J Clin Periodontol 2007; 34: 523–544 doi: 10.1111/j.1600-051X.2007.01083.x

Journal of Clinical Periodontology

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

Frank Peter Strietzel[1], Peter A. Reichart[1], Abhijit Kale[2], Milind Kulkarni[2], Brigitte Wegner[3] and Ingeborg Küchler[3]

[1]Department of Oral Surgery and Dental Radiology, Campus Virchow Clinic, Centre for Dental Medicine, Charité ' Medical University Berlin, Berlin, Germany ; [2]Clinic of General and Restorative Dentistry and Dental Implantology, Maharashtra Medical Foundation's Joshi Hospital, Pune, India; [3]Campus Charité Mitte, Institute for Biometry and Clinical Epidemiology, Charité – Medical University Berlin, Berlin, Germany

Strietzel FP, Reichart PA, Kale A, Kulkarni M, Wegner B, Küchler I. Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. J Clin Periodontol 2007; 34: 523–544. doi: 10.1111/j.1600-051X.2007.01083.x.

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.

Key words: dental implants; meta-analysis; odds ratio; smoking; success rate; survival rate

Accepted for publication 18 February 2007

Smoking was shown to be a primary risk factor for general health, responsible for many serious diseases, as for 90% of all lung cancers, 70% of chronic lung diseases, 80% of myocardial infarctions before the age of 50, and 30% of chronic ischaemic heart diseases and strokes (Fielding 1985, La Veccia et al. 1991, Peto et al. 1996). Currently, there are an estimated 1.3 billion smokers worldwide, and 4.9 million people die from tobacco smoking-related diseases per year (WHO 2005).

Besides the prominent role of health professionals to play in tobacco control and smoking cessation generally, certain aspects concerning current dental therapy should be considered in smokers for thorough patient information before oral surgical procedures and implant therapy planning. The increased risk of wound healing complications (Meechan et al. 1988, Miller 1988, Jones & Triplett 1992, Sands et al. 1993) as well as the risk of peri-implant bone loss and increased implant failure rates (Haas et al. 1996, Lindquist et al. 1996, Lemons et al. 1997) have to be emphasized. Impaired wound healing has to be expected due to less collagen production (Jorgensen et al. 1998), reduced peripheral blood circulation (Lehr 2000) and compromised function of polymorphonuclear leucocytes and macrophages

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.

(Kenney et al. 1977, MacFarlane et al. 1992). Moreover, smoking was indicated a significant subject-based risk factor for periodontitis by recently published literature reviews (Palmer et al. 2005, Ramseier 2005). Although not completely investigated, the known mechanisms of action of smoking on periodontitis were found to be the long-term chronic effect due to impairing the vasculature of periodontal tissues and affection of multiple functions of neutrophils and inflammatory response as well as impairment of fibroblasts (Palmer et al. 2005).

Therefore, identification of the smoking patient is required. Patient questionnaires considering general health issues, but also asking for smoking habits and alcohol consumption, seem to be necessary, though not generally used as a matter of routine yet (Reichart et al. 2000).

Thorough patient information about the planned treatment course and the expected outcomes, but also about risks and risk-associated factors is necessary to support the patient's decision making before implant therapy (Strietzel 2003). Therefore, a systematic analysis of the literature focusing on expected interactions between implant prognosis and smoking seemed to be necessary to provide quantitative facts including the likelihood of smoking-associated risks for implant prognosis and outcomes after augmentation procedures accompanying implant surgery, to support a risk analysis before therapy, and to substantiate the patient information.

This meta-analysis and systematic review focused on the question, if there is a significantly enhanced risk of implant failures in smokers compared with non-smokers. The influence of smoking on implants inserted with accompanying augmentation procedures was additionally investigated.

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 $\leqslant 1$ year; group 2: >1 and $\leqslant 5$ 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 cumulation of individual risks, studies publishing patient-related data were considered separately from those reporting implant-related data for meta-analysis.

Considering studies publishing implant-related data, implants were considered failures if they failed to osseointegrate (Balshi & Wolfinger 1999, Grunder et al. 1999, Keller et al. 1999, Kronström et al. 2001, Mayfield et al. 2001, Kumar et al. 2002, van Steenberghe et al. 2002), were lost or removed for any reason (Bain & Moy 1993, De Bruyn & Collaert 1994, Bain 1996, Minsk & Polson 1998, De Bruyn et al. 1999, Jones et al. 1999, Berge & Grønningsaeter 2000, Lambert et al.

