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# The Effect of Cigarette Smoking on Dental Implants and Related Surgery

Liran Levin, DMD\* and Devorah Schwartz-Arad, DMD, PhD†

**C**igarette smoking has come under increasing attack by numerous groups, both within the United States and worldwide. This attack has been partially fueled by the recognition of the increasing number of diseases with which smoking has been directly or indirectly associated. Currently, in the United States, there are approximately 50 million smokers.<sup>1</sup> The adverse effects on the cardiovascular system are common knowledge<sup>2,3</sup> and are implicated in the etiology of many cancers.<sup>2,4</sup> Smoking is now the leading avoidable cause of morbidity and mortality in the United States, with more than 500,000 deaths/year in the United States alone.<sup>2</sup>

Nearly 4000 different gases and chemicals are released during cigarette smoking, including nitrogen, carbon monoxide, carbon dioxide, ammonia, hydrogen cyanide, benzene, nicotine, nornicotine, anatabine, and anabasine.<sup>5</sup> Nicotine, considered the addictive component of cigarette smoke, has been implicated in the pathogenesis of numerous diseases.<sup>6,7</sup> Carbon monoxide has a stronger affinity for hemoglobin than oxygen, resulting in the displacement of oxygen from the hemoglobin and a lower oxygen tension in tissues.<sup>8</sup> Current and lifetime tobacco smoking are also associated with deterioration in bone quality.<sup>9</sup>

The purpose of this article is to describe the relationship between cigarette smoking and implant-related surgical

*Cigarette smoking is still considered a common habit. Of smokers, increased plaque accumulation, higher incidence of gingivitis and periodontitis, higher rate of tooth loss, and increased resorption of the alveolar ridge have been found in the oral cavity. Cigarette smoking may adversely affect wound healing, and, thus, jeopardize the success of bone grafting and dental implantation. Bone grafts and sinus lift operations are both common and well-documented procedures before dental implant placement. Heat as well as toxic by-products of cigarette smoking, such as nicotine, carbon monoxide, and hydrogen cyanide, have been implicated as risk factors for impaired healing, and, thus, may affect the success and complications of those surgical procedures. An associa-*

*tion among dental implants, grafting procedures (i.e., bone grafts, maxillary sinuses augmentation), and history of smoking has been reported. A higher degree of complication, or implant failure rates, were found in smokers with and without bone grafts. The relationship between cigarette smoking and implant-related surgical procedures, including the incidence of complications associated with these procedures, will be described and discussed based on relevant literature and results of our recent studies. (Implant Dent 2005;14: 357–363)*

**Key Words:** *success, sinus lift operation, onlay bone graft, nicotine, wound healing*

procedures (i.e., sinus lift operations, bone grafts, and dental implantations), including the incidence of complications related to these procedures, and long-term survival and success rates of dental implants among smokers and nonsmokers. The discussion is based on relevant literature and results of our recent studies. The facts presented will assist dental health professionals in treatment-planning decisions and provide them with important information to share with patients who use tobacco products.

## THE ORAL CAVITY, PERIODONTIUM, AND DENTAL IMPLANTS

Of smokers, an increase in plaque accumulation, a higher incidence of gingivitis and periodontitis, a higher

rate of tooth loss, and an increased resorption of the alveolar ridge have been found in the oral cavity.<sup>10</sup> The exact mechanisms in which tobacco exerts its influence on periodontal tissues 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 use of endosseous implants has increased over the past decade in certain edentulous situations. Bain and Moy<sup>11</sup> assessed the various factors that predispose implants to failure in a group of 540 patients who received 2194 Bränemark System® implants (Nobel Biocare USA Inc., Yorba Linda, CA). The most significant factor was smoking. De Bruyn and Col-

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Procedure	Criteria	Smokers	Non-Smokers	P value
Dental implants	Marginal Bone Loss	0.15 mm	0.04 mm	0.001
	5-Year Cumulative Survival Rate	87.8%	97.1%	0.001
	Complications	46%	31%	0.05
Onlay Bone Graft	Complications	50.0%	23.1%	0.05
	Graft exposure and graft mobility (Graft Failure)	33.3%	7.7%	0.05
Sinus Lift Operation	Complications	66.7%	63.3%	NS

