The Effect of Smoking on Early Bone Remodeling on Surface Modified Southern Implants®

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ABSTRACT

Introduction: Smoking affects the survival of turned titanium implants. Although smoking has less impact on the failure rate of rough surface implants, the effect on bone loss on rough surface implants has not been studied yet and may be an important factor in biological stability.

Aim: To determine the effect of smoking on early implant failures and bone remodeling around moderately rough implants (Southern Implants®, Southern Implants, Irene, South Africa).

Materials and Methods: Three hundred twenty-nine patient records, containing information on 712 installed implants, were scrutinized retrospectively and periapical radiographs were analyzed for interproximal bone level. Mann-Whitney *U*-test and Fisher's exact test were performed to compare bone level and implant survival in smokers and nonsmokers. Only implants with at least 6 months of function time were analyzed for bone level changes.

Results: The overall survival rate was 98.3%. Implants in smokers had a threefold higher failure rate compared with nonsmokers (5/104 = 4.8% vs 7/608 = 1.2%). This was statistically significant on implant level ($p = .007$) but not on patient level (1/41 vs 7/288, $p = .997$). Readable radiographs from 363 implants in 169 patients were available with a mean follow-up of 12 months (SD 5.11; range 6–28). The mean interproximal bone level was 1.36 mm ($n = 363$; SD 0.41; range 0.48–3.70). Bone levels were independent of jaw location. Sixty implants from 21 smokers lost statistically significantly ($p = .001$) more bone (mean 1.56; SD 0.53; range 0.75–3.22) than the 303 implants in 148 nonsmokers (mean 1.32 mm; SD 0.38; range 0.48–3.7). The maxilla is especially prone to bone loss compared with the mandible (1.70 mm vs 1.26 mm, $p < .001$).

Conclusion: The Southern Implants® system demonstrated a high absolute survival rate. Although smokers are not more prone to implant loss, more pronounced peri-implant bone loss was observed, especially in the maxilla. Whether this affects future biological complications remains to be investigated in prospective long-term studies.

KEY WORDS: bone loss, dental implant, implant success, implant survival, modified surface, smoking, Southern Implants®

INTRODUCTION

Smoking is generally known to have a negative impact on general health and has been identified as a risk factor for cancer, heart disease, peripheral vascular disease, and respiratory disease.[1–4] In oral health related studies, tobacco smoking has been associated with tooth loss, loss of periodontal attachment, vertical bone loss, and less healing response.[2,5,6]

Since the early days of implant dentistry, clinical studies have discovered that several patient related factors influence implant outcome, such as age, diabetes, head and neck radiation, hormonal therapy, and smoking.[7–9] Also, the prevalence of periodontitis has been linked to the use of tobacco over many years.[5,10,11] Because periodontitis-susceptible individuals have an increased risk for peri-implantitis,[12–15] it is reasonable to assume that smoking may also have an impact on the outcome of implant treatment.

Several studies have reported higher failure rates for implants installed in smokers.[7,16–19] The maxilla

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seems especially prone to failure.[20–23] In particular the risk of early failures, before prosthetic loading, is elevated, possibly because of the exposure of peri-implant tissue to tobacco and its negative impact on peri-implant and bone healing.[19,20,24,25] Although there is sufficient evidence that implant survival in smokers is hampered, little is known about bone remodeling around the implants in smokers.[26] A limited number of studies have reported more bone loss in smokers compared with nonsmokers.[16,22,26–28] This seems to be more pronounced in the maxilla than in the mandible.[22,29] One should clearly keep in mind that the afore mentioned studies were mainly describing the outcome of smooth surface implants. Studies on smoking with rough surface implants are limited and are not conclusive.

The aim of this retrospective study was therefore to evaluate the outcome of moderately rough implants (Southern Implants®, Southern Implants, Irene, South Africa) with respect to self-reported smoking habits of the patients.