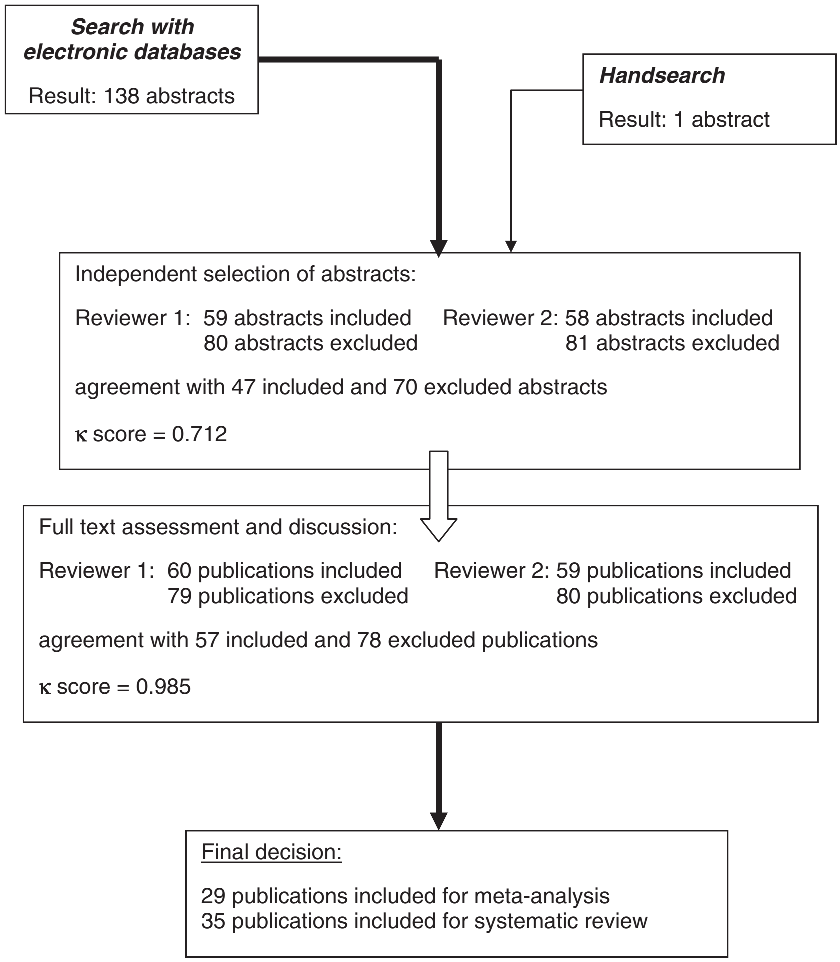


Fig. 1. Search strategy and results of identification and inclusion of publications considered for meta-analysis and systematic review. The κ-score expresses the agreement between the reviewers.

2000, Olson et al. 2000a, b, Schwartz-Arad et al. 2000, Geurs et al. 2001, Widmark et al. 2001, Örtorp & Jemt 2002, Penarrocha et al. 2002, Schwartz-Arad et al. 2002, Beschnidt et al. 2003, van Steenberghe et al. 2004, Moheng & Feryn 2005) or exceeded more than 50% bone loss (Bain & Moy 1993, Bain 1996) or more than 4 mm of vertical bone defect (Berge & Grønningsaeter 2000), if they failed one or more of the criteria proposed by Smith & Zarb (1989) (Kan et al. 2002), revealed mobility (without having removed implant prostheses for individual implant mobility test), persistent pain, peri-implant radiolucency and/or infections attributable to the implant (Gorman et al. 1994, Wallace 2000), or if they showed biologic complications (peri-implantitis) (Karoussis et al. 2003).

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 ($CI_{95\%}$) 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

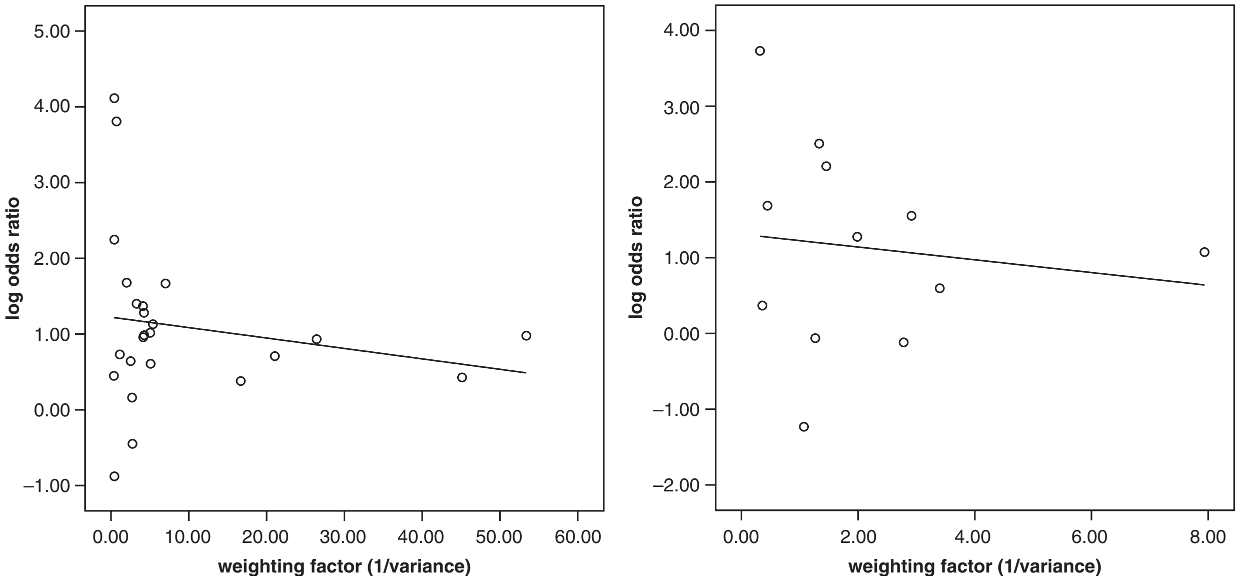


Fig. 2. (a) Funnel plot of the log OR calculated for studies providing implant-related data ($n = 24$). (b) Funnel plot of the log OR calculated for studies providing patient-related data ($n = 12$).

