Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis


Abstract

Aim: This systematic literature review was performed to investigate if smoking interferes with the prognosis of implants with and without accompanying augmentation procedures compared with non-smokers.

Methods: A systematic electronic and handsearch (articles published between 1989 and 2005; English and German language; search terms “dental or oral implants and smoking”; “dental or oral implants and tobacco”) was performed to identify publications providing numbers of failed implants, related to the numbers of smokers and non-smokers for meta-analysis. Publications providing statistically examined data of implant failures or biologic complications among smokers compared with non-smokers were included for systematic review.

Results: Of 139 publications identified, 29 were considered for meta-analysis and 35 for systematic review. Meta-analysis revealed a significantly enhanced risk for implant failure among smokers [implant-related odds ratio (OR) 2.25, confidence interval (CI) 95% 1.96–2.59; patient-related OR 2.64; CI 95% 1.70–4.09] compared with non-smokers, and for smokers receiving implants with accompanying augmentation procedures (OR 3.61; CI 95% 2.26–5.77, implant related). The systematic review indicated significantly enhanced risks of biologic complications among smokers. Five studies revealed no significant impact of smoking on prognosis of implants with particle-blasted, acid-etched or anodic oxidized surfaces.

Conclusion: Smoking is a significant risk factor for dental implant therapy and augmentation procedures accompanying implantations.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interest.

None of the authors received any benefit of any kind from commercial or official parties related directly or indirectly to the subject matter of this article. No grant or funding from any party was received to prepare or perform this work.
Material and Methods

Search strategy

A systematic literature search in electronic databases was conducted, using the following search term combinations: “dental implants AND smoking”, “dental implants AND tobacco”, “oral implants AND smoking” and “oral implants AND tobacco”.

Furthermore, a manual search was applied to three German-language peer-reviewed dental journals, focusing on articles related to the effect of smoking on dental implant treatment outcomes.

Inclusion criteria

Literature search was performed to identify meta-analyses and systematic reviews as well as randomized-controlled clinical trials, prospective or retrospective clinical studies, cohort studies or case-control studies.

Publications were included for meta-analysis or systematic review, if they were published between January 1989 and December 2005 in English language and listed in electronic databases Medline/Pubmed or Embase, or were published in German language in Deutsche Zahnärztliche Zeitschrift (January 1968–December 2005), Zeitschrift für Zahnärztliche Implantologie (January 1998–December 2005) and Implantologie (January 1996–December 2005).

Publications were included for meta-analysis, if implant survival rates or the number of failed implants were reported on an implant- or patient-related basis and the number of smoking as well as non-smoking patients were published and could be related to the number of failed and remaining implants, respectively.

Moreover, publications were included for systematic review although not meeting the inclusion criteria for meta-analysis, if odds ratios (OR), risk ratios (RR) or hazard ratios (HR) for implant failures among smokers were reported, or reports on biologic complications and findings known to influence the success of implant-prosthetic therapy in smokers compared with non-smokers were given, and if the results were statistically analysed considering the effects of smoking on treatment course or outcome.

As definition of smokers were different in several studies regarding quantities of smoked cigarettes per day and therefore were accordingly categorized differently, any patient who smoked was considered a smoker, following the definition given by Wallace (2000).

Selection of studies and data extraction

Titles and abstracts of the publications identified by electronic databases and handsearch using the search terms mentioned above were screened initially by two independent reviewers (F. P. S. and A. K. or M. K.). Publications were included for full text evaluation if the study design and content of the abstracts met the inclusion criteria and matched the focused question. Agreement between the reviewers was determined performing κ-statistic. Disagreements were resolved by evaluation of the full texts and discussion. Final authority for selection disagreements rested with F. P. S.

Full text assessment and data extraction were performed by the reviewers without any disagreements. The process of identification of the included studies from the initial yield is described in Fig. 1.

A categorization considering the duration of the observation periods reported in the studies identified for meta-analysis was performed additionally (group 1: observation period ≤1 year; group 2: >1 and ≤5 years; group 3: >5 years).

Furthermore, studies involving implant-prosthetic rehabilitation after augmentation procedures to enhance bone quantity at the implant site [sinus floor elevation and augmentation (SFEA) and/or lateral alveolar ridge augmentation by guided bone regeneration (GBR)] providing survival data of implants were considered for meta-analysis to evaluate the risk of smoking concerning augmentation procedures.

The frequency and percentage distribution of smokers and non-smokers regarding the frequency of implant success or failure were extracted from the studies included for meta-analysis.

Furthermore, the distributions of male and female patients, and of implants in the maxilla and mandible with special respect to the groups regarding different observation periods were considered.

To rule out the cumulative effect of individuals, studies publishing patient-related data were included separately from those reporting implant-related data for meta-analysis.

Fig. 1. Search strategy and results of identification and inclusion of publications considered for meta-analysis and systematic review. The κ-score expresses the agreement between the reviewers.


Considering publications providing with patient-related data, the treatment of one patient was accounted as failure if one or more implants were considered a failure due to the above-mentioned criteria.

Excluded studies

Publications were excluded if they did not meet the inclusion criteria (i.e. if they were considered case reports, animal or in vitro experiments, educational statements, expert opinions), if they did not provide implant- or patient-related data on failures or complications in implant treatment related to the smoking habit, or if they did not contain material matching the focused question. Excluded studies and the reasons for exclusion are listed in the reference list.

Statistical analysis

A funnel plot of the log odds ratios versus their SE was calculated to prevent a selected subset of studies, which is widely accepted to detect potential publication bias when the actual treatment effects of an intervention or the outcomes after exposure to certain parameters are homogeneous (Light & Pillemer 1984). Assuming that the underlying true exposure effect in each study is the same, a general non-parametric fixed-effects selection model was applied to the entire collection of the selected studies to estimate the extent and size of undetected reports (Hedges 1992, Blettner & Schlattmann 2005).

Furthermore, a mixed random-effects model was applied since deviations of the estimated effect sizes may also be explained by a random error. Therefore, a mixed model for calculation of heterogeneity was used to detect heterogeneity between the studies selected (Blettner & Schlattmann 2005).

For dichotomous parameters (smokers and non-smokers) and outcomes (lost implants and successful implants), the estimate of the effect of the parameter smoking was expressed as odds ratio (OR) together with the 95% confidence interval (CI95%) after performing univariate analysis, utilizing the data obtained from the studies providing with information about failed and successful implants related to smokers and non-smokers. According to the patient- or implant-related data basis, the synthesized ORs were calculated separately.