MATERIALS AND METHODS

Study Group and Criteria

During a 5-year period, 712 Southern Implants® were placed in two private periodontal specialty clinics in Belgium by two experienced periodontists. They were both trained at the same dental school, performed the surgery according to a given protocol, and took care of professional maintenance including radiographic follow-up. Only patients treated with the same implant system were selected. The implants had an enhanced abraded surface of rutile titanium obtained through sand-blasting, described as moderately rough. Data collection was based on anonymized patients' files and the protocol was accepted by the university hospital's ethics committee. Variables extracted from the files were: implant type, length, diameter, patient age and gender, implant position, loading protocol, date of surgery, 1 or 2 stage surgery, smoking status, complications, use of bone graft, implant site, and type of prosthetic reconstruction. Available periapical radiographs were scrutinized in order to evaluate bone levels. Radiographs were in general taken after abutment connection prior to sending the patient back to the referring dentist for prosthetic rehabilitation. Additional radiographs were taken by the periodontists during regular maintenance sessions. A radiographic film holder was used to have the x-ray beam perpendicular to the film in order to visualize the implant threads and bone-to-implant contact level. In order to have a consistent method of data collection only radiographs taken by the treating periodontists were included in the material. Unreadable radiographs were discarded and accordingly these patients were not included in statistical analysis. Only implants at least 6 months in function were included in the study group.

Radiographic and Statistical Analysis

Analyses were done by one independent examiner (S.V.) not involved in the actual patient's treatment. Radiographs were evaluated for interproximal bone level changes from the abutment-fixture interface, arbitrarily taken as baseline level. These were measured using DBSWIN software (Dürr Dental AG, Bietigheim-Bissingen, Germany) with an accuracy of 0.1 mm. Radiographs were calibrated using the known thread pitch as a reference. Mesial and distal values were averaged to obtain a single bone level value per implant. Statistics were performed with SPSS® v16 for Windows (SPSS Inc., Chicago, IL, USA). Mann-Whitney *U*-test was used for comparison of bone loss over time. Fisher's exact test was used for statistical comparison of implant failure and success rate in smokers and nonsmokers.

Survival rate was based only on the fact that the implant was still present but not related to the bone value. Implants lost or removed because of non-osseointegration or infection were called failures. The function time and survival rate calculation were considered from abutment connection until time of evaluation of the patient's record. This was done under the assumption that the patient would have returned or would have been referred in the event where the implant failure occurred. The individual implant success rate was calculated in order to compare smokers with nonsmokers, with respect to bone remodeling. An individual implant was dichotomized as either a success (value 1) or a survival (value 0) for Kaplan-Meier analysis. Implants up to 1 year in function were called a success when bone level during the first year was located ≤1.5 mm below the reference point; implants longer than 1 year in function were successful when bone level was $\leq 1.5 + [0.2 \times (\text{time in months} - 12)/12]$ mm.[30] The function time for bone level calculation was the time between abutment connection and date of last available radiograph.

All patients followed a maintenance protocol during the first months with the periodontist who placed the

TABLE 1 Implant and Patient Distribution of the Total Material and the Subgroup (at Least 6 Months in Function). Failures Are Given Between Brackets

Implant Survival (Total Group)			Implant Bone Level (Subgroup)	
Implants	Patients		Implants	Patients
712 (12)	329 (8)	Total	363	169
104 (5)	41 (1)	Smokers	60	21
608 (7)	288 (7)	Nonsmokers	303	148
325 (8)	141 (4)	Male	168	68
387 (4)	188 (4)	Female	195	101

implant. Afterwards, the patient was sent to the referring dentist for prosthetic work. Some patients preferred to have their regular maintenance at their own dentist and they were not included in the subgroup.

RESULTS

Implant Survival

In total 329 patient's records (141 males, 188 females) were evaluated (Table 1). The mean age was 54 years (SD 13.44, range 18–84) and 41 patients (12.5%) were smokers. After a mean survival period of 22 months ($n = 712$; SD 12.9; range 0–58), 12 implants had failed, resulting in an overall survival rate of 98.3%. An overview of implant length and diameter is shown in Table 2. Implant position is described in Figure 1. The 712 implants supported 204 single crowns, 99 fixed partial dentures, 23 fixed cross-arch bridges, and 66 overdentures.