**Fig. 1.** Study results on the relationship between cigarette smoking and implant-related surgical procedures. These are findings of the authors' recent studies concerning the influence of cigarette smoking on cumulative survival rate, MBL, and the prevalence of complications, as well as smoking influence on implant-related surgical procedures (*i.e.*, sinus lift and bone graft procedures).

laert<sup>12</sup> found that smokers have a significantly higher failure rate before functional loading of implants than nonsmokers. Lindquist *et al*<sup>13,14</sup> compared marginal bone loss (MBL) around osseointegrated dental implants among smokers and nonsmokers. Of smokers who also had poor oral hygiene, MBL was nearly 3 times as high as that in nonsmokers. According to Haas *et al*,<sup>15</sup> smokers can 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.

It is difficult to assess adverse effects of smoking on the prognosis of implants on the basis of implant failure alone. Specific factors, such as type (*e.g.*, coating, design) of implant and immediate *versus* late implantation, can also be assessed and compared between smokers and nonsmokers. These factors, related to clinical complications, enable the evaluation of the survival rate of the implants.

Our observations revealed a significantly higher incidence of complications following dental implantation among smokers. When the number of

cigarettes/day and smoking years were considered, a significantly higher incidence of complications was found in relation to quantity and duration of smoking. In the smokers group, there were more complications, regardless of the time of implantation (immediate *vs.* nonimmediate) (Fig. 1).<sup>16-18</sup>

In a subsequent study, the influence of smoking on MBL around implants was examined. In the maxilla, heavy smokers (>10 cigarettes/day) had the highest amount of bone loss, followed by mild smokers (<10 cigarettes/day) and nonsmokers. In the mandible, there was no distinction between heavy and mild smokers, and both had higher MBL than nonsmokers. Overall success rate for all implants was 93.2%. Nonsmokers had a higher success rate (97.1%) than smokers (87.8%) ( $P < 0.001$ ) (Fig. 1).

## WOUND HEALING

Cigarette smoking has long been suspected as adversely affecting wound healing. Arteriolar vasoconstriction and decreased blood flow are seen in response to smoking.<sup>11,12</sup> Toxic by-products, such as nicotine, carbon monoxide, and hydrogen cyanide, have been implicated as risk factors

for impaired healing.<sup>19</sup> Smoking impairs wound healing in various surgical operations, such as orthopedic (hip or knee arthroplasty, open tibial fractures)<sup>20,21</sup> and plastic surgery (elective facial esthetic procedures, cosmetic and reconstructive breast operations, abdominoplasty, free-tissue transfer, and replantation procedures).<sup>22</sup> Smoking also compromises healing after various mucogingival surgeries.<sup>23-26</sup>

## IMPLANT-RELATED SURGERIES

The most common augmentation procedures for dental implants include guided bone regeneration, sinus lift operation, and bone grafting. Guided bone regeneration is a common and well described procedure for augmentation, with considerable long-term results.<sup>27,28</sup> Sinus lift surgery has a predictable outcome as well, with an implant survival rate >90% for 3–5 years.<sup>29-33</sup> It is considered a safe treatment modality, with only minor complications.<sup>34</sup> The use of autologous bone grafts with dental implants was originally described by Bränemark *et al*<sup>35</sup> in 1975, and is now a well accepted procedure in oral and maxillofacial rehabilitation.<sup>36-39</sup>

It is noteworthy that smoking is considered a contraindication for protocols, such as bone regeneration and bone grafting.<sup>40</sup> The predictability and extent of periodontal regeneration are associated with cigarette smoking.<sup>41</sup> Smoking adversely affects treatment outcome, as measured by gains in clinical attachment levels of intrabony defects treated by regenerative therapy.<sup>42</sup> An association between dental implants placed in augmented maxillary sinuses and history of smoking has been reported.<sup>43</sup> Smokers, after rehabilitation of severely resorbed maxillae with and without bone grafts, have a higher implant failure rate.<sup>11,44,45</sup> Cigarette smoking is detrimental to implant osseointegration in grafted maxillary sinuses, regardless of the amount of cigarettes consumed.<sup>46</sup>