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 ($CI_{95\%}$ 1.96–2.59), revealing evidence for a significant association between smoking and implant failure. The test of heterogeneity of included studies yielded $p = 0.013$. Because of the heterogeneity further calculations using the mixed model taking into account the random effects of the studies on implant-related studies revealed an OR of 2.38 ($CI_{95\%}$ 1.93–2.93).

Considering the groups of different mean observation periods as covariates, the OR for implant failures in smokers calculated from studies with a mean observation period of up to 1 year ($n = 8$) was 2.83 ($CI_{95\%}$ 2.08–3.85). An OR of 2.25 ($CI_{95\%}$ 1.90–2.67) was calculated from studies reporting data regarding mean observation periods between more than one up to 5 years ($n = 13$). The implant-related ORs after observation periods after up to 1 year as well as between 1 and 5 years revealed a significantly enhanced risk of 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 with 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 (Grunder 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

Study	Implant characteristics	Study design	Smokers		Non-smokers		Sample sizes
			Impl. successful	Failure	Impl. successful	Failure	
Group 1: mean observation period period ⩽1 year							
Bain (1996)	Machined titanium, threaded*	Prospect.	38	9	166	10	223 implants 78 patients
Balshi & Wolfinger (1999)	Machined titanium, threaded*	Retrospect.	1 P	1 P	27 P	5 P	227 implants 34 patients[†]
De Bruyn & Collaert (1994)	Machined titanium, threaded*	Retrospect.	71	7	163	3	244 implants
		maxilla	11 P	5 P	43 P	2 P	61 patients
		mandible	36	0	171	1	208 implants
			10 P	0 P	45 P	1 P	56 patients
Gorman et al. (1994)	Not reported	Retrospect.	604	42	1373	47	2066 implants
			64 P	18 P	208 P	20 P	310 patients
Kronström et al. (2001)	Machined titanium, threaded*	Retrospect.	3 P	9 P	37 P	31 P	80 patients
Kumar et al. (2002)	Large-grit blasted and acid-etched, threaded	Prospect.	261	8	899	15	1183 implants 461 patients
Schwartz-Arad et al. (2000)	Machined titanium, threaded and HA-coated, threaded and cylindric	Retrospect.	5	1	45	5	56 implants[‡] 43 patients
van Steenberghe et al. (2002)	Machined titanium, threaded*	Prospect.	148	8	1088	19	1263 implants 399 patients
van Steenberghe et al. (2004)	Machined titanium, threaded*	Prospect. immediate loading (Bråne-mark novum), mandible	11 P	2 P	28 P	4 P	150 implants 45 patients
Widmark et al. (2001)	Machined titanium, threaded*	Prospect. maxilla, SFEA grafted	41	26	117	14	198 implants
		sites non-grafted	6	17	70	8	43 patients
			35	9	47	6	101 implants 97 implants
Group 2: mean observation period >1 and ⩽5 years							
Bain & Moy (1993)	Machined titanium, threaded*	Prospect.	346	44	1718	86	2194 implants 540 patients
Berge & Grønningsaeter (2000)	Ceramic implants, threaded	Prospect.	40	21	48	7	116 implants 30 patients
Beschnidt et al. (2003)	Machined titanium, threaded*	Prospect.	47	4	152	11	214 implants 76 patients
Geurs et al. (2001)	Not reported	Retrospect. maxilla, SFEA	55	7	266	13	341 implants
Grunder et al. (1999)	Acid-etched titanium, threaded	Prospect.	55	0	161	3	219 implants 74 patients
Jones et al. (1999)	Cylindrical HA- or TPS-coated implants	Prospect.	115	11	212	5	343 implants
			12 P	7 P	42 P	2 P	63 patients
Kan et al. (2002)	HA-coated threaded and non-threaded, titanium	Retrospect.maxilla, SFEA	58	12	147	11	228 implants 60 patients
Keller et al. (1999)	Machined titanium, threaded*	Retrospect. maxilla, SFEA	13	4	106	16	

Table 1. (Contd.)