As calculation of an OR is undefined if one value of the cells of the cross table is equal to zero, for the studies concerned, 0.5 was added to the values of all cells as suggested by Gart & Zweifel (1967) and Fleiss (1981).

As sample sizes of the included studies were different, the weighed mean values of the distributions of frequencies and SD regarding smokers and non-smokers, male and female patients and implants in the maxilla and mandible were calculated and compared.

Statistical calculations were performed using SPSS software version 12.0 (SPSS Inc., Chicago, IL, USA) and SAS software version 8.2 (SAS Institute Inc., Cary, NC, USA).

Results

Of the entire yield of 139 publications identified with electronic and handsearch, 75 were finally excluded from meta-analysis and systematic review after full text assessment.

Information on failures as well as success proportions of implants among smokers and non-smokers on patient-related and/or implant-related basis...
were retrieved for meta-analysis from 29 included studies. Of these, 15 were prospective studies (three reporting patient-related data, nine reporting implant-related data and three reporting both patient- and implant-related data) and 14 were retrospective studies (three reporting patient-related data, nine reporting implant-related data and two reporting both patient- and implant-related data).

Furthermore, 35 studies were included for systematic review, reporting on implant failures or biologic complications or findings known to negatively influence the success of implant-prosthetic therapy and complications in connection with augmentation procedures, related to smoking habit. Of these 35 studies, one was a randomized controlled trial, 11 were prospective and 21 retrospective studies. Additionally, one meta-analysis and one systematic review were included.

The risk of implant failures in smokers compared with non-smokers: Results obtained from meta-analysis

First, the existence of publication bias had to be investigated. Figure 2a and b show the funnel plots of the ORs by the inverse of the variances of each study included for meta-analysis, calculated on an implant-related as well as patient-related basis. Assuming that effects of smoking are homogeneous, no asymmetry indicating missing trials was detected. Considering the implant-related data obtained from the studies included for meta-analysis, the slope of the regression line was \(-0.014\) (CI\(_{95\%}\) –0.048–0.020, \(p=0.412\)), and for patient-related data, the slope of the regression line was \(-0.084\) (CI\(_{95\%}\) –0.529–0.361, \(p=0.682\)), revealing no significant differences of the slope of regression lines from zero. Therefore, no publication bias was detected, and the sample of the selected studies was considered adequate for meta-analysis.

The overview of the characteristics of studies included for meta-analysis is given in Table 1. The weighed mean values of frequencies’ distributions of smokers and non-smokers, gender and implant sites among maxilla and mandible of the studies considered for meta-analysis are shown in Tables 2–4.

Analysis of studies providing implant-related data

Implant-related data were obtained from 18 studies. Calculations of pooled risk by applying the fixed-effects model without covariates on studies providing implant-related data showed an OR of 2.25 (CI\(_{95\%}\) 1.93–2.93). The OR for implant failures in smokers of three studies with a mean observation period of more than 5 years was 1.33 (CI\(_{95\%}\) 0.84–2.11), which showed no significantly enhanced risk for implant failures in smokers and did not differ significantly \((p=0.1892)\). The OR of implant failures in smokers of three studies with a mean observation period of more than 5 years was 1.33 (CI\(_{95\%}\) 0.84–2.11), which showed no significantly enhanced risk for implant failures in smokers. Considering both groups of observation periods of more than 1 year combined, the ORs calculated from the mixed fixed-effects model with the covariate “observation period” were 2.83 (CI\(_{95\%}\) 2.08–3.85) for studies with a mean observation period up to 1 year and 2.12 (CI\(_{95\%}\) 1.80–2.48) for a mean observation period of more than 1 year, which were not significantly different \((p=0.0939)\).

Two studies reporting on implants with surfaces microstructured with acid etching and/or particle blasting (Gnader et al. 1999, Kumar et al. 2002), a summarized OR for implant failure in smokers of 1.49 (CI\(_{95\%}\) 0.64–3.46) was calculated, considering implant-related...
### Table 1. Characteristics of studies included for meta-analysis

<table>
<thead>
<tr>
<th>Study</th>
<th>Implant characteristics</th>
<th>Study design</th>
<th>Sample sizes</th>
<th>Implant successful</th>
<th>Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1: mean observation period ≤ 1 year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balshi &amp; Wolfinger (1999)</td>
<td>Machined titanium, threaded</td>
<td>Retrospect.</td>
<td>Retrospect. 71 7 163 3</td>
<td>34 patients</td>
<td>3</td>
</tr>
<tr>
<td>De Bruyn &amp; Collaert (1994)</td>
<td>Machined titanium, threaded</td>
<td>Retrospect.</td>
<td>Retrospect. 11 P 5 16 P</td>
<td>78 patients</td>
<td>10</td>
</tr>
<tr>
<td>Gorman et al. (1994)</td>
<td>Not reported</td>
<td>Retrospect.</td>
<td>Retrospect. 604 64 P 42</td>
<td>1183 implants</td>
<td>5</td>
</tr>
<tr>
<td>Kronström et al. (2001)</td>
<td>Machined titanium, threaded</td>
<td>Retrospect.</td>
<td>Retrospect. 3 9 P 37</td>
<td>80 patients</td>
<td>11</td>
</tr>
<tr>
<td>Kumar et al. (2002)</td>
<td>Large-grit blasted and acid-etched, threaded</td>
<td>Prospect.</td>
<td>261 8 899</td>
<td>1183 implants</td>
<td>19</td>
</tr>
<tr>
<td>Schwartz &amp; Ando et al. (2000)</td>
<td>Machined titanium, threaded and acid-etched, threaded</td>
<td>Retrospect.</td>
<td>Retrospect. 5 1 9</td>
<td>56 implants</td>
<td>5</td>
</tr>
<tr>
<td>Widmark et al. (2001)</td>
<td>Machined titanium, threaded</td>
<td>Retrospect.</td>
<td>Retrospect. 41 6</td>
<td>117 implants</td>
<td>9</td>
</tr>
<tr>
<td>Group 2: mean observation period &gt; 1 and ≤ 5 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geurs et al. (2001)</td>
<td>Not reported</td>
<td>Retrospect.</td>
<td>Retrospect. 55 6</td>
<td>343 implants</td>
<td>22</td>
</tr>
<tr>
<td>Jones et al. (1999)</td>
<td>Cylindrical HA or TPS-coated implants</td>
<td>Retrospect.</td>
<td>Retrospect. 15 4</td>
<td>63 implants</td>
<td>2</td>
</tr>
<tr>
<td>Kan et al. (2002)</td>
<td>HA-coated titanium and non-coated titanium</td>
<td>Retrospect.</td>
<td>Retrospect. 38 8</td>
<td>69 implants</td>
<td>13</td>
</tr>
<tr>
<td>Keller et al. (1999)</td>
<td>Machined titanium, threaded</td>
<td>Retrospect.</td>
<td>Retrospect. 30 12</td>
<td>167</td>
<td>16</td>
</tr>
</tbody>
</table>