Our observations found a complication rate of 23.1% following onlay bone grafts in nonsmokers, compared to a complication rate of 50% in smokers. Major complications were found in one third of the operations in smokers, compared to

7.7% in the nonsmokers ( $P = 0.04$ ). There was also a relationship between complications and past smoking, although not statistically significant ( $P = 0.06$ ). There was no relationship between sinus lift operation complications and smoking habits, including intraoperative and postoperative complications (Fig. 1).<sup>47,48</sup>

## DISCUSSION

Tobacco use is an important contributor to preventable morbidity and mortality in the United States.<sup>49</sup> A significant proportion of cardiovascular diseases, various oral and pulmonary neoplasms, nonmalignant respiratory diseases, and peripheral vascular disorders is attributed to cigarette use. In the dental literature, smoking has compromised healing after mucogingival surgery,<sup>23,24,27,28</sup> and is associated with oral cancer, periodontal disease, leukoplakia, stomatitis nicotina, and impaired gingival bleeding.<sup>50-52</sup>

Nonsmokers benefit significantly when dental implant failure and implant-related complications are considered.<sup>53-56</sup> Smoking has been a contributing factor to implant failure between the time of implant placement and second-stage surgery, with a failure rate among smokers twice that of nonsmokers.<sup>53</sup> Although the survival rate of immediate implantation is higher than nonimmediate ones,<sup>18,57-60</sup> smokers with an immediate implantation have a significantly higher rate of complications compared to nonsmokers.<sup>18</sup>

Smokers have a higher MBL,<sup>61,62</sup> which strongly agrees with the present findings. Our observations showed that maxillary bone was more sensitive to tobacco exposure; heavy smokers had more MBL than mild smokers. The maxilla is more prone to the deleterious effect of smoking.<sup>11</sup> Lambert *et al*<sup>61</sup> found that in smokers, maxillary implants failed 1.6 times more than mandibular implants. De Bruyn and Collaert<sup>12</sup> and Esposito *et al*<sup>62</sup> showed that smokers had a higher implant failure rate in the maxilla. It can be presumed that maxillary bone is compromised and, therefore, more prone to the detrimental effects of smoking.

Our finding of higher MBL around implants in the posterior re-

gions contradicts Lindquist *et al*,<sup>13</sup> who found bone loss around anterior sites almost twice as large as around the posterior sites. Bone loss and lower basic bone levels may be associated with smoking, even in patients with good oral hygiene. This result suggests that smoking is a risk factor in periodontal health.<sup>63,64</sup> It is unclear whether there is a dependable effect of smoking on the bacterial population selection, although recent studies suggest this.<sup>65-70</sup>

In addition to the fact that smoking causes a higher incidence of complications (spontaneous premature implant exposure) following implant placement,<sup>71</sup> we found that smokers had significantly higher postoperative complications following onlay bone graft operations. Smoking influence was less significant in sinus lift operation complications. Kan *et al*<sup>46</sup> evaluated the effect of smoking on implant success in grafted maxillary sinuses and showed a higher cumulative implant success rate in nonsmokers than in smokers. However, graft complications were not reported, as was in our study.

There was no statistically significant difference between complications and past smoking,<sup>47</sup> which indicates that the risk of complications can be reduced up to the normal nonsmoker complication rate when smoking ceases. Numerous smoking cessation protocols have been proposed to improve the surgical outcome in smokers.<sup>72,73</sup> However, the effect of short-term smoking cessation upon the risk of complicating tissue and wound healing or other complications of general surgery is still controversial.<sup>74,75</sup>

