WJARR

World Journal of
Advanced
Research and
Reviews

World Journal Series
INDIA

(REVIEW ARTICLE)

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Smoking as an environmental hazard to the periodontal and peri-implant tissues: A brief review

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Abstract

While dental plaque is considered the etiological factor for the development of periodontal and peri-implant diseases, many studies from recent years point to smoking as the most significant environmental factor contributing to disease severity. This effect is evident at the epidemiological level as well as on our understanding of the biological mechanisms involved. The present review presents abundant scientific evidence showing that smoking negatively affects the local blood supply, interferes with the reaction of the immune system to bacterial insult, is toxic to gingival and periodontal ligament cells, impedes the response of the periodontal attachment apparatus to treatment, and is linked to dental implant failure.

Over the past 30 years, more than 200 million people have died as a result of smoking tobacco use. There are more than 1 billion current smokers worldwide and these numbers are likely to increase over the coming years. And yet, the effect of smoking on periodontal and peri-implant health has been a controversial issue. It was argued, that it is difficult to prove such an effect due to poor adherence of smokers to oral hygiene, which creates a confounding factor inseparable from the effect of the smoking itself. Unfortunately, even some of the more recent publications cast doubt as for the importance of smoking cessation on peri-implant health, as a prerequisite for a successful treatment.

The aim of the present review was to question the validity of these reports by presenting multiple evidence to support the quiet widely accepted common knowledge that is the numerous hazards to the oral biology which are the result of a heavy and prolonged smoking habit.

Keywords: Periodontitis; Periodontal-therapy; Peri-Implantitis; Implant-Success; Smoking;

1. Epidemiological and Clinical Observations in Smokers

The rate of smokers decreases with age and is about 35% at age 35 and 12% at age 75 [1]. A recent study found that the rate of current smokers in the US is 5% and about 60% for former smokers. The incidence of periodontal disease is twice as high in smokers (25%) as compared to non-smokers (13%) [2]. In 28% of smokers (S), at least one site was found with loss of periodontal attachment (CAL) as compared to only 9% among non-smokers (NS). There is an increased risk (Odds Ratio (OR) =3) for periodontal disease in subjects who smoke half a pack per day, while those who stopped smoking within the last two years are still with a similar risk. Moreover, OR of 6 was found between smoking a pack and a half a day and periodontal disease. The authors of the research state that smoking might explain about half of all periodontitis cases [3]. Advanced periodontal disease was found in 15% among S, compared to just 3.5% among NS [4]. In a longitudinal study in Sweden, only 9% of examined patients without periodontitis where smokers in

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comparison to 38% in the NS group. In that study, an increased risk of OR=20 was found for smoking and periodontitis [5]. A higher percentage of smokers was found among advanced periodontitis patients (58%) as compared with those who were diagnosed with an initial disease (10%). Smokers have an OR of 12 to be diagnosed with advanced periodontitis compared to the mild form [6] . More smokers were found with rapidly progressing than with adult periodontitis [7]. In S, there is a constant increase in clinical attachment level (CAL), measurable pocket depth (PD) and number of missing teeth. At a younger age, the difference is mainly in pocket depth (PD) and CAL. In the older age, this difference is mainly in CAL and missing teeth.

The relationship between age and smoking is additive but not synergistic. For S under age 40 the same CAL was found as for NS over age 50. Each year of age adds 0.02 mm to CAL while every pack year adds 0.01 mm [8, 9]. A longitudinal study found that CAL is three times higher in smokers. There is a correlation between cotinine level and CAL. A five-fold increased risk was found for advanced CAL in smokers [10]. In a ten-year longitudinal study, Bergstrom and colleagues found, that there was a decrease in height of the alveolar ridge in S but not in NS is spite of the periodontal treatment provided. No difference was found between S and EX-smokers (ES). There is a significant impact for duration and the amount of smoking [11]. Smokers have more angular bone resorption lesions. Bone loss over two standard deviations (SD) from average exists only in smokers. Smoking has an effect on bone resorption and also on formation of angular bony lesions. In about 74% of the young patients and 100% of adults who smoke, bone resorption is about 2 SD above the mean [12]. Rate of CAL as expressed in recessions is twice as high, mostly on the buccal side [13].

