tends to downregulate IL-1 beta secretion.[102,119] These findings indicate that different cell types respond differently to nicotine exposure. Furthermore, while nicotine is the most widely studied component of tobacco, tobacco products contain thousands of chemicals that have the potential to influence host response, and additional clinical studies are needed to clarify the effect of smoking on cytokine production.

## Effects of Tobacco Cessation on Periodontal Status

The periodontal status of former smokers ranks between that of never smokers and current smokers,[11,13,17,34,37] which suggests that smoking causes some irreversible changes in the periodontium but that the deterioration does not continue after cessation. It is encouraging to note that former smokers respond to periodontal therapy in a manner similar to nonsmokers.[43,45] Furthermore, there does not appear to be a relationship between numbers of years since cessation and treatment response.[45] In fact, Bain[126] reported that patients who cease smoking between one week before and eight weeks following implant placement had success rates similar to nonsmoking patients. Older women with poor bone density were the least likely to benefit from cessation. Collectively, this data provides a strong basis for tobacco cessation counseling in the dental office.

## Summary

Tobacco users are at increased risk for oral disease. In smokeless tobacco users, the primary alterations are white mucosal lesions and gingival recession at the site of tobacco placement, which occur in 50-60 percent and 25-30 percent of smokeless tobacco users, respectively. Evidence supports smoking as a risk factor in chronic (adult) periodontitis and periodontitis in young adults, as well as refractory periodontitis. Smokers are approximately three times more likely to have severe periodontitis than nonsmokers and exhibit about half as much improvement following periodontal therapy as nonsmokers. Given the overwhelming evidence of the negative impact of tobacco on periodontal status and the response to periodontal therapy, the American Academy of Periodontology's Parameters of Care[127] recommends tobacco cessation therapy for the periodontal patient when appropriate. It is encouraging to note that clinical studies demonstrate periodontal disease progression slows in patients who quit smoking and that these individuals have a similar response to periodontal therapy as nonsmokers. These facts are important for treatment planning and are powerful motivating factors for dental health professionals to use in tobacco cessation counseling.

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