Smoking interferes with the prognosis of dental implant treatment

© 2007 The Authors. Journal compilation © 2007 Blackwell Munksgaard
<table>
<thead>
<tr>
<th>Study</th>
<th>Implant characteristics</th>
<th>Study design</th>
<th>Smokers</th>
<th>Non-smokers</th>
<th>Sample sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impl. successful</td>
<td>Failure</td>
<td>Impl. successful</td>
</tr>
<tr>
<td>Lambert et al. (2000)</td>
<td>Not reported</td>
<td>Retrospect.</td>
<td>874</td>
<td>85</td>
<td>1813</td>
</tr>
<tr>
<td>Mayfield et al. (2001)</td>
<td>TPS-coated and machined titanium, threaded</td>
<td>Prospect. SFEA, GBR</td>
<td>6 P</td>
<td>2 P</td>
<td>12 P</td>
</tr>
<tr>
<td>Moheng &amp; Feryn (2005)</td>
<td>Cylindrical TPS coated, and particle-blasted</td>
<td>Prospect.</td>
<td>11 P</td>
<td>4 P</td>
<td>75 P</td>
</tr>
<tr>
<td>Olson et al. (2000a)</td>
<td>HA-coated and non-coated titanium, threaded</td>
<td>Retrospect. maxilla, SFEA</td>
<td>48 P</td>
<td>3 P</td>
<td>65 P</td>
</tr>
<tr>
<td>Penarrocha et al. (2002)</td>
<td>TPS-coated, threaded</td>
<td>Retrospect.</td>
<td>27 P</td>
<td>7 P</td>
<td>70 P</td>
</tr>
<tr>
<td>Schwartz-Arad et al. (2002)</td>
<td>Not reported</td>
<td>Retrospect.</td>
<td>175 P</td>
<td>205 P</td>
<td>402 P</td>
</tr>
<tr>
<td>Wallace (2000)</td>
<td>Machined titanium, threaded</td>
<td>Retrospect.</td>
<td>60 P</td>
<td>12 P</td>
<td>107 P</td>
</tr>
<tr>
<td>De Bruyn et al. (1999)</td>
<td>Microtexture and HA-coated, threaded</td>
<td>Prospect. maxilla</td>
<td>24 P</td>
<td>6 P</td>
<td>23 P</td>
</tr>
<tr>
<td>Karoussis et al. (2003)</td>
<td>TPS-coated hollow screws</td>
<td>Prospect.</td>
<td>26 P</td>
<td>2 P</td>
<td>81 P</td>
</tr>
<tr>
<td>Minsk &amp; Polson (1998)</td>
<td>Not reported</td>
<td>Retrospect. HRT†</td>
<td>269 P</td>
<td>26 P</td>
<td>908 P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>non-HRT†</td>
<td>16 P</td>
<td>6 P</td>
<td>47 P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>98 P</td>
<td>6 P</td>
<td>253 P</td>
</tr>
</tbody>
</table>

*Bränemark fixtures or related implant types.

†All patients suffered from diabetes mellitus.

‡Immediate implants.

§Biologic complications considered failure (spontaneous implant exposure, requiring or not requiring surgical intervention or complete implant failure).

†Female patients above the age of 50 years, divided into two groups: patients receiving postmenopausal hormone replacement therapy (HRT) and patients non-receiving HRT (non-HRT).

P, patient-related data; HA-coated, hydroxyapatite-coated; TPS-coated, titanium plasma spray-coated; Prospect., prospective studies; Retrospect., retrospective studies.

SFEA implants inserted in conjunction with sinus floor elevation and augmentation.

GBR implants inserted in conjunction with bone defect augmentation by guided bone regeneration.
Smoking interferes with the prognosis of dental implant treatment

Data and observation periods of 6 and 34 months, respectively. After second stage surgery and prosthetic loading, no implant failure was noted (Grunder et al. 1999).

Table 5 shows the ORs and CI 95% of the studies reporting implant-related data. Data of studies reporting on implants inserted with accompanying augmentation procedures are not included here.

Analysis of studies considering augmentation procedures

Table 6 shows the ORs and CI 95% of the studies reporting patient-related data. Data of studies reporting on implants inserted with accompanying augmentation procedures are not included here. Only one study provided patient-related data allowing for calculation of the OR for implant failures in smokers undergoing augmentation procedures (Mayfield et al. 2001, Kan et al. 2002). Considering studies providing implant-related data for implant treatment with accompanying augmentation procedures (n = 18 studies), an OR of 3.61 (CI 95% 2.26–5.77) for an enhanced frequency of implant failure in smokers (n = 6 studies), which was significantly different from the OR of 2.15 (CI 95% 1.86–2.49) for implant failures in smokers without accompanying augmentation procedures (n = 12 studies). Although in three studies at most a tendency (Geurs et al. 2001) or no significant associations were found between smoking and enhanced frequency of implant failures in augmented sites (Keller et al. 1999, Olson et al. 2000, Schwartz-Adar et al. 2002, Widmark et al. 2001), three studies showed a significantly enhanced risk of implant loss in augmented sites in smokers, which clearly exceeded the ORs for implant failures calculated for smokers without accompanying augmentation procedures (Mayfield et al. 2001, Widmark et al. 2001, Kan et al. 2002).

