

# Impact of Smoking on Marginal Bone Loss

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**Purpose:** To compare marginal implant bone loss (MBL), survival, and radiographic evidence of success of dental implants among smokers and nonsmokers. **Materials and Methods:** Consecutive records of 161 patients (aged 23 to 89 years, mean 57 years) treated with a total of 646 implants between the years 1995 and 1998 were examined. Patients were divided into 3 groups: nonsmokers, moderate smokers, and heavy smokers. Tobacco exposure was calculated by cigarettes per day and by pack-years. Follow-up ranged from 1 to 7 years (mean 3.8 years). Postoperative panoramic radiographs obtained before implant exposure and annually thereafter were analyzed for MBL changes. The influence of smoking and other variables on MBL was analyzed at all implant sites. **Results:** Generally, smokers had more MBL than nonsmokers ( $0.153 \pm 0.092$  mm and  $0.047 \pm 0.048$  mm, respectively;  $P < .001$ ). When each jaw was examined separately, smoking had a greater effect on MBL in the maxilla than in the mandible ( $0.158 \pm 0.171$  mm versus  $0.146 \pm 0.158$  mm, respectively;  $P < .001$ ). Furthermore, in the maxilla, heavy smokers had the greatest amount of MBL ( $0.1897 \pm 0.1825$  mm), followed by moderate smokers ( $0.123 \pm 0.156$  mm) and nonsmokers ( $0.0460 \pm 0.070$  mm) ( $P < .001$ ). In the mandible, there was no distinction between heavy and moderate smokers, and both had greater MBL than nonsmokers ( $P < .001$ ). Only 3 of the 646 implants failed; the cumulative survival rate was 99.5%. Overall radiographic success rate was 93.2%. Nonsmokers had a higher radiographic success rate (97.1%) than smokers (87.8%) ( $P < .001$ ). **Conclusions:** This study demonstrated a relationship between MBL and smoking habits. A higher incidence of MBL was found in the smoking group, and this was more pronounced in the maxilla. INT J ORAL MAXILLOFAC IMPLANTS 2005;20:605-609

**Key words:** dental implants, implant survival, marginal bone loss, radiographic success, smoking

The criteria for long-term efficacy of dental implants proposed by Albrektsson and associates<sup>1</sup> are the criteria most commonly used today. Among other proposed clinical signs, the operator usually evaluates the success of dental implants after loading by studying the radiographic image of each implant to determine signs of mar-

ginal bone loss (MBL). Cigarette smoking has long been associated with a variety of oral pathologic conditions, including periodontal disease,<sup>2-4</sup> bone and tooth loss,<sup>5,6</sup> peri-implantitis,<sup>7,8</sup> and implant failure.<sup>9</sup> Nicotine in tobacco has been implicated as a cause of reduced blood flow in oral tissues<sup>10</sup> and impaired gingival bleeding<sup>11,12</sup>; its detrimental effect in other sites of the body has also been reported.<sup>13</sup>

Although the precise mechanism by which smoking affects osseointegration of titanium implants is not understood, some harmful effects of smoking have been shown. Smoking compromises the function of macrophages and polymorphonuclear leukocytes<sup>14</sup> by reducing phagocytosis and delaying migration<sup>15</sup> and diapedesis, as well as aggregation and adhesion of leukocytes<sup>16</sup> to the endothelium in venules and arterioles.

Individuals who cease smoking are at a lower risk for tooth loss and periodontitis than active smokers. Bain<sup>17</sup> has shown that smoking cessation increases

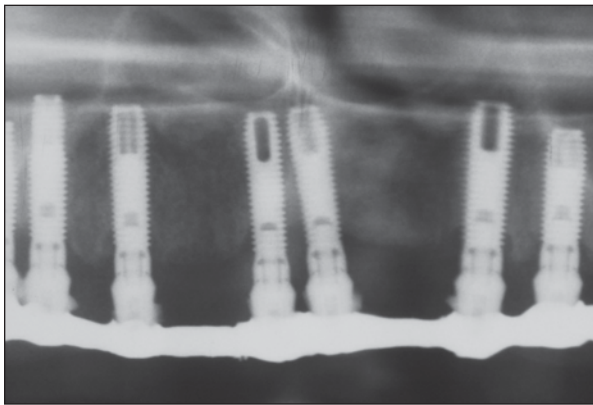
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**Fig 1** Radiograph demonstrating an MBL of 4.5 threads at the distal aspect of the implant, which replaced the right central incisor.

the probability for successful implant osseointegration, and Krall and colleagues<sup>18</sup> found that smoking cessation significantly benefits the likelihood of tooth retention.

The purpose of this study was to compare MBL, survival, and radiographic evidence of success of dental implants among smoking and nonsmoking individuals.