Smoking, is also associated with a greater tooth loss [14]. In a ten-year longitudinal study, the difference was reflected in increased number of teeth lost in smokers (4 teeth) compared to non-smokers (2.5 teeth), but no difference in CAL or PD. This difference is not accompanied by a parallel difference at the level of cotinine in the crevicular fluid [15]. Smokers have about 16 teeth on average, compared to 23 in NS [13]. From a group of patients with Generalized-Early Onset Periodontitis, about 70% were smokers vs. only 40% with Localized - Early Onset Periodontitis [16]. At age 75, about 41% of smokers are toothless compared to only 35% of NS. The difference in the number of missing teeth between non-smokers and smokers increased from a younger age (0.6) to adults (5.8). The difference in reduction of the level of periodontal attachment also increases from a younger age (0.4) to adults (1.3) [1]. Among the few studies, with conflicting conclusions is the one by Bostrom et al., who argued that there is no difference in clinical indices between S and NS [17]. Also, no correlation was found between sites with CAL and pack years in the Chinese population [18].

2. Plaque levels and the microbiological profile

As for quantity and composition of biofilm, according to some studies, it can be concluded that there is no difference between S and NS [1, 8, 10, 17]. In contrast, Gunsolley and colleagues argue that these are higher in smokers [13]. Eighty six percent of surfaces were found with plaque in S in comparison to 65% in NS or in former smokers (ES). Other investigators suggest that the effect of smoking is thus reversible [19] and there is more plaque and sites with PD >4 mm in S after age 40 [12]. In S there is an 11-fold probability for the presence of periodontopathic bacteria compared to NS [20]. Levels of *Bacteroides forsythus* are higher in S, especially in pockets of medium depth [21]. In a sample of S without periodontal disease, at least one periodontopathogen was found in 30% of cases compared to 0.5 % in NS. An OR of 18 was found between smoking and the presence of periodontopathogens [22] and OR = 9 for the presence of positive N-benzoyl-dL-arginine-2-napthylamide (BANA) bacteria. Also, there is an OR = 5 between former smokers and the presence of positive BANA bacteria [23] and OR = 1.5 between smoking and presence *B. forsythus* [4] and elevated levels of *Treponema denticola* in pockets of S [24]. An opposing view but in minority, stands the opinion of Darby et al., who state that there is no microbiological difference between S and NS [25].

3. Local blood supply and gingival inflammation

Lower oxygen pressure in the gingival tissues was found in smokers, although there is no decrease in saturation of oxygen in their blood hemoglobin. A positive correlation exists in nonsmokers between PD and PO_2. This correlation does not exist in smokers. In healthy gingiva the oxygen pressure is higher in nonsmokers [26]. No difference in blood flow between S and NS in short term reaction to controlled smoking [27] was observed. However, following local infiltration of anesthetic, a 25% higher resistance is measured in S compared to NS (28). Most of the studies, point to lower bleeding index in S [2, 8, 17, 21]. Also, bleeding index following probing is lower in S [9, 25]. Bleeding index at the gingival margin is only 15% in S compared to 30% in NS. Bleeding at the pocket base was found to be 27% in S as compared to 44% in NS. The transition from a healthy state to gingivitis is faster in NS [29]. Gingival index is lower in S in spite of a similar disease severity as in NS [30]. Bleeding index is 36% in NS compared to 14% in S. Moreover, smokers possess one more tooth with furcation involvement as compared with NS [31]. In contrast, Kinane et al. suggest that no difference exists between S and NS in bleeding after probing [1, 12, 32]. However, more bleeding after probing and less

reduction in pocket depth was found in S following therapy [33, 34, 35]. Only one study showed higher gingival index and crevicular fluid in S without periodontal disease [36].