Table 2. Weighed mean values (WMV) and standard deviations (SD) of percentage distributions of smokers (S) and non-smokers (NS) considering different observation periods (group 1: observation period ≤ 1 year; group 2: > 1 and ≤ 5 years; group 3: > 5 years) and studies considered

<table>
<thead>
<tr>
<th>Observation period</th>
<th>Implant-related</th>
<th>Patient-related</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMV (%)</td>
<td>SD (%)</td>
<td>WMV (%)</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bain &amp; Moy (1993), Beschnadt et al. (2003), Geurs et al. (2001), Grunder et al. (1999), Jones et al. (1999), Kan et al. (2002), Keller et al. (1999), Lambert et al. (2000), Mayfield et al. (2001), Olson et al. (2000a), Schwartz-Adar et al. (2002), Wallace (2000)</td>
<td>28.3</td>
<td>0.51</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>De Bruyn et al. (1999), Karoussis et al. (2003), Minsk &amp; Polson (1998)</td>
<td>24.6</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Data of studies reporting on implants inserted with accompanying augmentation procedures were not included here.
Table 3. Weighed mean values (WMV) and standard deviations (SD) of percentage distributions of female (F) and male patients (M) considering different observation periods (group 1: observation period <1 year; group 2: >1 and ≤5 years) and studies considered

<table>
<thead>
<tr>
<th>Observation period</th>
<th>WMV (%)</th>
<th>SD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 F ≤1 year</td>
<td>57.0</td>
<td>1.80</td>
</tr>
<tr>
<td>Group 1 M ≤1 year</td>
<td>43.0</td>
<td></td>
</tr>
<tr>
<td>Group 2 F &gt;1 year</td>
<td>54.6</td>
<td>1.44</td>
</tr>
<tr>
<td>Group 2 M &gt;1 year</td>
<td>45.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Weighed mean values (WMV) and standard deviations (SD) of percentage distributions of implant sites (maxilla Mx; mandible Md) considering implant-related data and different observation periods (group 1: observation period <1 year; group 2: >1 and ≤5 years; group 3: >5 years) and studies considered

<table>
<thead>
<tr>
<th>Observation period</th>
<th>WMV (%)</th>
<th>SD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 Mx ≤1 year</td>
<td>62.8</td>
<td>1.10</td>
</tr>
<tr>
<td>Group 1 Md ≤1 year</td>
<td>37.2</td>
<td></td>
</tr>
<tr>
<td>Group 2 Mx &gt;1 year</td>
<td>51.0</td>
<td>0.62</td>
</tr>
<tr>
<td>Group 2 Md &gt;1 year</td>
<td>49.0</td>
<td></td>
</tr>
<tr>
<td>Group 3 Mx &gt;5 years</td>
<td>72.9</td>
<td></td>
</tr>
<tr>
<td>Group 3 Md &gt;5 years</td>
<td>27.1</td>
<td></td>
</tr>
<tr>
<td>De Bruyn et al. (1999)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7 shows ORs and CI95% calculated from studies reporting implant- or patient-related data, including augmentation procedures.

Results obtained from the systematic literature review

Implant failure

Five studies reporting on RR or HR for implant failures in smokers, among them one study reporting on HR for implant failures among smokers after augmentation procedures are listed in Table 8. Apart from one study considering a 10-months observation period (Eckert et al. 2001), for smokers, the RR or HR for implant failures with or without augmentation procedures were reported significantly enhanced.

Furthermore, three studies reported on significantly enhanced implant failure frequencies in smokers, compared with non-smokers. In contrast, one study (Lemmerman & Lemmerman 2005) and one meta-analysis (Bain et al. 2002) including implants with recently introduced implant surfaces microstructured by acid-etching, revealed no significant influence of smoking on implant failure frequency (Table 9).

The risk of peri-implant inflammation

Soft tissue and inflammatory peri-implant complications associated with current tobacco smoking were assessed by five retrospective and two prospective studies, revealing an enhanced risk for smokers to develop peri-implant soft tissue complications. One prospective study investigating the effect of smoking on implants in a small cohort of periodontally compromised patients showed an enhanced risk of implant failures in smokers (Leonhardt et al. 2003) (Table 10).

The risk of peri-implant bone loss

Thirteen studies focused on radiographic assessment of peri-implant bone loss. In 11 studies, a significantly enhanced marginal bone loss was found in smokers, compared with non-smokers, including two studies investigating the effect of smoking on marginal bone loss around implants in patients undergoing a periodontitis or peri-implantitis treatment.

Two studies considered implants with microstructured surfaces conditioned by particle blasting and/or acid-etching or anodic oxidation. One of these studies revealed no significant differences of marginal bone loss around implants in smokers compared with non-smokers (Aalam & Nowzari 2005). In another study significantly more bone loss was found at implants in smokers with periapical radiographs, which was not reproducible in panoramic radiograph assessment, however (Penarrocha et al. 2004) (Table 11).

Smoking as a risk factor for augmentation procedures

Four retrospective studies considered the impact of smoking on the course and outcome of horizontal and/or vertical augmentation procedures, SFEA and GBR for the treatment of alveolar ridge defects before or simultaneously with implantation. Although the augmentation methods and materials as well as barrier materials used were different, three studies reported significantly more failures and complications in smokers, compared with non-smokers. The defect filling in smokers was found less compared with non-smokers but showed no significant difference, however (Table 12).

In a systematic review smoking was confirmed as a significant risk factor for implant failure in connection with SFEA procedures (0.03 < p < 0.05) (Strietzel 2004).
**Discussion**

Methods of evidence-based dentistry have been introduced for optimization of decision making processes in dental diagnostics and treatment, and for a comprehensive patient information in preparation of diagnostic and therapeutic interventions, particularly before elective treatment. Therefore, patient’s decision making before implant–prosthetic rehabilitation should be supported by information about risks and risk-associated factors.

This meta-analysis and systematic review were performed to provide a summary of cumulative information on smoking-associated risks for implant prognosis and outcomes after augmentation procedures. Moreover, smoking reduction advice, given in conjunction with...
with dental health information may have a marked effect on smokers’ attitude to their habit and provide sufficient incentive to cut down or even stop smoking as well (Macgregor 1996).

Although tobacco smoking is widely accepted as a risk factor for oral health generally (Sham et al. 2003), smoking was considered a risk factor for implant treatment since first publication on this issue by Bain & Moy (1993). Nevertheless, the impact of consideration of the patient’s status as a smoker or non-smoker in implant treatment planning seems not to be controversial but indistinct. A national questionnaire to NHS-consultants to evaluate their attitudes concerning relevant medical and oral factors considered in patient selection for dental implant treatment in 1999 revealed, that – among others – smoking was one of the most important medical factors contra-indicating implant treatment (Butterworth et al. 2001).

A survey among Finnish dentists evaluating the association of various patient characteristics or possible contra-indications for dental implant treatment revealed, that significantly more dentists working in the public or private sector recommended implant therapy compared with staff of dental schools in case of smoking patients (p = 0.002).