Study	Implant characteristics	Study design	Smokers		Non-smokers		Sample sizes
			Impl. successful	Failure	Impl. successful	Failure	
							139 implants 37 patients
Lambert et al. (2000)	Not reported	Retrospect.	874	85	1813	115	2887 implants
Mayfield et al. (2001)	TPS-coated and machined titanium, threaded and cylindric	Prospect. SFEA, GBR	6 1 P	7 2 P	26 12 P	0 0 P	39 implants 15 patients
Moheng & Feryn (2005)	Cylindrical TPS coated, and particle-blasted threaded implants	Prospect.	11 P	4 P	75 P	3 P	93 patients
Olson et al. (2000a)	HA-coated and non-coated titanium, threaded and cylindric	Retrospect. maxilla, SFEA	48	3	65	0	116 implants 36 patients
Örtorp & Jemt (2002)	Machined titanium, threaded*	Prospect.	33 P	10 P	78 P	5 P	729 implants 126 patients
Penarrocha et al. (2002)	TPS-coated, threaded	Retrospect.	27 P	7 P	70 P	10 P	441 implants 114 patients
Schwartz-Arad et al. (2002)	Not reported	Retrospect.	175	205§	402	177§	959 implants 261 patients
Wallace (2000)	Machined titanium, threaded*	Retrospect.	60	12	107	8	187 implants 56 patients
Group 3: mean observation period >5 years							
De Bruyn et al. (1999)	Microtexture and HA-coated, threaded	Prospect. maxilla	24 8 P	6 2 P	23 7 P	9 6 P	62 implants 23 patients
Karoussis et al. (2003)	TPS-coated hollow screws	Prospect.	26	2	81	3	112 implants 53 patients
Minsk & Polson (1998)	Not reported	Retrospect. HRT¶ non-HRT¶	269 16 98	26 6 6	908 47 253	60 2 22	1263 implants 116 patients¶ 71 HRT 379 non-HRT

*Brånemark 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.

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

Observation period	Implant-related		Patient-related	
	WMV (%)	SD (%)	WMV (%)	SD (%)
Group 1	S 24.0 NS 76.0	0.58	S 20.1 NS 79.9	1.22
	Bain (1996), De Bruyn & Collaert (1994), Gorman et al. (1994), Kumar et al. (2002), Schwartz-Arad et al. (2000), van Steenberghe et al. (2002), Widmark et al. (2001)		Balshi & Wolfinger (1999), De Bruyn & Collaert (1994), Gorman et al. (1994), Kronström et al. (2001), Kumar et al. (2002), van Steenberghe et al. (2004), Widmark et al. (2001)	
Group 2	S 28.3 NS 71.4	0.51	S 30.4 NS 69.3	1.60
	Bain & Moy (1993), Beschnidt 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-Arad et al. (2002), Wallace (2000)		Berge & Grønningsaeter (2000), Grunder et al. (1999), Jones et al. (1999), Mayfield et al. (2001), Moheng & Feryn (2005), Örtorp & Jemt (2002), Penarrocha et al. (2002), Schwartz-Arad et al. (2002), Wallace (2000)	
Group 3	S 24.6 NS 75.4	1.14	S 28.9 NS 71.1	5.20
	De Bruyn et al. (1999), Karoussis et al. (2003), Minsk & Polson (1998)		De Bruyn et al. (1999), Karoussis et al. (2003)	

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 providing patient-related data

Patient-related data were obtained from ten studies. Calculations of pooled risk by applying the fixed-effects model without covariates on studies providing patient-related data showed an OR of 2.64 ($CI_{95\%}$ 1.70–4.09). Test of heterogeneity of included studies yielded $p = 0.07$, revealing no heterogeneity of included studies.

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.

Analysis of studies considering augmentation procedures

Considering studies providing implant-related data for implant treatment with accompanying augmentation procedures as covariate, the calculation using the mixed effects model procedure revealed an OR of 2.15 ($CI_{95\%}$ 1.86–2.49) for implant failures in smokers without augmentation procedures ($n = 18$ studies), and an OR of 3.61 ($CI_{95\%}$ 2.26–5.77) for implant failures in smokers undergoing augmentation procedures ($n = 6$ studies), which was significantly different ($p = 0.039$).

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. 2000a, b), 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).

Only one study provided patient-related data allowing for calculation of the OR for implant failures in smokers undergoing augmentation procedures.

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

Observation period	WMV (%)	SD (%)
Group 1	F 57.0 M 43.0	1.80
	Balshi & Wolfinger (1999), De Bruyn & Collaert (1994), Schwartz-Arad et al. (2000), Kronström et al. (2001), van Steenberghe et al. (2002), van Steenberghe et al. (2004), Widmark et al. (2001)	
Group 2	F 54.6 M 45.3	1.44
	Bain & Moy (1993), Berge & Grønningsaeter (2000), Beschnidt et al. (2003), Grunder et al. (1999), Jones et al. (1999), Kan et al. (2002), Keller et al. (1999), Mayfield et al. (2001), Moheng & Feryn (2005), Olson et al. (2000a), Penarrocha et al. (2002), [28-1]Wallace (2000)	

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

Observation period	WMV (%)	SD (%)
Group 1	Mx 62.8 Md 37.2	1.10
	Balshi & Wolfinger (1999), De Bruyn & Collaert (1994), Kumar et al. (2002), Schwartz-Arad et al. (2000)	
Group 2	Mx 51.0 Md 49.0	0.62
	Bain & Moy (1993), Beschnidt et al. (2003), Grunder et al. (1999), Jones et al. (1999), Lambert et al. (2000), Penarrocha et al. (2002), Wallace (2000)	
Group 3	Mx 72.9 Md 27.1	
	De Bruyn et al. (1999)	

Table 7 shows ORs and $CI_{95\%}$ 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 oxidization. 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).