4. Immune system

A decrease in IgG_2 level was found in smokers with Generalized-Early Onset Periodontitis [37, 38, 39]. According to Persson and colleagues, in S similar levels of Lactoferrin and elastase, but lower levels of antitrypsin and lower concentration of macroglobulin compared to NS in medium and deep pockets were found. Since these are antibacterial enzymes produced by polymorphonuclear cells, this difference may reflect a diminished responsiveness of the immune system in smokers [40]. Moreover, smoking has a negative effect on the PMN count, antitrypsin and lgG levels, but not on the formation of free radicals by polymorphonuclear cells [41]. *In vitro*, nicotine combined with lipopolysaccharide of *P. gingivalis*, increased PGE_2 but not Il-1β secretion by peripheral mononuclear cells. The combination between them has an additive effect resulting in a higher level of PGE_2 than each substance alone [42]. TNF-α levels were 3 times higher in S as compared to ES, and five times higher in ES versus NS. No correlation was found between PD and TNF level, but TNF-α level was higher in smokers [17]. In contrast, no difference was found between S and NS in PGE_2 levels. In patients with periodontal disease, higher levels can be found than in patients with gingivitis [43]. There is no difference in lg, Il1-β and Il1-α between NS and S. An OR=7 was found between smoking and advanced periodontal disease, but only 1.7 combined with smoking and a positive genotype of Il-1β and advanced disease [44].

5. Toxicity

Arecoline and nicotine synergistically act as inhibitors of proliferation of fibroblast from the PDL and diminish protein synthesis [45]. Nicotine inhibits proliferation, chemotaxis, and adherence of fibroblasts from the PDL in a manner which is concentration dependent [46]. A synergism exists between bacterial endotoxin and nicotine which is formed during smoking. For example, LPS alone at a sub-clinical concentration does not kill fibroblasts, but only in combination with nicotine [47]. In the tissues there are more free radicals in S. Injection of nicotine to animals in combination with ligature placement promotes plaque formation and bone resorption [48]. Smoking inhibits fibroblasts adherence, ALP activity and chemotaxis of PDL cells [46]. It has been found that nicotine interferes with the intercellular adherence capabilities (β-integrin) of fibroblasts [49]. In summary, smoking has inhibitory influence on positive processes but does not interfere with negative ones that promote the propagation of periodontal diseases [50].

6. Response to Treatment

Clinical reduction in pocket depth was found to be smaller in S after phase 1 therapy [51]. Following full mouth disinfection, in which treatment is performed within 24 hours, more gain is obtained in periodontal attachment as compared to the standard protocol (quadrants technique). The difference between these protocols is greater in NS [52]. Repeated scaling and planing of roots in smoking patients with recurrent periodontal disease does not contribute to clinical improvement [53]. In S, there is less improvement in periodontal attachment (1.8 mm), than in NS (2.8 mm), in pocket depths over 6 mm. In S, there is 1.4 times higher probability not to improve their PD to below 3.0 mm and CAL more than 2.0 mm [54]. The mean reduction of PD is 2.5 mm in NS compared to 1.9 mm in S after initial periodontal treatment. In S there is some reduction in PD and an improvement in periodontal attachment, but not in furcation lesions. Furthermore, they have a greater deterioration during maintenance [55]. After removing calculus and root planing there is less benefit in S in pocket depth changes and attachment levels [56]. Response to surgical treatment and expected change in bone height after five years is 1% in S compared to 7% in NS. There was however no difference between S and NS groups before treatment [17]. In S, there is no correlation between initial condition and post-treatment improvement. The lack of correlation is more pronounced in deep pockets. The changes were observed mostly in PD, but not in CAL or bleeding during probe examination [31]. Percentage of sites with improved attachment after initial treatment is higher in NS (14%) compared to S (9%). There was less loss of CAL in non-smokers and no bone loss over the study period [57]. About 11% of NS patients required postoperative surgical initial treatment vs. 42 % among S [58].

