REVIEW ARTICLE

Effects of smoking on the outcome of implant treatment: A literature review

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ABSTRACT

Statement of Problem: The use of osseointegrated implants as a foundation for the prosthetic replacement of missing teeth has become widespread in the last decade. Owing to the remarkable success of dental implants, there has been growing interest in identifying the factors associated with implant failure. Given the well-documented deleterious effect of smoking on wound healing after tooth extraction and its association with poor quality bone and periodontal disease, a negative effect of tobacco use on implant success is to be expected.

Purpose: To establish the relationship between smoking and implant-related surgical procedures (i.e., sinus lift procedures, bone grafts and dental implants), including the incidence of complications related to these procedures and the long-term survival and success rates of dental implants among smokers and nonsmokers based on relevant literature.

Materials and Methods: Relevant clinical studies published in English between 1990 and 2006 were reviewed. The articles were located through Medline and, manually, through the references of peer-reviewed literature. This was supplemented with a hand search of selected dental journals and text books.

Results: The majority of the past and current literature implicates smoking as one of the prominent risk factors affecting the success rate of dental implants with only a handful of studies failing to establish a connection. Most of the studies report the failure rate of implants in smokers as being more than twice that in nonsmokers. These findings are difficult to ignore. There is a statistically significant difference between smokers and nonsmokers in the failure rates of dental implants. Smoking also has a strong influence on the complication rates of implants: it causes significantly more marginal bone loss after implant placement, it increases the incidence of peri-implantitis and affects the success rates of bone grafts. The failure rate of implants placed in grafted maxillary sinuses of smokers is again more than twice that seen in nonsmokers.

Conclusion: Smokers have higher failure rates and complications following dental implantation and implant-related surgical procedures. The failure rate of implants placed in grafted maxillary sinuses of smokers is more than twice that seen in nonsmokers.

Key words: Cessation, dental implants, failure, nicotine, recommendations, smoking, success

INTRODUCTION

Cigarette smoking has been found to have deleterious effects in the oral cavity due to increase in plaque accumulation, higher incidence of gingivitis and periodontitis, higher rate of tooth loss and increased resorption of the alveolar ridge.[1]

Smoking has also been associated with poorer healing after mucogingival surgery and this has been attributed to the more frequent occurrence of refractory periodontitis.[2-4]

Nicotine may have an effect on cellular protein synthesis and may impair the gingival fibroblast's ability to adhere, thus interfering with wound healing and/or exacerbating periodontal disease.[5] Cigarette smoke may have a cytotoxic effect on human gingival fibroblasts, which results in a decrease in their capacity for adhesion and proliferation.[6] This could result in impaired maintenance, integrity and remodeling of oral connective tissue.

Sheiham[7] suggested that although periodontal breakdown was generally higher in smokers, this was associated with poor oral hygiene and was simply caused by the increased volume of plaque and not by the smoking itself. However, some other studies have also shown that patients who smoke have an increased risk for both the occurrence and
the severity of periodontal disease. Tobacco produces a greater loss of alveolar bone height in smokers than in nonsmokers, even when the former maintain a good level of hygiene. This suggests that tobacco itself can directly produce periodontal bone loss, regardless of bacterial plaque levels, which are known to be the main etiological factors in the onset of periodontitis and peri-implantitis. The exact mechanisms by which tobacco exerts its influence on periodontal breakdown are not completely known. It is likely that smoking primarily has a systemic influence by altering the host response and/or by directly damaging the periodontal cells.

The direct cutaneous vasoconstrictive action of nicotine, the increased levels of fibrinogen, hemoglobin and blood viscosity, excessive levels of carboxyhemoglobin in blood, compromised polymorphonuclear neutrophil (PMN) leukocyte function, as well as increased platelet adhesiveness have all been hypothesized to be mechanisms by which smoking compromises wound healing.

The use of osseointegrated implants as a foundation for the prosthetic replacement of missing teeth has become widespread in the last decade. Owing to the remarkable success of dental implants, there has been growing interest in identifying factors associated with implant failure. Given the well-documented deleterious effect of smoking on wound healing after tooth extraction and its association with poor quality bone and periodontal disease, a negative effect of tobacco use on implant success is to be expected.

In light of the facts presented, it becomes important to establish the effect of smoking on implant-related surgical procedures (i.e. sinus lift procedures, bone grafts and dental implantations). It is also necessary to study the literature on the incidence of the complications related to these procedures and the long-term survival and success rates of dental implants among smokers and nonsmokers. These facts will assist dental professionals in formulating treatment plans and provide them with important information to share with patients who are users of tobacco products so as to obtain informed consent prior to surgery.