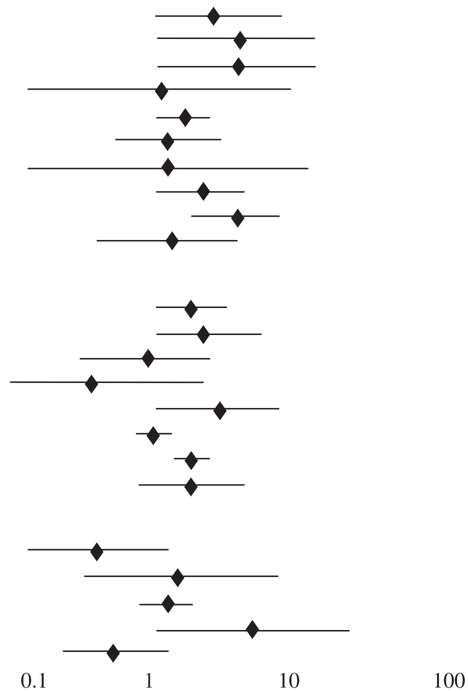
Smoking as a risk factor for augmentation procedures

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).

Table 5. Odds ratios (OR) and confidence intervals ($CI_{95\%}$) calculated from studies reporting implant-related data without consideration of augmentation procedures

	OR	$CI_{95\%}$	*p*
Mean observation period ⩽1 year			
Bain (1996)	3.93	1.50–10.34	0.007
De Bruyn & Collaert (1994)	5.46	1.35–21.31	0.014
Maxilla	5.36	1.57–19.02	0.007
Mandible	1.57*	0.16–15.27	0.541
Gorman et al. (1994)	2.03	1.32–3.11	0.001
Kumar et al. (2002	1.84	0.77–4.38	0.164
Schwartz-Arad et al. (2000)	1.80	0.17–18.64	0.511
van Steenberghe et al. (2002)	3.10	1.33–7.20	0.013
Widmark et al. (2001) entire sample	5.30	2.53–11.12	0.0001
Non-grafted sites (maxilla)	2.01	0.65–6.18	0.169
Mean observation period >1 and ⩽5 years			
Bain & Moy (1993)	2.54	1.74–3.72	0.0001
Berge & Grønningsaeter (2000)	3.60	1.39–9.33	0.005
Beschnidt et al. (2003)	1.18*	0.36–3.87	0.789
Grunder et al. (1999)	0.42*	0.05–3.41	0.357
Jones et al. (1999)	4.06	1.38–11.96	0.007
Lambert et al. (2000)	1.53	1.14–2.05	0.004
Schwartz-Arad et al. (2002)	2.66	2.66–3.48	0.0001
Wallace (2000)	2.68	1.04–6.91	0.037
Mean observation period >5 years			
De Bruyn et al. (1999) (maxilla)	0.64	0.19–2.08	0.327
Karoussis et al. (2003)	2.08	0.33–13.12	0.367
Minsk & Polson (1998)† entire sample	1.46	0.90–2.36	0.079
HRT	8.81	1.61–48.14	0.009
Non-HRT	0.70	0.28–1.79	0.518

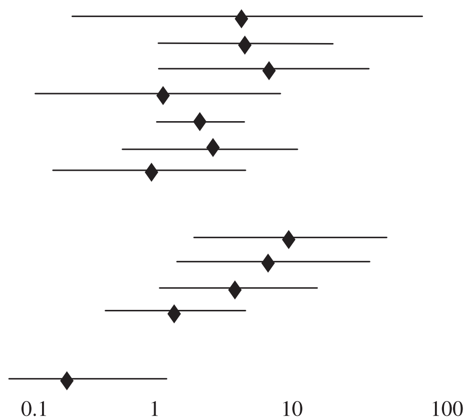


*Calculated following the suggestion by Gart & Zweifel (1967) and Fleiss (1981).

†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).

Table 6. Odds ratios (OR) and confidence intervals ($CI_{95\%}$) calculated from studies reporting patient-related data without augmentation procedures

	OR	$CI_{95\%}$	*p*
Mean observation period ⩽1 year			
Balshi & Wolfinger (1999)	5.40	0.29–101.3	0.326
De Bruyn & Collaert (1994)	6.89	1.54–31.57	0.013
Maxilla	9.77	1.67–57.29	0.011
Mandible	1.44*	0.14–14.59	0.574
Gorman et al. (1994)	2.92	1.46–5.86	0.002
Kronström et al. (2001)	3.58	0.89–14.39	0.057
van Steenberghe et al. (2004)	1.27	0.20–7.97	0.567
Mean observation period >1 and ⩽5 years			
Jones et al. (1999)	12.2	2.24–66.88	0.002
Moheng & Feryn (2005)	9.09	1.79–46.18	0.012
Örtorp & Jemt (2002)	4.73	1.50–14.90	0.007
Penarrocha et al. (2002)	1.82	0.63–5.25	0.203
Mean observation period >5 years			
De Bruyn et al. (1999) (maxilla)	0.29	0.04–1.94	0.195



*Calculated following the suggestion by Gart & Zweifel (1967) and Fleiss (1981).