One hundred-four implants were installed in 41 smokers (20 males, 21 females) and five failed (4.8%); of the total 608 implants installed in 288 nonsmokers (121 male, 167 female) seven failed (1.2%). In the smokers group, 5/51 (9.8%) implants failed in the maxilla, whereas 0/53 implants failed in the mandible. In the nonsmoking group, 3/261 (1.1%) implants failed in the maxilla and 4/347 (1.2%) in the mandible. In total, eight patients out of 329 (2.4%) experienced implant failures. However, only one out of 41 smokers (2.4%) compared with seven out of 288 nonsmokers (2.4%) experienced implant failures. Hence, no significant difference was found in implant failure rate on patient level between smokers and nonsmokers ($p = 1.000$).

Implant Bone Level

A subgroup of 363 implants from 169 patients was selected on the basis of readable radiographs and a

TABLE 2 Implant Distribution According to Implant Length and Diameter. Failed Implants Are Given Between Brackets

Length (mm)	Diameter (mm)						
	3.50	3.75	4.00	4.30	5.00	6.00	Total
8.50	0	4	0	0	12	6	22
10.00	0	8	46	0	21 (1)	15 (1)	90 (2)
10.50	3	0	0	4	0	0	7
11.50	0	26	73 (1)	0	30	8 (1)	137 (2)
12.00	0	0	2	0	0	0	2
13.00	0	33 (1)	97 (4)	0	34 (2)	8	172 (7)
13.50	10	0	0	8	0	0	18
15.00	0	46	167	0	42 (1)	3	258 (1)
16.50	1	0	0	1	0	0	2
18.00	0	4	0	0	0	0	4
Total	14	121 (1)	385 (5)	13	139 (4)	40 (2)	712 (12)

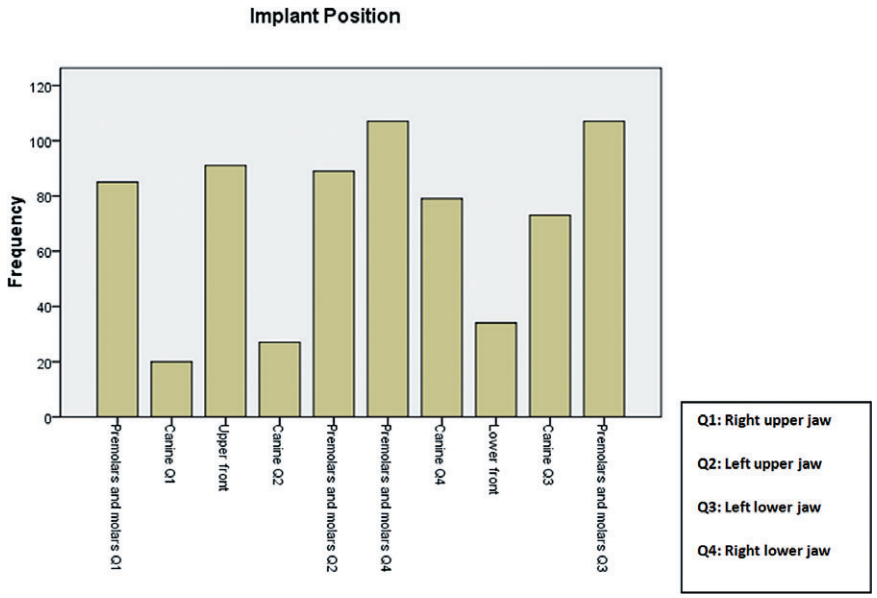

Figure 1 Implant distribution according to position.

function time of at least 6 months (see Table 1); 21 smokers with 60 implants and 148 nonsmokers with 148 implants were included. After a mean follow-up of 1 year ($n = 363$; SD 5.11; range 6–28), the overall mean interproximal bone level was 1.36 mm (SD 0.41; range 0.48–3.70). Bone levels were independent of jaw location ($p = .481$). Table 3 gives an overview of bone level changes in smokers and nonsmokers. Implants installed in smokers lost significantly more bone compared with those in nonsmokers in the maxilla ($p < .001$) but not in the mandible ($p = .253$).