It is beyond the scope of this article to discuss the possible mechanisms in which smoking increases failure rate, and complications in both implant-related surgical procedures and dental implantation. It does not provide any insight into the mechanism associated with failures and complications in smokers. However, it is probable that these relate to any or all factors, such as systemic vasoconstriction, reduced blood flow, increased platelet aggregation, and polymorphonuclear leukocyte dysfunction, which have been identified in smokers.<sup>76-79</sup> Nicotine may have an effect on cellular

protein synthesis and impair gingival fibroblast ability to adhere, thus impairing wound healing and/or exacerbating periodontal disease.<sup>80</sup> Cigarette smoke could have a cytotoxic effect on human gingival fibroblasts, which results in capacity loss for adhesion and proliferation.<sup>81</sup> The consequences of this result could be impaired maintenance, integrity, and remodeling of the oral connective tissue. These mechanisms are most crucial in implant-related procedures, such as onlay bone grafts, in which primary tissue closure is essential for surgical success. Smokers undergoing both implant-related surgical procedures and dental implantation should be encouraged by their dentists, oral and maxillofacial surgeons, or treating physicians to cease smoking, emphasizing that smoking can increase complications and reduce the success rate of these procedures.

## CONCLUSION

Smokers had a higher incidence of failure rate and complications following dental implantation and implant-related surgical procedures. The risk of failure and complications are reduced once smoking ceases. Potential implant patients should be advised that smoking could have a detrimental effect on dental implantation and implant-related surgical procedures.

## Disclosure

The authors claim to have no financial interest in any company or any of the products mentioned in this article.

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**Auswirkungen des Rauchens von Zigaretten auf Zahnimplantierungen und damit in Verbindung stehende chirurgische Eingriffe**

**ZUSAMMENFASSUNG:** Nach wie vor gehört das Rauchen von Zigaretten für viele zur Normalität. Unter Rauchern sind in der Mundhöhle vermehrt Ansammlungen von Plaque, ein erhöhtes Vorkommen von Zahnfleischentzündungen und Wurzelhautentzündungen, vermehrter Zahnverlust sowie eine verstärkte Resorption des Alveolarkamms zu beobachten. Das Rauchen von Zigaretten kann eine Erschwernis für die Wundheilung darstellen und somit auch den Erfolg von Knochentransplantierungen und Zahnimplantierungen gefährden. Die Transplantation von Knochengewebe und Behandlungen hinsichtlich einer Anhebung des Sinus sind gängige und ausführlich dokumentierte Methoden im Vorfeld einer Implantatsetzung. Die während des Rauchens entstehende Hitze sowie die beim Rauchen hervorgerufenen toxischen Nebenprodukte wie Nikotin, Kohlenmonoxid und Blausäure werden als Risikofaktoren bei erschwerter Heilungsneigung angesehen und können daher auch den Erfolg sowie die möglichen Komplikationen derartiger chirurgischer Eingriffe mit bestimmen. Festgestellt wurde eine Verbindung zwischen Zahnimplantierungen, Transplantierungsbehandlungen (Transplantierung von Knochengewebe, Anreicherungsbehandlung der Oberkiefer sinusbereiche usw.) und der Patientenspezifischen Entwicklungsgeschichte des Rauchens. Bei Rauchern wurden mehr Komplikationen bzw. eine vermehrte Anzahl von fehlgeschlagenen Implantierungen, ungetacht einer Knochentransplantation. Die Beziehung zwischen dem Rauchen von Zigaretten und in Zusammenhang mit Implantierungen stehenden chirurgischen Eingriffen inklusive des Eintretens von eventuellen Komplikationen bei diesen Behandlungsschritten wird beschrieben und auf Basis der entsprechenden Literatur und der Ergebnisse unserer kürzlich durchgeführten Studien kontrovers diskutiert.

**SCHLÜSSELWÖRTER:** Behandlungserfolg, Eingriff zur Anhebung des Sinus, Spannlagerung, Nikotin, Wundheilung

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**4 El efecto del fumar cigarrillos en los implantes dentales y cirugía relacionada**