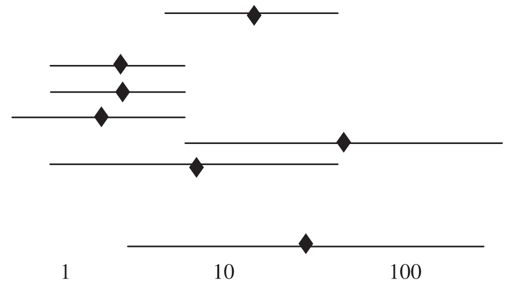
Discussion

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

Table 7. Odds ratios (OR) and confidence intervals ($CI_{95\%}$) calculated from studies reporting implant- or patient-related data, including augmentation procedures

	OR	$CI_{95\%}$	*p*
Implant-related data			
Mean observation period ⩽1 year			
Widmark et al. (2001) grafted sites*	20.0	6.33–63.20	0.0001
Mean observation period >1 and ⩽5 years			
Geurs et al. (2001)*	2.60	0.99–6.83	0.051
Kan et al. (2002)*	2.76	1.16–6.62	0.02
Keller et al. (1999)*	2.03	0.59–7.03	0.210
Mayfield et al. (2001)*/†	61.2‡	7.39–506.0	0.0001
Olson et al. (2000a)*	9.45‡	1.14–78.11	0.014
Patient-related data			
Mean observation period >1 and ⩽5 years			
Mayfield et al. (2001)*/†	41.7‡	3.56–486.9	0.001



*SFEA.
†Lateral alveolar ridge augmentation/GBR).
‡Calculated following the suggestion by Gart & Zweifel (1967) and Fleiss (1981).

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) (Heinikainen 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 distincted 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 (Brånemark 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 8. Characteristics of studies reporting on the risk of implant failures, included into the systematic review

Study	Implant system	Study design	Mean observation period	HR OR RR	$CI_{95\%}$	p	Sample sizes
Baelum & Ellegaard (2004)	Threaded, TPS-coated or particle-blasted	Retrospect.	> 6 years	HR 2.6*	0.9–7.6	< 0.05	258 implants: mandible: 57, maxilla: 201 140 patients†
Chuang et al. (2002b)	HA- or TPS-coated or uncoated/passivated screw-like shape with fins	Retrospect.	≤8 years	HR 2.9‡	1.6–5.3	< 0.01	2349 implants: mandible: 934, maxilla: 1415 677 patients
Eckert et al. (2001)	Machined titanium threaded‖,¶	Retrospect.	10 months	HR 2.4*	Not reported	= 0.16	85 implants: mandible: 57, maxilla: 28 55 patients
Moy et al. (2005)	Different; most implants machined titanium, threaded§	Retrospect.	Not reported, implanted between 1982 and 2003	RR 1.56 ‖	1.0–2.4	< 0.05	4680 implants: mandible: 2427, maxilla: 2253 1140 patients
Augmentation of alveolar crest width and/or height or internal or external sinus floor elevation and augmentation							
Woo et al. 2004)	HA- or TPS-coated or uncoated/passivated screw-like shape with fins	Retrospect.	≤8 years	HR 4.4**	2.0–9.8	< 0.001	677 implants: mandible: 252, maxilla: 425 677 patients (1 implant considered per patient)

*Cox's proportional hazard model.
**Multivariate Cox model.
†Periodontally compromised patients.
‡Clustered Cox's regression analysis.
§Brånemark fixtures or related implant types.
¶Brånemark Mark-II wide platform and wide diameter implants were used exclusively.
‖ Univariate analysis.
HR, hazard ratio; RR ,risk ratio; expressing the risk of implant failures among smokers, compared with non-smokers.

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, Örtorp & 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

Study	Implant characteristics	Study design	Mean observation period	Sample sizes	Evaluation criteria, statistics, outcomes	p
Bain et al. (2002)	Threaded, machined titanium* or acid-etched† implants	Meta-analysis	60.1 months* 43.7 months†	3 prospective multicenter studies (2609 implants * in 1013 patients; 6 prospective studies (2274 implants † in 778 patients)	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	
Kourtis et al. (2004)	Cylindric, TPS-coated or threaded, particle-blasted implants	Retrospective	4.6 years	1692 implants in 405 patients (853 implants in smokers; 839 implants in non-smokers)	Failure: implant removal or loss χ^2 test Significantly higher failure rate in smokers compared with non-smokers	<0.001
Lemmerman & Lemmerman (2005)	Cylindric, TPS-coated‡; threaded, machined titanium* and threaded, acid-etched† implants	Retrospective	5.3 years	1003 implants in 376 patients 146 implants‡ 348 implants * 655 implants†	Failure: implant removal or loss ANOVA No correlations between smoking and implant failures	$= 0.945$
Örtorp & Jemt (2004)	Threaded, machined titanium implants	RCT	5 years	792 implants in 126 patients	Failure: implant removal or loss Life-table analysis Significantly higher failure rate in smokers compared with non-smokers	patient-related <0.01; implant-related <0.05
Wilson & Nunn (1999)	Threaded, TPS-coated or machined implants	Retrospective	Failed implants: 8 months, success-ful implants: 3.2 years	33 failed implants in 27 patients 68 successful implants in 38 patients	Failure: Implant loss or 50% bone loss RR 2.5 ($CI_{95\%}$ 1.13–5.55) Log-rank test Significantly higher failure rate in smokers compared with non-smokers	$= 0.024$