Older dentists (40–49 years) were found more in favour for implant therapy in smokers than were younger dentists (30–39 years) (Heinkainen et al. 2002). Estimating smoking as a risk factor for treatment decisions therefore might differ among dentists. This impression seems to be confirmed by different attempts made to quantify the amount of smoked cigarettes per day: some studies included for meta-analysis and systematic review considered a patient a smoker regardless quantity of smoked cigarettes per day or quality of tobacco smoking (Bain & Moy 1993, De Bruyn & Collaert 1994, De Bruyn et al. 1999, Jones et al. 1999, Geurs et al. 2001). In other studies light and heavy smokers were distinguished by quantification: patients smoking up to 10 cigarettes per day (Schwartz-Arad et al. 2002) or less than 20 cigarettes per day (Gruica et al. 2004) were considered light smokers, whereas patients smoking 10 (Schwartz-Arad et al. 2002) or 20 cigarettes per day or more (Gruica et al. 2004) were considered heavy smokers. As quantification of smoking was different considering the included studies, in this meta-analysis and systematic review, any patient who smoked was considered a smoker according to Wallace (2000). In all included studies, patient questionnaires were used to detect the smoking status. The relatively high reliability of patient self-reports of smoking habits were shown in several studies (Fox et al. 1989, O’Loughlin et al. 2002).

Treatment outcome evaluation criteria were different in several included studies. Besides calculation of differences between cumulative success rates or implant failure frequency between smokers and non-smokers, frequencies of implant failures or biologic complications were recorded. The risk of occurrence of implant failures for smoking patients was expressed as OR, calculated from studies included into meta-analysis by the fixed-effects model as well as the random-effects model, and calculated for single studies on basis of univariate analysis.

Our meta-analysis revealed a significantly enhanced risk for implant failure among smokers compared with non-smokers, expressed by synthesized ORs of 2.4 considering all included studies providing implant-related data, or 2.6 considering all included studies providing patient-related data. Comparing the implant-related ORs for implant failure in smokers considering different observation periods, the risk of implant failure for smokers ranged from 2.8 after up to 1 year decreasing to about 2.3 up to 5 years, indicating a higher risk of early implant failure. Nevertheless, the risk of implant failures among smokers was found significantly enhanced even after 5 years considering the findings of the systematic review. Here, the effects of smoking on the enhanced frequency of peri-implant soft tissue complications, limited peri-implantitis treatment outcomes and enhanced peri-implant bone loss, known as factors limiting the long-term implant prognosis were emphasized.

In an earlier literature review on studies reporting on threaded implants with a machined surface (Bränemark type fixtures) predominantly, consensus had been reached that smoking has a negative influence on implant survival (Esposito et al. 1998). Findings of our meta-analysis and systematic review were obtained from studies involving threaded titanium implants with machined, TPS- or HA-coated surfaces predominantly, whereas

Table 7. Odds ratios (OR) and confidence intervals (CI95%) calculated from studies reporting implant- or patient-related data, including augmentation procedures

<table>
<thead>
<tr>
<th>OR</th>
<th>CI95%</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implant-related data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean observation period ≤ 1 year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Widmark et al. (2001) grafted sites*</td>
<td>20.0</td>
<td>6.33–63.20</td>
</tr>
<tr>
<td>Mean observation period &gt; 1 and ≤ 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geurs et al. (2001)*</td>
<td>2.60</td>
<td>0.99–6.83</td>
</tr>
<tr>
<td>Kan et al. (2001)*</td>
<td>2.76</td>
<td>1.16–6.62</td>
</tr>
<tr>
<td>Kelleher et al. (1999)*</td>
<td>2.03</td>
<td>0.59–7.03</td>
</tr>
<tr>
<td>Mayfield et al. (2001)*</td>
<td>61.2</td>
<td>7.39–506.0</td>
</tr>
<tr>
<td>Olson et al. (2000a)*</td>
<td>9.45</td>
<td>1.14–78.11</td>
</tr>
<tr>
<td>Patient-related data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean observation period &gt; 1 and ≤ 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mayfield et al. (2001)*</td>
<td>41.7</td>
<td>3.56–486.9</td>
</tr>
</tbody>
</table>

*SEFA.

†Lateral alveolar ridge augmentation/GBR.

Calculated following the suggestion by Gart & Zweifel (1967) and Fleiss (1981).
studies including implants with microstructured surfaces recently introduced (acid etched and/or particle blasted) meeting the inclusion criteria for this meta-analysis were rarely published.

One study on wide diameter-threaded machined titanium implants revealed a non-significant HR of 2.4 for implant failure in smokers after a 10-months observation period (Eckert et al. 2001). Apart from three more studies included into systematic review indicating a significantly enhanced risk of implant failure for smokers (Wilson & Nunn 1999, Kourtis et al. 2004, Ortrop & Jemt 2004), four studies (Grunder et al. 1999, Kumar et al. 2002, Aalam & Nowzari 2005, Lemmerman & Lemmerman 2005) and one systematic review (Bain et al. 2002) on implants with acid-etched, particle-blasted or anodic oxidized surfaces, revealed no associations between implant failures and smoking nor significant differences of implant failure frequencies among smokers and non-smokers, respectively. Furthermore, a comparison between threaded implants with machined and anodic-oxidized surfaces showed no significant influence of smoking on implant failures for implants with an anodic-oxidized surface (Rocci et al. 2003).

Although smoking was shown to be a significant risk factor within the limits of this meta-analysis and systematic review referring to studies reporting on implants with machined or TPS- or HA-coated surfaces predominantly, future studies focusing on implant surface condition using acid etching and/or particle blasting should be analysed regarding influence of tobacco smoking on early as well as long-term outcomes to allow for a more substantiated statement concerning this issue.

Our findings considering the implant-related OR for implant failures in smokers were similar to those published by Hinode et al. (2006), who performed a meta-analysis on the influence of smoking on osseointegrated implants, based on implant-related data. As earlier investigations revealed a within-patient dependence of implant success rates (Herrmann et al. 1999, 2003), patient-related ORs were calculated separately to exclude cumulative effects of individual risk factors. Compared with 18 studies providing implant-related data, only five prospective and five retrospective studies reported patient-related data.
Table 9. Characteristics of studies reporting on the frequency of implant failures in smokers compared with non-smokers, included into the systematic review