Implant Success

The Kaplan-Meier survival curve was calculated on individual implants with their respective loading time in nonsmokers and smokers. In the latter group 20% less success was found after 1 year (Figure 2). The overall success rate based on mean bone level, based on radiographs taken between 6 and 28 months, was 71.9%; 76.2% in nonsmokers, compared with 50.0% in smokers ($p < .001$). Table 4 gives an overview of success rates per jaw for smokers and nonsmokers. In the maxilla and mandible, the success rate was significantly higher in the nonsmokers than in the smokers.

DISCUSSION

Although the Southern Implants® system lacks long-term survival studies, some good clinical studies are available showing an implant survival of 96.5% (77–100%).[31–37] With a 98.3% survival rate the present study confirms this good clinical outcome albeit limited to a 1 to 2 years of function time. More long-term studies are needed to give insight in the long-term prognosis. Additionally, the present study reflects the everyday clinical situation and reports a good clinical outcome that is comparable with other systems.

TABLE 3 Overview of Bone-Level Changes in Smokers and Nonsmokers Given per Jaw

	Nonsmoker	Smoker	*p* Value
Maxilla & Mandible	1.32 mm ($n = 303$; SD 0.38; range 0.48–3.70)	1.56 mm ($n = 60$; SD 0.53; range 0.75–3.22)	0.001*
Maxilla	1.26 mm ($n = 119$; SD 0.31; range 0.59–2.06)	1.70 mm ($n = 29$; SD 0.60; range 0.84–3.22)	<0.001*
Mandible	1.36 mm ($n = 184$; SD 0.41; range 0.48–3.70)	1.43 mm ($n = 31$; SD 0.42; range 0.75–2.37)	0.053
p Value	0.084	0.108	

*Statistically significant at 0.05 level with Mann-Whitney *U*-test.

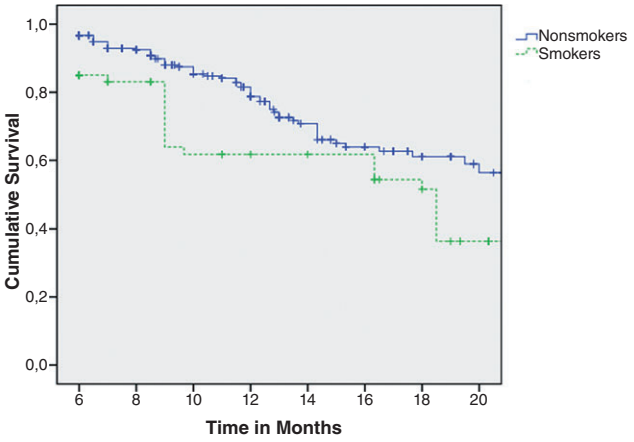

Figure 2 Kaplan-Meier survival curve, showing the increased bone remodeling in time in smokers compared to nonsmokers. The situation in the nonsmokers group is moving to a steady state after 1 year, whereas the smokers continue to loose bone.

Recent studies report good survival and success rates when the implants were immediately loaded.[32,33] Only a small number of implants (11.4%) in the present study were immediately loaded with a survival rate was 80/81 (98.8%).