**REVIEW OF LITERATURE**

The aim of this current literature review is to present the studies related to the effects of smoking on dental implant success. This review identifies the conclusions and shortcomings of the studies and presents recommendations for improving treatment outcomes. Relevant clinical studies written in English between 1990 and 2006 were reviewed. The articles were searched through Medline and, manually, through the references of peer-reviewed literature.

Bain and Moy in 1993, were the first to evaluate the influence of smoking on the failure rate of dental implants. They compared the results between dental implants placed in smokers vs those placed in nonsmokers. The overall failure rate of 5.92% was found to be consistent with other studies; however, when patients were subdivided into smokers and nonsmokers, it was found that a significantly greater percentage of failures occurred in smokers (11.28%) than in nonsmokers (4.76%) (P<0.001). The findings of this study, for the first time, identified smoking as a major factor in implant failure. Subsequently, a few other studies also implicated smoking as a leading cause of implant failure.

Bain and Moy also found differences between moderate and heavy smokers, with increased tobacco use correlated to an increased implant failure rate. The authors have found that the prevalence of Type IV bone was twice as high among heavy smokers as compared to nonsmokers or even light smokers.

A smoking cessation protocol was put in place by Bain in 1997 and he found through his study that there was a statistically significant difference in the failure rates between those who continued to smoke and those who were on the protocol. Because all failures occurred prior to prosthetic loading, they were not likely to be a result of prosthodontic overload or other external factors.

Other studies have also identified tobacco use as one of the statistically significant (P<0.004) factors associated with an increased risk of implant failure, with a hazard ratio of 4.3, i.e., the risk of implant failure in smokers is 4.3 times that in nonsmokers.

Specifically, rather than affecting the process of integration, the negative effect of smoking seems to occur after the second-stage surgery. Gorman et al., in his study of patients who had received over 2000 implants, found significantly more failures in smokers after second-stage surgery. After loading, the differences between smokers and nonsmokers were not significant, but there was no long-term follow-up of the patients. Lambert et al., also conducted a longitudinal study to assess the influence of smoking in a group of patients with over 2900 endosteal dental implants. The results did not show the expected early failure after the initial surgery but showed more failures after the second stage of surgery. The authors theorized that the effect of tobacco on healing after implant placement was different from that after tooth extraction, because implant wounds were closed and the intimate adaptation of the implant to the bone tissue did not allow the same magnitude of interference in healing by the vasoconstrictive action of nicotine. After the implants were uncovered, the soft tissues around them were adversely affected by tobacco in a manner similar to that by which periodontal tissues were adversely affected. Shuler and Armitage and Turner showed that nicotine also had a local vasoconstrictive effect.
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since it was absorbed through the oral mucosa into the blood vessels during smoking. Therefore, a dental implant may be doubly at risk.

Baelum and Ellegard\[29\] have shown, through their prospective longitudinal study in periodontally compromised patients, that smoking was associated with high failure rate. Implants were explanted in smokers at a rate which was 2.6 times higher than the rate of explantation in nonsmokers. Corroborating the findings of many previous studies,\[26,30-32\] the results of the present study also implicate smoking as a risk factor for implant failure as well as for the development of deepened pockets and inflammation around implants.

In another retrospective cohort study,\[33\] the risk factors for implant failure were determined by evaluating a total of 4,680 implants placed in 1,140 patients over a 21-year period from 1982 to 2003. Most of the subjects were followed up over 20 years. Smoking was found to be a significant predictor of implant failure, with a relative risk (RR) of 1.56 (P=0.03). Most of the failures occurred within the first year, with very few failing at later time points. Patients who disclosed a history of smoking had a failure rate of 20%. These failure rates were higher than the previously reported rates of 6.50% and 11.28% in smokers.\[20,25\] Age and location of implant, also, had a significant effect on failure rate. Implants placed within the maxilla experienced almost twice the failure rate of those placed in the mandible (P<0.001). Implants placed in the anterior mandible had the lowest failure rate of any location. Advanced age increased the risk of implant failure: patients older than 60 years were twice as likely to have adverse outcomes.

Galindo-Moreno et al.,\[34\] conducted a prospective clinical study to explore the possible link between peri-implant bone loss and the widespread habits of tobacco smoking and alcohol consumption. Although tobacco is described in the literature as one of the most influential etiological agents in peri-implant marginal bone loss, it did not appear to play such an important role in the present study. A mean peri-implant marginal bone loss of 1.66 mm was seen in alcoholics compared with a loss of 1.25 mm in patients who were nonalcoholics, a statistically significant difference. Alcohol induced more marginal bone resorption than tobacco in the present study.