## MATERIALS AND METHODS

The study was based on a consecutive cohort of patients who received implants between 1995 and 1998. Data regarding the incidence of complications and survival rate of these implants in the time span from implantation to exposure have previously been published.<sup>19</sup> The present study focused on the evaluation of the same group of patients after implant exposure. Patients with a follow-up time of less than 6 months after exposure, and those who had concomitant surgical procedures, ie, sinus and bone augmentations, were excluded from the study. Acceptance criteria were a thorough medical and dental history, clinical and radiographic evaluation, and detailed prospective information of smoking habits. Patients suffering from systemic diseases were excluded from the study.

The study consisted of 161 patients ranging in age from 23 to 89 years (mean 57 years) with a total of 646 implants, of which 391 (61%) were immediately placed implants. Follow-up ranged from 9.4 to 86.6 months (mean follow-up 45.5 months). There were 102 nonsmokers (375 implants) and 59 smokers (271 implants). Mean follow-up was 42.9 months for smokers and 48.4 months for nonsmokers. One sur-

geon (DSA) placed all implants in a private clinic, following the protocol of Schwartz-Arad and colleagues.<sup>20-23</sup>

Postoperative panoramic radiographs were obtained before implant exposure and yearly thereafter. All radiographs were analyzed by 2 examiners (DN and AM) for changes in MBL. Examiners had no information regarding any clinical parameters or patients' smoking habits.

### Bone Level Measurements

MBL was measured on radiographs (orthopantomographs) using the implant threads as an internal standard, a technique suggested by Haas and coworkers.<sup>24</sup> Bone level at the time of implant exposure was compared with that at the most recent follow-up. The number of threads unsupported by bone on both the mesial and distal sides of each implant was counted, and the average number was used to calculate bone loss (Fig 1). The accuracy level of this method is half a pitch of the implant thread. The number of threads was converted to millimeters using the given millimeter-per-thread information for that particular implant. The manufacturers supplied the information concerning pitch and surface areas of different implants used.

### Smoking Habits

Patients were divided into 3 groups: nonsmokers, moderate smokers (10 cigarettes or less per day), and heavy smokers (more than 10 cigarettes per day). Smokers were also divided into 2 groups according to tobacco consumption, ie, less than 16 pack-years (PY) or more than 16 PY. This value was chosen because it was the median value of PY in the studied patient cohort.

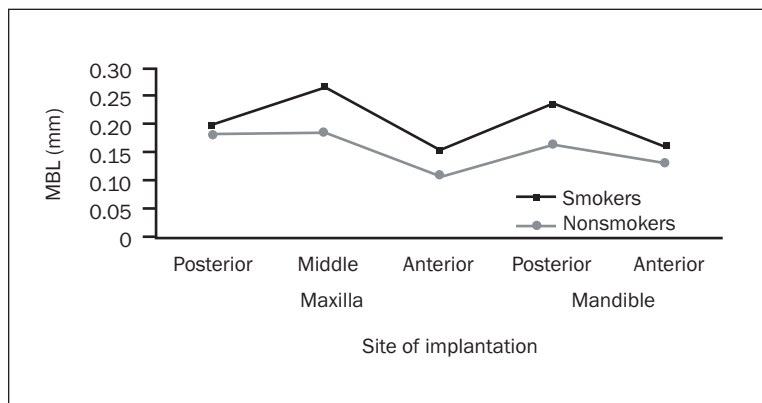
### Implant Location

The implants were studied by their placement in 1 of the following 5 areas:

- Anterior mandible (between the mental foramina)
- Posterior mandible (second premolar and molar sites)
- Anterior maxilla (between the canines)
- Middle maxilla (premolar sites)
- Posterior maxilla (molar sites)

The rationale for dividing the maxilla into 3 different areas was based on the anatomic fact that there is limited bone available for implantation in the anterior and posterior maxilla because of the presence of the maxillary sinuses and piriform aperture versus the unlimited bone in the canine fossa area. Bone quality is another difference between the maxillary areas.<sup>25</sup>

**Fig 2** MBL around implants according to site of implantation in smokers versus nonsmokers.



### Success Rate (Radiographic)

Radiographic evidence of implant success was evaluated using a modification of the criteria suggested by Albrektsson and associates.<sup>1</sup> An implant was considered successful if bone loss apical to the implant neck was less than 0.3 mm per year (starting from the first year).

### Statistical Methods

The influence of smoking and other variables on MBL was analyzed using *t* test and 1-way analysis of variance (ANOVA). Kaplan-Meier analysis was used to calculate the cumulative survival rate. The chi-square test was used to calculate success rate.  $P < .05$  was considered statistically significant.

## RESULTS

Smokers had an average of 4.6 implants per person, while nonsmokers had an average of 3.7 implants, a statistically significant difference ( $P = .041$ ). Mean follow-up time for smokers was 42.9 months, compared to 48.4 months for nonsmokers, which was also a statistically significant difference ( $P = .046$ ).

No difference in MBL was noted in regard to implant system or gender.