In the present report, a mean bone level value of 1.36 mm after an average function time of nearly 1 year is within the limits of the internationally accepted success criteria.[30] The inclusion of radiographs with at least 6 months of follow-up was based on earlier studies, reporting that the initial bone remodeling after surgery and abutment connection stabilizes after 6 months in the maxilla and the mandible.[38,39] Additionally, success rate was calculated on implant level. As suggested by De Bruyn and Collaert,[40] the calculation on patient level can hide some clinical information when multiple implants are present. Indeed, one implant with a more pronounced bone loss can be masked when the other implants have a normal bone adaptation. Calculating success per individual implant is a more appropriate way to evaluate biologically related problems such as bone loss but may result in lower implant success rate. As a level for success 1.5 mm was arbitrarily chosen because currently, there are no success criteria dealing with early bone remodeling between fixture insertion and connection of the prosthesis as described by Åstrand and colleagues.[41] The same methodology was used recently to compare smooth turned titanium implants (Brånemark System, Nobel Biocare, Zurich, Switzerland) with moderately rough TiOblast implants (Astra Tech Dental, Mölndal, Sweden).[42] The success was 57.1 and 78.4%, respectively, after 1 year. In the present report, after nearly 1 year, the individual success was 74.1%. Although the Southern Implant® has a design similar to the Brånemark implant, the surface topography may probably account for the better performance in bone preservation. Whether this may affect the prevalence of peri-implantitis in the long run remains to be investigated in long-term follow-up studies. Kaplan-Meier survival calculation reveals that the bone level in the nonsmokers decreases after 1 year to reach a steady state, whereas the implants in the smokers continue to lose bone (see Figure 2).

The present study shows that implants in smokers fail 3.7 times more frequently than in nonsmokers. This is in accordance with earlier data reporting 2.6, 4.3, and even nine times more failures in smokers.[9,20,43] These results are mainly caused by the situation in the maxilla, where a more pronounced failure rate was observed. This is in contrast with the situation in the mandible, where no differences in failures were found between smokers and nonsmokers.[7,17,20,22,23,29,44,45] Some authors found no difference in failure rate with surface modified implants between smokers and nonsmokers,[46–50] whereas others reported more implant failures in smokers.[11,29,51,52] However, some of the afore mentioned papers included in their studies also turned surface implants next to moderate rough surface implants that may obscure the conclusions.[46,50]

Although the present study showed more absolute implant failures in smokers compared with nonsmokers, this could not be confirmed on patient level. Hence, the statement that smokers are more at risk for early implant failure can therefore not be sustained. One should, however, keep in mind that the proportion of smokers in the present study was only 12.5% of the total group, which is smaller than is to be expected in the Belgian population. In 2004, 28% of the Belgian population

TABLE 4 Overview of Implant Success Levels in Smokers and Nonsmokers Given per Jaw

	Nonsmoker	Smoker	*p* Value
Maxilla & Mandible	76.2%	50.0%	<0.001*
Maxilla	77.3%	41.4%	<0.001*
Mandible	75.5%	58.1%	0.050
p Value	0.783	0.301	

*Statistically significant at 0.05 level with Fisher's exact test.

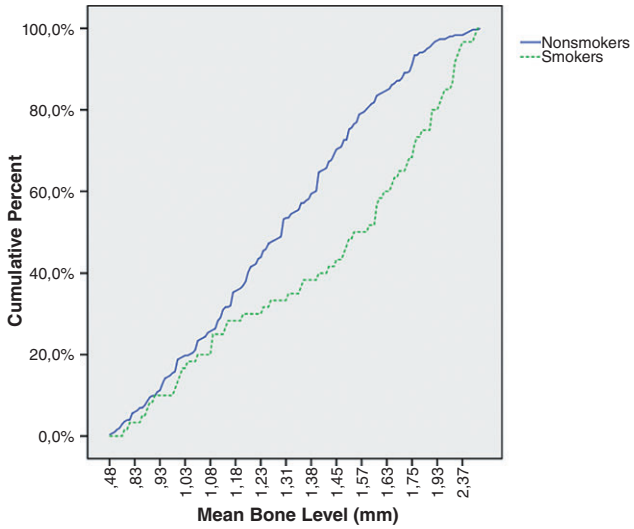

Figure 3 Cumulative percentage of peri-implant bone remodeling based on all radiographs (6–28 months in function), smokers compared with nonsmokers.

were smokers.[53] A positive patient selection may enhance the positive outcome and hence, it is recommendable to inform the smoking patient of possible multiple implant failures.