Microbiologically, levels of *B. forsythus* and *P. gingivalis* in S were higher after periodontal treatment compared to NS [59]. The reduction in the *Spirochete* rate was smaller in S after removal of calculus and planing of roots [51]. There is no decrease in *T. denticola*, *B .forsythus* and *P.gingivalis* levels after initial treatment in S [60]. Moreover, no decreased PD and CAL were observed. A smaller decrease was measured in PD in S about six months after initial treatment and more bleeding found on examination with a probe and the presence of the bacterium *Aggregatibacter actinomycetemcomitans* [32].

Following guided tissue regeneration and gingival grafting, 100 % of cases were found with membrane exposure in S compared to 50 % in NS. Also, in cases where the membrane has been exposed there was a decrease of 50 % in periodontal attachment gain. In S more recession developed following treatment [61, 62] with no significant gain in periodontal attachment using a membrane compared with the control [63]. Using a resorbable Guidor membrane, there is twice as much bone filling in the intra bony lesions in NS [64]. After treatment, recession was measured 0.1 mm in NS compared to 1.3 mm in S. Resorption of the alveolar crest was close to 0 mm in NS compared to 0.7 mm in S. Resolution of horizontal furcation, was about 2.8 mm in NS compared to 1.5 mm in S [65]. There was a non-resorbable PTFE membrane exposure at a higher rate in S. Parallelly, reduction of recession was smaller in S (2.5 mm, 57 % coverage) compared to NS (3.6 mm, 78% coverage) [61]. Thus, smoking negatively affects mucogingival root coverage procedures [66].

7. Dental Implant Failure

From the first publications reporting the consequences of smoking on the success of implants, Bain & Moy's research stands out encompassing more than 2,000 implants over six years. The authors of the article conclude that the rate of failure in smokers, is more than double (11%) in comparison to non-smokers (4.7%) [67]. These differences between groups were expressed in all areas of mouth except in the posterior mandible [67, 68]. Smoking cessation (ES), improves success rates compared to S, without difference between the ES group and the non-smoking group [69]. Around implants in smokers, there are more sites with mucositis, deeper pockets and more advanced bone resorption compared with implants in non-smokers [70]. Smokers are 2.5 times more likely to implant failure within 4-6.5 years following actual placement and augmentation with bone mineral [71]. At follow-up of 60 months in implants inserted into the maxillary sinus area after augmentation, a success rate of 82% was recorded in NS compared to only 67% in smokers [72, 73]. A recently published article emphasizes the following factors that were identified as risk indicators for peri-implantitis: smoking (OR = 3.59;), moderate/severe periodontitis (OR = 2.77), <16 remaining teeth (OR = 2.23), plaque (OR = 3.49), implant malposition (too vestibular implant placement: OR = 2.85), implant brand (OR = 4.41), restoration type (bridge vs. single crown: OR = 2.47), and trauma as reason of tooth loss (vs. caries: OR = 6.51) [74].

8. Peri-implant complications in Patients with a History of Periodontitis and Supportive Periodontal Therapy

Abundant data is available showing higher rates of peri-implant disease in patients diagnosed with periodontitis. For example, Hardt et al. [75] have found that after 5 years, 24% of the patients without periodontal disease lose above 2 mm of bone surrounding the implants. In comparison, this figure is more than 60% for patients diagnosed with periodontitis. Karoussis et al. [76] shows that while implant failure rate in patients losing teeth from non-periodontal reasons after 10 years of follow-up was only 4%, in patients losing teeth due to poor periodontal prognoses, this figure is much higher, at about 10%.