A recent study by Nitzan et al.,\[35\] shows greater marginal bone loss among smokers, which is consistent with earlier studies.\[36,37\] In this study, maxillary bone was seen to be more sensitive to tobacco exposure. Others have also found the maxilla to be more susceptible to the deleterious effects of smoking. Bain and Moy\[20\] found that the smoking caused more implant failures in the maxilla than in the mandible. Lambert et al.,\[26\] also noted that in smokers, maxillary implants failed 1.6 times more often than mandibular implants. De Bruyn and Collaert\[21\] and Esposito et al.,\[32\] too, confirmed that smokers had a higher implant failure rate in the maxilla. Haas et al.,\[30\] also found the effects of smoking to be more damaging to the maxillary bone. Presumably, maxillary bone is of lower quality and, therefore, more susceptible to the detrimental effects of smoking.

There are some studies that have shown that the amount of cigarette consumption is associated with higher implant failures.\[31,38\] Fartash et al.,\[38\] published a prospective study on mandibular implant overdentures, citing higher implant failure in heavy smokers (30-40 cigarettes per day) with type IV bone. In addition, Lindquist et al.,\[31\] reported significantly greater marginal bone loss around implants in heavy smokers (>14 cigarettes per day) than in those with low cigarette consumption (<14 cigarettes per day).

A recent study\[39\] has also shown higher failure rates for former smokers and a dose-response effect between the duration of smoking and implant failure rates, suggesting that permanent tissue damage from smoking may occur in addition to the immediate local and systemic effects.

Two retrospective studies by Kan et al.,\[40,41\] published in 1999 and 2002, evaluated the effect of smoking and the number of cigarettes smoked, on the success rates of implants placed in grafted maxillary sinuses. There was a significantly higher cumulative implant success rate in nonsmokers (82.7%) than in smokers (65.3%) (P=0.027). Overall cumulative implant success rate was 76%. There was no correlation found between implant success rates and the amount of cigarette consumption. The values in this study seem to correspond to the results reported by Jensen et al.,\[42\] who found that the implant failure rate in grafted maxillary sinuses of smokers (12.7%) was more than twice that in nonsmokers (4.8%).

Though most of the available literature implicates smoking as a significant factor in implant failure, there are some reports that have shown no significant differences between smokers and nonsmokers in the success of implants. One such report was by Bain et al.,\[43\] describing the outcome of a meta-analysis of clinical studies on the integration, success and longevity of machined-surface implants and dual acid-etched implants; there was also an attempt to isolate the effects of smoking. Contrary to what had been reported in literature, this study did not show any differences in the cumulative success rates between smokers and nonsmokers after a follow-up of 3 years. One possibility is that the difference might have been significant; had the comparison been made between heavy smokers and nonsmokers. Also, smoking cessation during the studies were not recorded and accounted for. However, this study agrees with an earlier study done by Grunder et al.,\[44\] which also found no significant difference in implant failures between smokers and nonsmokers. Some other smaller studies have also failed to find a link between smoking and implant failures.\[45,46\]
Smoking has been specifically associated with a variety of implant complications, e.g. increased incidence of peri-implantitis (deep mucosal pockets around dental implants), inflammation of the peri-implant mucosa and increased resorption of peri-implant bone.[30,47] It has also been found to adversely affect wound healing and, thus, jeopardize the success of bone grafting and dental implantation.[40,45,48-50]

The most common augmentation procedures for dental implants include sinus lift operation and bone grafting. It is noteworthy that smoking is considered a contraindication for protocols such as bone regeneration and bone grafting.[51] Schwartz–Arad et al.[50,52] showed a complication rate following onlay bone grafts of 23.1% in nonsmokers compared to 50% in smokers. In the same study, major complications were found in one-third of the operations in smokers, compared to only 7.7% in nonsmokers (P=0.04). There was also a relationship between complications and past smoking, although it was not statistically significant (P=0.06). According to Haas et al.,[34] smokers are also likely to have detrimental effects around successfully integrated maxillary implants, with a significantly higher bleeding index, higher mean peri-implant pocket depth, more frequent peri-implant inflammation and radiographically higher mesial and distal bone loss.