<table>
<thead>
<tr>
<th>Study</th>
<th>Implant characteristics</th>
<th>Study design</th>
<th>Mean observation period</th>
<th>Sample sizes</th>
<th>Evaluation criteria, statistics, outcomes</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bain et al. (2002)</td>
<td>Threaded, machined titanium* or acid-etched† implants</td>
<td>Meta-analysis</td>
<td>60.1 months* 43.7 months†</td>
<td>3 prospective multicenter studies (2609 implants * in 1013 patients; 6 prospective studies (2274 implants † in 778 patients)</td>
<td>Implant survival Kaplan-Meier survival analysis 3-year CSR In non-smokers: 92.8% *implants 98.4% †implants; In smokers: 93.5% *implants 98.7% †implants No significant difference of implant survival was observed between smoking and non-smoking patients</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Kourtis et al. (2004)</td>
<td>Cylindric, TPS-coated or threaded, particle-blasted implants</td>
<td>Retrospective</td>
<td>4.6 years</td>
<td>1692 implants in 405 patients (853 implants in smokers; 839 implants in non-smokers)</td>
<td>Failure: implant removal or loss χ² test Significantly higher failure rate in smokers compared with non-smokers</td>
<td>= 0.945</td>
</tr>
<tr>
<td>Lemmerman &amp; Lemmerman (2005)</td>
<td>Cylindric, TPS-coated‡; threaded, machined titanium* and threaded, acid-etched† implants</td>
<td>Retrospective</td>
<td>5.3 years</td>
<td>1003 implants in 376 patients 146 implants‡ 348 implants * 655 implants †</td>
<td>Failure: implant removal or loss ANOVA No correlations between smoking and implant failures</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Örtorp &amp; Jemt (2004)</td>
<td>Threaded, machined titanium implants</td>
<td>RCT</td>
<td>5 years</td>
<td>792 implants in 126 patients</td>
<td>Failure: implant removal or loss Life-table analysis Significantly higher failure rate in smokers compared with non-smokers patient-related &lt;0.01; implant-related &lt;0.05</td>
<td>= 0.024</td>
</tr>
<tr>
<td>Wilson &amp; Nunn (1999)</td>
<td>Threaded, TPS-coated or machined implants</td>
<td>Retrospective</td>
<td>Failed implants: 8 months, success-ful implants: 3.2 years</td>
<td>33 failed implants in 27 patients 68 successful implants in 38 patients</td>
<td>Failure: Implant loss or 50% bone loss RR 2.5 (CI₉₅% 1.13–5.55) Log-rank test Significantly higher failure rate in smokers compared with non-smokers</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

*Bränemark fixtures or related threaded titanium implants with a machined surface.
†Threaded titanium implants with an acid-etched surface.
‡TPS-coated cylindric titanium implants.

RCT, randomized clinical trial; RR, risk ratio; expressing the risk of implant failures among smokers, compared with non-smokers. CSR, cumulative survival rate.
Table 10. Characteristics of studies reporting on the frequency of soft tissue and peri-implant complications in smokers compared with non-smokers, included into the systematic review

<table>
<thead>
<tr>
<th>Study</th>
<th>Implant characteristics</th>
<th>Study design</th>
<th>Mean observation period</th>
<th>Sample sizes</th>
<th>Statistics, outcomes</th>
</tr>
</thead>
</table>
| Ataoglu et al. (2002) | Root-form implants, no further characterization             | Prospective  | At least 1 year         | 42 implants in 14 patients 10 non-smokers, representing 24 implants | Mann–Whitney U-test  
Significantly increased inflammation-related clinical parameters (probing depth, modified plaque index, gingival index and sulcus fluid flow rate) in smokers  
Peri-implant crevicular fluid sampling showed significantly decreased neutrophil elastase activity and concentration in smokers |
| Attard & Zarb (2002) | Threaded, machined titanium implants                        | Retrospective | 18.3 years for hypo-thyroid patients; 16.6 years for healthy control patients | 27 hypothyroid patients, 82 implants; 29 healthy control patients, 81 implants | Logistic regression  
OR 3.9  
(CI 95% 1.1–13.5)  
Significantly higher risk for smokers to develop peri-implant inflammatory soft tissue complications |
| Gruica et al. (2004) | TPS-coated hollow cylinder or hollow-or solid-threaded implants | Retrospective | At least 8 years        | 292 implants in 180 patients 53 smokers, 127 non-smokers | Multivariate logistic regression model  
Significantly higher risk for smokers to develop peri-implant inflammatory complications |
| Haas et al. (1996)  | Cylindric, TPS-coated and threaded, machined titanium implants | Retrospective | 22 months               | 1366 implants in 107 smokers; 1000 implants in 314 non-smokers | Wilcoxon rank test  
Higher scores in bleeding index, mean probing depth, degree of peri-implant mucosal inflammation and bone loss in smokers, compared with non-smokers |
| McDermott et al. (2003) | HA- or TPS-coated or uncoated/passivated screw-like shape with fins | Retrospective | 8 years                 | 23-49 implants in 677 patients | Cox proportional hazard regression model  
HR 2.6  
(CI 95% 1.41–4.84)  
Significantly higher risk for smokers to develop peri-implant inflammatory complications |
| Oates et al. (2004) | HA- or TPS-coated cylindric titanium implants               | Prospective   | At least 60 months      | 104 implants in 16 patients (50 implants in eight smokers) | Analysis of variances (ANOVA)  
Pyridinoline levels in peri-implant crevicular fluid were found significantly enhanced in smokers compared with non-smokers, suggesting that smoking may contribute to implant failure by increasing bone resorption in smokers |
| Weyant (1994)       | Not reported                                                | Retrospective | Not reported            | 2098 implants in 598 patients | Bivariate analysis, logistic regression  
OR 1.8  
Significantly more peri-implant soft tissue pathoses in smokers, compared with non-smokers |

Investigations on the effect of smoking on implants in patients undergoing treatment of periodontitis and peri-implantitis