A greater deterioration in periodontal indices were found in S [55] during supportive periodontal therapy. Twelve months following periodontal treatment, 3-fold more CAL loss was noted along with recession in S. There were twice as many smoking patients with bone loss after taking in account confounding factors such as education and income. Positive correlations were found between CAL and blood cotinine level, and between *B. forsythus* levels and PD in S [11]. Smoking was a significant, negative predictor for supportive periodontal treatment duration [77]. Qualitatively, significantly less smokers returned for SPT than non-smokers or former smokers [78].

9. Conclusion

In a special edition of the Journal of Clinical Periodontology published recently, Berglundh et al. stated that data identifying smoking as potential risk indicators for peri-implantitis are inconclusive [79]. Another study, suggested that Periodontitis and Periimplantitis are two distinct diseases [80]. Combining these two notions together might create a dangerous impression for the readers that maybe, a smoking patient is at no greater risk for implant failure just because he smokes. Moreover, since abundant evidence exists as to the higher incidence of periimplantitis in periodontally susceptible patients, these two diseases cannot be truly separated for smokers.

So, while dental plaque is considered the etiological factor for the development of periodontal and peri-implant diseases, many studies from recent years point to smoking as the most significant environmental factor contributing to disease severity. This effect is evident at the epidemiological level as well as the biological mechanisms involved. The abundant data presented here, unequivocally support the view that smoking negatively affects the local blood supply and gingival

inflammation, interferes with the reaction of the immune system, is toxic to gingival and periodontal ligament cells, impedes the response of the periodontal attachment apparatus to treatment, and is linked to dental implant failure.

Therefore, patients seeking our treatment should be informed of the dangers posed by their smoking and urged to get professional help for smoking cessation prior to giving full consent to being treated. The dental professionals hold a key position as health providers not only as far as oral health is concerned, but as part of a global effort to combat this harmful addiction [81].
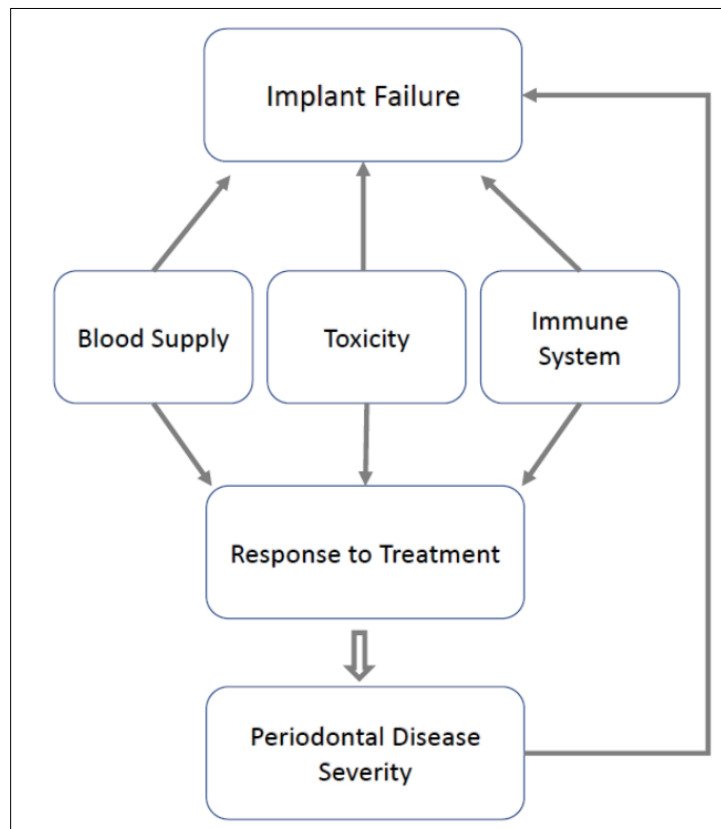
Figure 1 Diagram representing the effect patterns smoking has on the periodontal and peri-implant health

Compliance with ethical standards

Disclosure of conflict of interest

The corresponding author states that no conflict of interest was involved in writing this paper

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