**ABSTRACTO:** Fumar cigarrillos se considera todavía una costumbre habitual. Entre los fumadores, se ha encontrado una mayor acumulación de placa, mayor ocurrencia de gingivitis y periodontitis, tasa más alta de pérdida de dientes y mayor reabsorción de la cresta alveolar en la cavidad oral. Fumar cigarrillos puede afectar negativamente la curación de heridas, y por lo tanto, poner en peligro el éxito de un injerto de hueso y los implantes dentales. Los injertos de hueso y las operaciones para levantar el seno son procedimientos comunes y bien documentados antes de la colocación de implantes dentales. El calor, así como los subproductos tóxicos del fumar cigarrillos, tales como la nicotina, monóxido de carbono e cianuro de hidrógeno, han sido reconocidos como factores de riesgo para una curación problemática y por lo tanto, pueden afectar el éxito y las complicaciones de dichos procedimientos quirúrgicos. Se ha reconocido la asociación entre implantes dentales, procedimientos de injerto (injerto de hueso, aumento del seno maxilar, etc.) y haber fumado cigarrillos. Se encontró una tasa más alta de complicaciones o falla de los implantes, en los fumadores con y sin injertos de hueso. La relación entre fumar cigarrillos y los procedimientos quirúrgicos relacionados con implantes, incluyendo la incidencia de complicaciones asociadas con estos procedimientos se describirá y explicará según las publicaciones relevantes y los resultados de nuestros estudios recientes.

**PALABRAS CLAVES:** éxito, operación para levantar el seno, injerto de hueso con incrustación, nicotina, curación de heridas

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## *O Efeito do Consumo de Cigarros sobre os Implantes Dentários e Cirurgia Relacionada*

**RESUMO:** O consumo de cigarros ainda é considerado um hábito comum. Entre os fumantes, acúmulo aumentado de placa, maior incidência de gengivite e periodontite, maior taxa de perda de dente e reabsorção aumentada do rebordo alveolar foram encontrados na cavidade oral. O consumo de cigarros pode afetar adversamente a cura de feridas e assim colocar em risco o sucesso de enxerto de osso e implantação dentária. Enxertos de osso e operações de elevação da cavidade são procedimentos tanto comuns quanto bem documentados antes da colocação do implante dentário. O calor, bem como subprodutos tóxicos do consumo de cigarros, com a nicotina, monóxido de carbono e cianeto de hidrogênio foram implicados como fatores de risco para cura prejudicada e assim podem afetar o sucesso e complicações daqueles procedimentos cirúrgicos. Uma associação entre implantes dentários, procedimentos de enxerto (enxertos de osso, aumento das cavidades maxilares, etc.) e histórico de fumo foi relatada. Um grau mais alto de complicações ou taxas de falha do implante, foram encontrados em fumantes com e sem enxertos de osso. O relacionamento entre o consumo de cigarros e procedimentos cirúrgicos relacionados a implantes, incluindo a incidência de complicações associadas a esses procedimentos, será descrito e discutido com base em literatura relevante e em resultados de nossos estudos recentes.

**PALAVRAS-CHAVE:** sucesso, operação de elevação da cavidade, enxerto ósseo onlay, nicotina, cura de feridas

### デンタルインプラントとそれに関連する手術への喫煙の影響

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**要約：**喫煙の習慣は依然一般的である。喫煙者の口腔には、ブラーク蓄積の増大、歯肉炎・歯周炎の増加、歯損失の多発、歯槽堤吸収の悪化などが観察される。喫煙は傷の治癒に悪影響を与え、そのため骨移植とデンタルインプランテーションの成功を妨害する。骨移植と副鼻腔増大術はデンタルインプラント装着前に行われる一般的な処置であり、それに関する論文も多い。喫煙に関しては、その熱とともにニコチン、一酸化炭素、hydrogen cyanideなどの毒性副産物が治癒妨害性であり、このような外科処置の成功率を下げたり合併症を起こしたりするリスク要因として指摘されてきている。またデンタルインプラントや移植処置（骨移植、上顎洞増大術など）と、喫煙の習慣との関連性についても報告されている。喫煙者には骨移植のあるなしに関わらず、合併症とインプラント失敗の発生率がより高いことが知られている。本論文では、過去の論文の調査と当スクールの研究結果をふまえて、喫煙とインプラント関連外科処置との関係とこれらの処置に関連する合併症について説明し論じられる。

**キーワード：**成功、副鼻腔増大術、オンレイ骨移植、ニコチン、傷の治癒

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