**DISCUSSION**

The majority of the literature implicates smoking as one of the prominent risk factors affecting the success rate of dental implants, with only a handful of studies failing to establish a connection. Most of the studies have reported the failure rates of implants in smokers being more than twice that in nonsmokers.[20,24-26,29,33]

There is a statistically significant difference in the failure rates of dental implants between smokers and nonsmokers. Smoking also has a strong influence on the complication rates of implants in that it causes significantly more marginal bone loss after implant placement.[34-37] It also increases the incidence of peri-implantitis and adversely affects the success of bone grafts.[36-47,50-52]

The failure rates of implants placed in the grafted maxillary sinuses of smokers are again more than twice that seen in nonsmokers.[40-42]

In general, smoking appears to have a greater impact on maxillary implants than on mandibular implants.[21,36] DeBruyn and Collaert,[23] in a retrospective study of over 200 implants, found that prior to loading, there was a difference in the success rates in smokers between maxillary and mandibular implants. Maxillary success rates were adversely affected but those in mandible were not. Also, a study by Haas et al.[30] found peri-implantitis as being significantly worse in the maxilla in smokers than in nonsmokers, but this relationship was not found in the mandible.

Patients who quit smoking tend to have a reduction of the adverse effects of smoking on implant survival,[23,26] but the length of the time after cessation that is necessary for a significant improvement has not been sufficiently investigated.

If the vasoconstriction caused by the local absorption of nicotine into the bloodstream were a significant factor as shown by some studies,[27,28] it could well account for the lower failure rates in the posterior mandible among smokers, since it is the area most removed from the local influence of tobacco smoke and is, moreover, protected by the tongue. This aspect has to be further investigated.

Some studies have shown that there is no statistically significant, increased occurrence of complications in past smokers,[32] which indicates that the risk of complications can be reduced to the normal nonsmoker levels by cessation of smoking.

Following a protocol of complete cessation for 1 week before and 8 weeks after initial implant placement surgery, Bain[24] showed that implant failure was significantly lower in the group who stopped smoking than in those who continued. Furthermore, the failure rate was not significantly higher in the group who stopped smoking than in nonsmokers over the same period.

At the very least, smokers should be advised to follow a smoking cessation protocol, which is a logical step if we accept the fact that smoking has a detrimental effect on implant prognosis. The initial recommendations by Bain and Moy[20,23] suggest that long periods of abstinence are required. They suggested that the patient cease smoking at least 1 week prior to surgery to allow reversal of the increased levels of platelet adhesion and blood viscosity, as well as the shorter-term effects associated with nicotine. The patient should continue to avoid tobacco for at least 2 months after implant placement, by which time bone healing would have progressed to the osteoblastic phase and early osseointegration would have been established. They realized that this period would be perceived by some as unrealistic as far as compliance is concerned; however it had a biologic rationale. Prior to surgery, careful explanation of the harmful effects of smoking and of the patient’s responsibilities in the attempt to achieve the best prognosis would ensure the best obtainable level of compliance; this would also cover the clinician in the event of implant failure in a noncompliant patient. These early recommendations, though based on a sound rationale, were not substantiated by clinical research data.

Unfortunately, while most of the patients complete the protocol successfully and stay off smoking for several months, the vast majority return to smoking. It is left to the discretion of the clinician whether or not to undertake
implant treatment in high-risk situations, but should the surgeon decide to go ahead, the patient’s fully informed consent is essential before proceeding.

For heavy smokers, it is less likely that bone quality will improve significantly in such a short time.

There are some important factors to be kept in mind when deciding to proceed with implant treatment. First, the surgeon must consider the location of the implant. In the presence of a long history of smoking, an implant in the maxillary posterior area entails a high risk, even after applying the smoking cessation protocol. This is because of the long-term effect of smoking on the density of the bone. There is high chance of failure in such situations. Second, if the patient is unable to give up smoking, the decision to proceed with implant treatment has to be made by the clinician depending upon the number of cigarettes smoked, the risk of failure, etc. Some studies have shown that mild to moderate smoking has no significant effect on the implant failure rate. Informed consent plays a very important role, with the clinician explaining all the facts and getting the patient’s signature on the appropriate forms: the patient attests that all information has been conveyed, but he or she is unable to co-operate in spite of the warnings.

Based on the above review, we make the following recommendations:

1. The smoking history should first be obtained; this should include the duration of smoking, the intensity (past and present) and the present status. It is especially important to identify former heavy smokers who have recently stopped.

2. Appropriate oral hygiene instructions should be given and the deleterious effects of smoking on oral hygiene should be highlighted, with special mention made of the effect of smoking as a risk factor for periodontal disease. The periodontal status of the patient is also a valuable indicator of the prognosis.

3. The patient should then be advised of the poor prognosis of implants in smokers, especially in the maxillary region. Increasing the predictability of the success of dental implants is one strong reason why patients should be advised to stop smoking permanently.

**CONCLUSION**

1. There is a statistically significant difference in the failure rates of dental implants between smokers and nonsmokers. Smokers have a higher incidence of failure and complications following dental implantation and implant-related surgical procedures.

2. The failure rates of implants placed in grafted maxillary sinuses of smokers are more than twice that seen in nonsmokers.

**REFERENCES**