Leonhardt et al. (2003) Threaded, machined titanium implants Prospective 5 years 26 implants in nine patients More implants (seven of 18) failed in smokers compared with (one of eight) non-smokers
<table>
<thead>
<tr>
<th>Study</th>
<th>Implant characteristics</th>
<th>Study design</th>
<th>Mean observation period</th>
<th>Sample sizes</th>
<th>Statistics, outcomes</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aalam &amp; Nowzari (2005)</td>
<td>Anodic oxidized or dual acid etched or machined threaded titanium implants</td>
<td>Retrospective</td>
<td>2 years</td>
<td>198 implants (58 implants, 52 implants, 88 implants) in 74 patients</td>
<td>ANOVA</td>
<td>$&gt;0.05$</td>
</tr>
<tr>
<td>Carlsson et al. (2000)</td>
<td>Threaded, machined titanium implants</td>
<td>Prospective</td>
<td>15 years</td>
<td>273 implants in 44 patients (21 smokers)</td>
<td>$t$-test</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Feloutzis et al. (2003)</td>
<td>TPS-coated, hollow cylinder or hollow or solid threaded implants</td>
<td>Prospective</td>
<td>5.6 years</td>
<td>182 implants in 90 patients</td>
<td>$\chi^2$ test, stratified analysis, Fisher exact test</td>
<td>$&lt;0.04$</td>
</tr>
<tr>
<td>Galindo-Moreno et al. (2005)</td>
<td>Machined or TPS-coated threaded or HA-coated cylindrical implants</td>
<td>Prospective</td>
<td>3 years</td>
<td>514 implants in 185 patients (63 smokers)</td>
<td>Contingency tables, Pearson's correlation coefficient</td>
<td>$&lt;0.02$</td>
</tr>
<tr>
<td>Haas et al. (1996)</td>
<td>Cylindrical, TPS-coated and threaded, machined titanium implants</td>
<td>Retrospective</td>
<td>22 months</td>
<td>1366 implants in 107 smokers; 1000 implants in 314 non-smokers</td>
<td>Wilcoxon rank test</td>
<td>$&lt;0.01$</td>
</tr>
<tr>
<td>Karoussis et al. (2004)</td>
<td>TPS-coated, hollow cylinder or hollow threaded implants</td>
<td>Prospective</td>
<td>10 years</td>
<td>179 implants in 89 patients</td>
<td>Multiple stepwise regression analysis</td>
<td>$&lt;0.0001$</td>
</tr>
<tr>
<td>Lindquist et al. (1996)</td>
<td>Threaded, machined titanium implants</td>
<td>Prospective</td>
<td>15 years</td>
<td>278 implants in 47 patients</td>
<td>$t$-test</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Lindquist et al. (1997)</td>
<td>Threaded, machined titanium implants</td>
<td>Prospective</td>
<td>10 years</td>
<td>266 implants in 45 patients (21 smokers, 24 non-smokers, edentulous mandibles)</td>
<td>$t$-test</td>
<td>$&lt;0.001$</td>
</tr>
</tbody>
</table>
without consideration of accompanying augmentation procedures and were included into meta-analysis. The patient-related OR for implant failures among smokers was calculated 2.6 and was found significantly enhanced, although three studies (De Bruyn et al. 1999, Penarrocha et al. 2002, van Steenberge et al. 2004) revealed no significantly enhanced ORs, and one study (Kronström et al. 2001) revealed a tendency of an enhanced OR for implant failure. Nevertheless, this implicates, that even considering patient-related data, the risk of implant failures for smokers should be considered critically in patient information.

Besides univariate analysis and consideration of implant failures in smokers in the meta-analysis, peri-implant parameters as there are peri-implant mucosal status or peri-implant bone level known to be associated with the implant prognosis (Misch 1993, Buser et al. 1997, Roos et al. 1997, Sennerby & Roos 1998, Schubert et al. 2001, Cochran et al. 2002) were included into the systematic review concerning associations with patients’ tobacco smoking status. The systematic review identified studies investigating on peri-implant soft tissues and the quality and components of the peri-implant crevicular fluid, revealing a significantly enhanced risk for peri-implant inflammatory complications in periodontally compromised smokers (Table 10). Although these studies focused on single aspects and therefore the supposed complex mechanisms of smoking side effects on the peri-implant soft tissues might not be completely discovered, an enhanced risk for inflammatory peri-implant complications might be expected – among others – due to tobacco smoking-associated vasoconstrictive effects at the end-arterial gingival vessels (Sham et al. 2003) and the significant decrease of neutrophil elastase activity in smokers, which might result in a reduced inflammatory reaction in smokers (Ataoglu et al. 2002). These effects seem to blur the inflammatory peri-implant reaction, whereas certain biomarkers for early peri-implant bone loss, as there are pyridinoline (Oates et al. 2004) or β-glucuronidase levels (Schubert et al. 2001) were found significantly enhanced in peri-implantitis. Therefore, a regular and strict recall of smokers undergoing implant treatment is necessary for early detection of implant complications.
Table 12. Characteristics of studies reporting on outcomes of augmentation procedures and GBR before or simultaneously with implantation in smokers compared with non-smokers, included into the systematic review

<table>
<thead>
<tr>
<th>Study</th>
<th>Augmentation procedure</th>
<th>Observation parameters</th>
<th>Sample sizes</th>
<th>Statistics, outcomes</th>
<th>Outcomes, comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strietzel et al. (2001)</td>
<td>Bone substitution materials with or without barrier membranes for ridge augmentation</td>
<td>Defect reduction after re-entry</td>
<td>72 patients (19 smokers), 72 augmentation sites</td>
<td>Wilcoxon’s test, $n=0.41$</td>
<td>$n=0.16$</td>
</tr>
<tr>
<td>Schwartz-Arad et al. (2005b)</td>
<td>Augmentation of horizontal defects with simultaneous or staged GBR using a porcine collagen membrane for ridge augmentation</td>
<td>Defect reduction after re-entry</td>
<td>75 patients (24 smokers), 112 implants, 112 augmentation sites</td>
<td>Wilcoxon’s test, $n=0.41$</td>
<td>$n=0.16$</td>
</tr>
<tr>
<td>Zitzmann et al. (1999)</td>
<td>Autogenous bone block grafts for horizontal and vertical ridge augmentation and augmentation (SEAT)</td>
<td>Complications: post-surgical swelling and membrane exposure/removal</td>
<td>64 autogenous bone grafts, 64 augmentation sites</td>
<td>Pearson’s correlation coefficient</td>
<td>$n=0.04$</td>
</tr>
<tr>
<td>Levin et al. (2004)</td>
<td>Autogenous onlay bone grafts for sinus floor elevation postsurgery</td>
<td>Follow-up at least 6 months</td>
<td>64 OBG in 56 patients; $n=0(n=OBG)$, sinus floor elevation postsurgery</td>
<td>Pearson’s correlation coefficient</td>
<td>$n=0.04$</td>
</tr>
<tr>
<td>Schwarts-Arad et al. (2005b)</td>
<td>Bone onlay grafts with or without simultaneous GBR</td>
<td>Complications: post-surgical swelling, hematoma, temporary paresthesia, swelling, sinus infection</td>
<td>64 autogenous bone grafts, 79 SFEA in 72 patients</td>
<td>Pearson’s correlation coefficient</td>
<td>$n=0.04$</td>
</tr>
<tr>
<td>Strietzel et al. (2004)</td>
<td>Augmentation of 1-, 2-, 3-wall defects around implants using deproteinized bovine bone mineral for defect filling and a porcine collagen membrane for GBR</td>
<td>Augmentation of horizontal defects with simultaneous or staged GBR using a porcine collagen membrane for ridge augmentation</td>
<td>72 patients (19 smokers), 72 augmentation sites</td>
<td>Wilcoxon’s test, $n=0.41$</td>
<td>$n=0.16$</td>
</tr>
</tbody>
</table>

Smoking was also found to have a significant negative impact on the marginal bone level at implants with machined or TPS- or HA-coated surfaces, which again was not confirmed by two studies on implants with particle-blasted and acid-etched (Penarrocha et al. 2004) or dual acid-etched or anodic-oxidized surfaces (Aalam & Nowzari 2005), showing no association between smoking and marginal bone loss. As shown for implant failure, microstructured implant surfaces seem to have positive influence on marginal bone level around implants in smokers within the limits of this literature review.