*Brånemark 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

Study	Implant characteristics	Study design	Mean observation period	Sample sizes	Statistics, outcomes	p
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 Spearman's rank-correlation 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	< 0.05
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	$= 0.034$
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 (Suppuration from the peri-implant sulcus, fistula, peri-implantitis and bone loss)	$= 0.008$
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	< 0.01
Mc Dermott et al. (2003)	HA- or TPS-coated or uncoated/passivated screw-like shape with fins	Retrospective	8 years	2349 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	$= 0.002$
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	$= 0.0001$
Weyant (1994)	Not reported	Retrospective	Not reported	2098 implants in 598 patients	Bivariate analysis, logistic regression OR 1.8 Significantly more periimplant soft tissue pathoses in smokers, compared with non-smokers	$= 0.001$
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 11. Characteristics of studies reporting on peri-implant bone-level changes in smokers compared with non-smokers, included into the systematic review

Study	Implant characteristics	Study design	Mean observation period	Sample sizes	Statistics, outcomes	p
Aalam & Nowzari (2005)	Anodic oxidized[1] or dual acid etched[2] or machined[3] threaded titanium implants	Retrospective	2 years	198 implants (58 implants[1], 52 implants[2], 88 implants[3]) in 74 patients	ANOVA No significant differences of marginal bone loss were found between smokers and non-smokers in all three groups of implants	>0.05
Carlsson et al. (2000)	Threaded, machined titanium implants	Prospective	15 years	273 implants in 44 patients (21 smokers)	*t*-test Smokers lost significantly more peri-implant bone than non-smokers. The mean peri-implant alveolar bone loss in the mandible exceeded that in the maxilla significantly in smokers	<0.001
Feloutzis et al. (2003)	TPS-coated, hollow cylinder or hollow or solid threaded implants	Prospective	5.6 years	182 implants in 90 patients 14 heavy smokers, 14 moderate smokers, 23 former smokers, 39 non-smokers	χ^2 test, stratified analysis, Fisher exact test A stratified analysis for smoking and IL-1 genotype positive group revealed significantly higher absolute bone level difference and annual bone loss for heavy smokers compared with non-smokers	<0.04
Galindo-Moreno et al. (2005)	Machined or TPS-coated threaded or HA-coated cylindrical implants	Prospective	3 years	514 implants in 185 patients (63 smokers)	Contingency tables, Pearson's correlation coefficient The peri-implant marginal bone loss was significantly enhanced in smokers	<0.02
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 bone loss, especially in the maxilla in smokers, compared with the mandible and implants in the maxilla of non-smokers	<0.01
Karoussis et al. (2004)	TPS-coated, hollow cylinder or hollow threaded implants	Prospective	10 years	179 implants in 89 patients	Multiple stepwise regression analysis Peri-implant marginal bone loss was significantly enhanced in smoking patients	<0.0001
Lindquist et al. (1996)	Threaded, machined titanium implants	Prospective	15 years	278 implants in 47 patients	*t*-test The average marginal bone loss around implants was significantly greater in smokers than in non-smokers	<0.001
Lindquist et al. (1997)	Threaded, machined titanium implants	Prospective	10 years	266 implants in 45 patients (21 smokers, 24 non-smokers, edentulous mandibles)	*t*-test Bivariate correlation The average marginal bone loss around implants was significantly greater in smokers than in non-smokers Among smokers, the bone loss was smaller in posterior regions compared with incisor regions, and those with poor oral hygiene had a greater bone loss than those with good oral hygiene	<0.001 <0.001 <0.001

Table 11. (Contd.)

Study	Implant characteristics	Study design	Mean observation period	Sample sizes	Statistics, outcomes	p
Nitzan et al. (2005)	Not reported	Retrospective	42.9 months for smokers; 48.4 months for non-smokers	646 implants in 161 patients 271 implants in 59 smokers; 375 implants in 102 non-smokers	*t*-test ANOVA Significantly higher mean bone loss around implants in smokers both in the maxilla and mandible, compared with non-smokers	= 0.001
Penarrocha et al. (2004)	Sand-blasted, large-grit, acid-etched, threaded implants	Retrospective	1 year	108 implants in 42 patients 47 implants in 16 smokers, 61 implants in 26 non-smokers	ANOVA Assessment of panoramic radiographs showed no significant association between marginal bone loss and smoking Periapical radiographs revealed a positive linear association between smoking and peri-implant bone loss	< 0.01
Schwartz-Arad et al. (2005a)	Not reported	Retrospective	37.9 months	277 implants in 61 patients 50 implants in eigth smokers; 227 implants in 53 non-smokers	χ^2 test Significantly more cervical bone loss at 27 of 50 implants in smokers and at 54 of 227 implants in non-smokers	< 0.0001
Investigations on the effect of smoking on peri-implant bone level in patients undergoing treatment of periodontitis or peri-implantitis						
Wennström et al. (2004a)	Particle-blasted, threaded titanium implants	Prospective	At least 1 year, up to 5 years	148 implants in 51 patients 137 implants in 47 patients	*t*-test, multiple regression models Significantly enhanced bone-level change around dental implants after a 5-years observation period in smokers compared with non-smokers	= 0.022
Wennström et al. (2004b)	Particle-blasted, threaded titanium implants	Prospective	5 years	47 patients (15 smokers, 32 non-smokers)	Stepwise backward regression analysis Significant greater bone loss in smoking patients compared with non-smokers	< 0.05