The findings from the present study show that the mean peri-implant bone level is lower in smokers compared with nonsmokers (Figure 3) after the initial 9 months. This confirms the findings by other studies.[16,17,26,29,54,55] This difference is not observed in the mandible (Figure 4) but evident in the maxilla and in conjunction with other papers.[26]

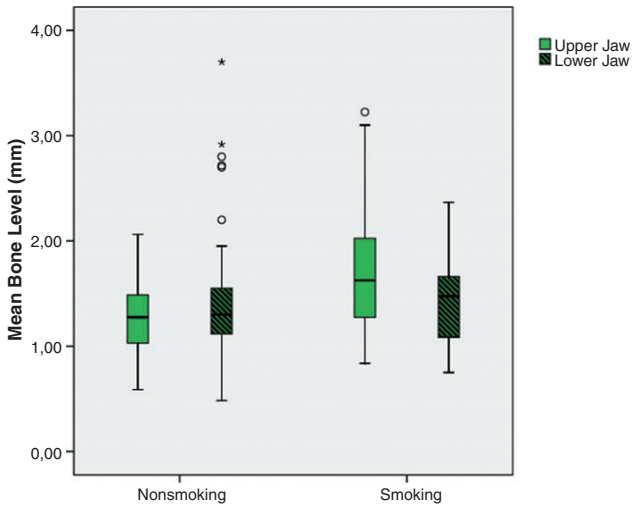

Figure 4 Box plot representing peri-implant bone level in smokers and nonsmokers after at least 6 months in function, comparing mandible and maxilla.

Although the effect of smoking on implant treatment outcome is not completely known, the fact that especially the maxilla seems to be more prone to failures and bone loss leads to the question what different influence cigarette components can have on the maxilla and the mandible. The first hypothesis is related to the bone quality. Several studies report worse bone quality in the maxilla compared with the mandible, even in nonsmoking patients.[56,57] Some authors suggested that smoking has an adverse effect on the bone mineralization in the whole human body, which results in a decreased bone density.[20,58,59] Because good bone quality is one of the factors of success for implant treatment, this might explain the higher failure rate in smokers, especially in the maxilla.[21,57,60–62] Unfortunately, information of the subjective perception of bone quality could not be retrieved from the patients' records. Today, with the availability of surface modified implants and wider implants, this is probably not the most decisive issue as implant stability can be improved by choosing an appropriate implant. Additionally, the surgeon usually adapts the drilling protocol to improve bone compression and enhance initial implant stability.[38] The second explanation is related to the local influence of tobacco on the peri-implant tissues. Several studies report two times more complications during wound healing after surgery.[18,63–67] It is suggested that the direct exposure of the peri-implant tissues to tobacco and increased vasoconstriction after nicotine inhalation may be responsible.[20,22,24,25,45,56] This may result in inadequate integration of the implant.[45,68] Also, higher levels of plaque and bleeding were reported in smokers, which results in more bone loss around the implant and can lead to failure over time.[6,22] The mandible is partially protected by the tongue to these negative influences, which might explain the better results in the mandible, comparable to the results in nonsmokers.[22,56] Kourtis and colleagues[51] found more peri-implant bone loss in smokers, but included a mixture of different rough implant surfaces.

And finally, some surface modifications, such as the acid-etched roughened surface,[58] the anodized surface,[11] or titanium oxide sandblasted surfaces,[38] are preserving bone loss, but whether this also pertains to smokers remains inconclusive and more prospective and randomized control trials are warranted.

CONCLUSION

Although some authors report smoking as a risk factor for early implant failure, this could not be sustained in the present study. On the other hand, pronounced peri-implant bone loss was seen among smokers, especially in the maxilla, which may lead to future biological complications. More research is needed to identify the impact of different surfaces on the treatment outcome in smokers. Until then, it is advised to warn smoking patients of the risk when undergoing implant surgery.

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