The impact of smoking on the outcome of SFEA and GBR seems rarely reported considering the studies identified within this literature search. This might be due to the fact, that smoking is often considered an exclusion criterion for patient recruitment for prospective studies on SFEA or GBR procedures. Nevertheless, our meta-analysis revealed a synthesized OR of about 3.6 and, therefore, a significantly enhanced risk of implant failures for smokers undergoing augmentation procedures. These findings based on studies reporting outcomes after SFEA and confirmed earlier findings from a systematic review (Strietzel 2004). Two studies on GBR and ridge augmentation procedures showed a significantly enhanced risk of graft or barrier membrane exposures requiring partial or complete graft or membrane removal (Strietzel 2001, Schwartz-Arad et al. 2005b). A study on outcomes after alveolar ridge defect augmentation using deproteinized bovine bone mineral for defect filling and a porcine collagen membrane for GBR revealed a reduced defect filling in smokers, which was not significantly different from non-smokers (Zitzmann et al. 1999). Whether the use of collagen membranes significantly minimizes the risk of negative treatment outcomes for GBR in smokers, was not confirmed due to insufficient number of available studies and data, respectively.

Reviews identified within this literature search confirmed, that smoking is one of the factors related to implant failure by reporting conclusions of several studies showing that smoking is associated with higher failure rates, complications and altered peri-implant tissue conditions (Esposito et al. 1998, Sennerby & Roos 1998, Sham et al. 2003, Wood & Vermilyea 2004). An
Smoking interferes with the prognosis of dental implant treatment

In conclusion, smoking was identified a significant risk factor for dental implant therapy. This should be addressed thoroughly in patient information before implant treatment. A strict recall regime throughout the whole treatment course to early detect negative changes of peri-implant tissues or implant failure is necessary. This requires identification of smokers at all.

As augmentation procedures comprise enhanced potential risks of complications generally, smoking should be considered an additional risk and therefore indication should be considered cautiously and critically, evaluated in context with additional risk factors revealed by medical history.

A limited number of studies available on implants with sand-blasted, large grit, acid-etched and/or acid-etched or anodic-oxidized surfaces did not show significant associations between smoking and implant failure and marginal bone loss. Whether these implant surfaces indeed significantly improve outcomes in smokers, has to be confirmed including more studies providing data on implant failure in relation to smokers and non-smokers and by larger sample sizes as well.

References


dontitis associated with abnormal PMN leu-


Miller, P. D. (1988) Regenerative and recon-

tistry, pp. 29–42. St. Louis: Mosby.


naire about knowledge, practices and opini-
on among dentists in Berlin. Mund-, Kiefer- und Gesichtschirurgie 4, 45–49, (arti-
cle in German).

ating implant success: a 5-year retrospective analysis of the Bränemark implant. Interna-


Sennerby, L. & Roos, J. (1998) Surgical deter-
minants of clinical success of osseointegrated oral implants: a review of the literature.


Strietzel, F. P. (2003) Patient’s informed con-
sent prior to implant-prosthetic treatment: a retrospective analysis of expert opinions. International Journal of Oral and Maxillofa-
cial Implants 18, 433–439.


dence-based treatment planning for dental implants: report of the Committee on Research in Fixed Prostho

References included into meta-
analysis

cial Implants 11, 756–759.


Balsi, T. J. & Wollinger, G. J. (1999) Dental implants in the diabetic patient: a retrospec-


De Bruyn, H., Colletta, B., Lindén, U., Johans-

graphic analysis of sinus graft and implant placement procedures from the Academy of Osseointegration consensus conference on sinus grafts. International Journal of Periodon-
tics and Restorative Dentistry 21, 517–523.


Grander, U., Gärberthiel, T., Böitel, N., Imo-
ing the prosthetic predictability. Compendium of Continuing Education in Dentistry 20, 628–640.

sprayed and titanium plasma-sprayed cylin-
der dental implants. Oral Surgery, Oral Med-


nous bone graft reconstruction of compro-
missed maxilla: a 12-year retrospective study. International Journal of Oral and Maxillofa-
cial Implants 14, 707–721.


ure: a 2-year follow-up study. Implant Dent-
istry 14, 281–288.

Olson, J. W., Dent, C. D., Morris, H. F. & Ochi, S. (2000a) Long-term assessment (5 to 71

© 2007 The Authors. Journal compilation © 2007 Blackwell Munksgaard


References included for systematic review


References excluded from meta-analysis and/or systematic review


© 2007 The Authors. Journal compilation © 2007 Blackwell Munksgaard
Smoking interferes with the prognosis of dental implant treatment


Address: Frank Peter Strietzel Department of Oral Surgery and Dental Radiology Centre for Dental Medicine Charité – Medical University Berlin Campus Virchow Clinic Augustenburger Platz 1 13353 Berlin, Germany E-mail: frank.strietzel@charite.de

**Clinical Relevance**

**Scientific rationale for the study:** A meta-analysis and systematic literature review focusing on interactions between implant success and smoking including the likelihood of smoking-associated risks for outcomes after augmentation procedures accompanying implant surgery were performed to support patient information and decision making before implant therapy.

**Principal findings:** The risk of implant failures and biologic complications with and without accompanying augmentation procedures was found significantly enhanced in smokers compared with non-smokers. Five of six studies on implants with particle-blasted, acid-etched or anodic-oxidized surfaces revealed no enhanced risk for implant failures in smokers.

**Practical implications:** Smoking is a significant risk factor for dental implant therapy and augmentation procedures. This should be addressed in patient information before implant treatment. A regular recall of smokers undergoing implant treatment is necessary for early detection of implant complications. Therefore, identification of smokers is required.

© 2007 The Authors. Journal compilation © 2007 Blackwell Munksgaard