### Location

Average MBL was greater for smokers than for nonsmokers ( $0.153 \pm 0.092$  mm versus  $0.047 \pm 0.048$  mm;  $P < .001$ ). Smoking had a greater effect on MBL in the maxilla than in the mandible ( $0.158 \pm 0.171$  mm and  $0.146 \pm 0.158$  mm, respectively;  $P < .001$ ) when each jaw was examined separately. There was also a statistical interaction in MBL among the different implantation sites between smokers and nonsmokers (Fig 2).

In the maxilla, heavy smokers experienced the greatest bone loss ( $0.1897 \pm 0.1825$  mm), followed by

moderate smokers ( $0.123 \pm 0.156$  mm) and nonsmokers ( $0.046 \pm 0.070$  mm) ( $P < .001$ ) (Table 1).

Similar results were found when analyzing MBL in regard to both the total tobacco consumed (PY) and the rate of cigarette smoking (cigarettes per day). In the mandible, there was no distinction between heavy smokers and moderate smokers; both had greater MBL than nonsmokers ( $P < .001$ ).

### Survival and Success Rates

Of the 646 implants, 8 (1.2%) failed; 5 were lost at the time of implant exposure and therefore were excluded in the cumulative survival analysis, and 3 were lost after loading.

The 7-year cumulative survival rate as calculated with the Kaplan-Meier analysis was 99.5% (Table 2). The overall radiographic success rate for all implants was 93.2%. Nonsmokers had a higher radiographic success rate than smokers (97.1% versus 87.8%;  $P < .001$ ).

## DISCUSSION

In 2003, about 24.3% of adults in Israel were cigarette smokers, according to a report by the Israel Ministry of Health.<sup>26</sup> In the present study, the rate of smokers was 36.6%. The difference can be explained by the fact that smokers are more prone to tooth loss<sup>6,18</sup> and therefore are in greater need of dental treatment. Although the ratio of smokers to nonsmokers is greater among patients with implants than among the general population, and they receive more implants and have greater MBL, they are less likely to appear for routine follow-up.

Greater MBL has been found among smokers,<sup>5,7</sup> which is consistent with the present results. Furthermore, the pattern of MBL in smokers and nonsmokers was similar in all areas of the maxilla and mandible.

**Table 1** MBL Differences Between Heavy Smokers, Moderate Smokers, and Nonsmokers

	n	Mean (mm)	SD	P
Mandible				
Nonsmokers	102	0.0487	0.09115	.001
Moderate smokers	30	0.1502	0.15867	
Heavy smokers	29	0.1390	0.15990	
Total	161	0.0845	0.12831	
Maxilla				
Nonsmokers	102	0.0460	0.07035	.001
Moderate smokers	30	0.1233	0.15559	
Heavy smokers	29	0.1897	0.18247	
Total	161	0.0867	0.12918	

Tukey's method for multiple comparisons shows,

Mandible: nonsmoker ≠ moderate smoker, heavy smoker.

Maxilla: nonsmoker ≠ moderate smoker ≠ heavy smoker.

**Table 2** 5-Year Cumulative Survival Rate After Loading (Kaplan-Meier Analysis)

Year	No. of failures	Survival (%)
1	0	100.0
2	2	99.7
3	1	99.5
4	0	99.5
5–7	0	99.5

In the present study, maxillary bone was more sensitive to tobacco exposure. Heavy smokers had more MBL than moderate smokers. Others have also found the maxilla to be more susceptible to the deleterious effects of smoking. Bain and Moy<sup>27</sup> evaluated 2,194 implants and found that smoking was the most significant factor in implant failure and that the maxilla was affected more than was the mandible. Lambert and coworkers<sup>28</sup> noted that in smokers, maxillary implants failed 1.6 times more often than mandibular implants. De Bruyn and Collaert<sup>29</sup> and Esposito and colleagues<sup>30</sup> also found that smokers had a higher implant failure rate in the maxilla. Haas and associates<sup>7</sup> also found the effects from smoking more damaging to the maxillary bone. It can be presumed that the maxillary bone is of lower quality and therefore is more susceptible to the detrimental effects of smoking.

The present finding of greater MBL around the implants in posterior regions was in contrast to Lindquist and coworkers,<sup>31</sup> who found bone loss around anterior sites to be almost twice as great as around posterior sites.

The use of panoramic radiographs to measure MBL is feasible because of the use of the implant's thread as an internal standard, a fact that compensates for the inaccuracy of panoramic radiographs.

Smoking has been associated with higher rates of implant complications<sup>32</sup> and failure.<sup>33,34</sup> In the present study, the risk of implant failure in nonaugmented sites was low for both smokers and nonsmokers. Therefore, the survival rate was not affected by tobacco exposure. However, the success rate was affected by smoking, as previously shown by Gorman and associates.<sup>35</sup>

## CONCLUSIONS

The present study demonstrated a relationship between MBL and smoking habits. A greater amount of MBL was found in the smoking group, and this was apparent in all areas of the maxilla and mandible in this patient population. The maxilla was more susceptible than the mandible to the deleterious effects of smoking.

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