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 Steenberghe 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 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

Study	Augmentation procedure	Observation parameters	Sample sizes	Statistics, outcomes	p
Levin et al. (2004)	Autogenous onlay bone grafts (OBG)*, sinus floor elevation and augmentation (SFEA)**	Follow-up at least 6 months postsurgery Complications: graft exposure or mobility*; swelling, sinus infection**	64 OBG in 56 patients; 79 SFEA in 72 patients	ANOVA; Pearson's correlation coefficient Complications following OBG occurred in 1/3 of smokers and in 7.7% of non-smokers. Complications following SFEA occurred in 23.2% of smokers and 6% of non-smokers	= 0.04
Schwartz-Arad et al. (2005b)	Autogenous bone block grafts for horizontal and/or vertical ridge augmentation before implantation no barrier membranes	Complications: inflammatory symptoms, hematoma, swelling, temporary paresthesia Failures: graft exposure/removal	56 patients (11 smokers), 64 autogenous bone grafts	χ^2 test Pearson's correlation coefficient complications in 50% of smokers and in 23% of non-smokers failures in 33% of smokers and in 7.7% of non-smokers	= 0.04
Strietzel (2001)	Bone substitution materials with or without autogenous bone GBR with non-resorbable barrier membranes (expanded polytetrafluoro-ethylene) for horizontal alveolar ridge defect augmentation	Premature membrane exposure, requiring membrane removal	72 patients (19 smokers), 72 augmentation sites	χ^2 test The risk for premature membrane exposure in smokers is significantly enhanced compared with non-smokers	= 0.04
Zitzmann et al. (1999)	Augmentation of horizontal defects (1-, 2-, 3-wall defects) around implants, using deproteinized bovine bone mineral and a porcine collagen barrier membrane for GBR	Defect reduction after re-entry	75 patients (24 smokers), 112 implants, 112 augmentation sites	Wilcoxon's test, χ^2 test The mean defect reduction at implants inserted in smokers was found less (82%) compared with non-smokers (88%), but did not differ significantly. Smoking was not found to be significantly associated with treatment success (OR 0.51, $CI_{95\%}$ 0.21–1.28)	= 0.41 = 0.16

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 earlier review revealed a significant association between smoking and marginal bone loss, biologic complications, reduced survival rate of implants ($0.001 < p < 0.05$) and the outcome of onlay bone grafts ($p < 0.05$) as well, but no significant correlation was found between complications after SFEA and smoking (Levin & Schwartz-Arad 2005).

Besides the general suggestion to stop smoking regarding a protocol suggested (Bain 1996) or to quit smoking consequently, the peri-operative use of antibiotics (Gorman et al. 1994) as well as additional local risk factors as for example the use of flat instead of high cover screws should be considered in smokers to prevent postoperative and soft tissue complications (Schwartz-Arad et al. 2002).

Moreover, individual peculiarities of the patients' medical history might be supposed to confound or even enhance the risk of implant failures attributable to smoking. Three studies were included into meta-analysis, although confounding parameters might be expected due to selected patient cohorts. Although Balshi & Wolfinger (1999) did not find a significant influence of smoking on osseointegration in a population of diabetic patients undergoing metabolic control, a rate of 5.7% of non-osseointegrated implants at time of second stage surgery might indicate diabetes mellitus as a risk factor for osseointegration. In postmenopausal women undergoing hormone replacement therapy (HRT) to prevent osteoporosis (Minsk & Polson 1998), a significant influence of smoking on the frequency of implant loss was found in contrast to patients not receiving HRT as well as in the entire cohort. Thus, a detrimental interaction between HRT and smoking was concluded. Besides smoking, hypothyreoidism was supposed to interfere with bone physiology even if correctly medically managed. Attard & Zarb (2002) found no significant differences in osseointegration between hypothyroid patients and a matched healthy control group, but hypothyroid patients showed significantly more soft tissue complications during the postoperative course and significantly more marginal bone loss compared with the control group.

Therefore, medical risk factors should be considered critically in context with a smoking history in decision making before implant therapy.

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

Blettner, M. & Schlattmann, P. (2005) Chapter II.2: meta-analysis in epidemiology. In: Ahrens, W. & Pigeot, I. (eds). *Handbook of Epidemiology*, pp. 829–859. Heidelberg: Springer.

Buser, D., Mericske-Stern, R., Bernard, J. P., Behneke, A., Behneke, N., Hirt, H. P., Belser, U. C. & Lang, N. P. (1997) Long-term evaluation of non-submerged ITI implants. Part I: 8-year life table analysis of a prospective multi-center study with 2359 implants. *Clinical Oral Implants Research* **8**, 161–172.

Butterworth, C. J., Baxter, A. M., Shaw, M. J. & Bradnock, G. (2001) The provision of dental implants in the National Health Service hospital dental services – a national questionnaire. *British Dental Journal* **190**, 93–96.

Cochran, D. L., Buser, D., ten Bruggenkate, C. M., Weingart, D., Taylor, T. M., Bernard, J.-P., Peters, F. & Simpson, J. P. (2002) The use of reduced healing times on ITI implants with a sandblasted and acid-etched (SLA) surface: early results from clinical trials on ITI SLA implants. *Clinical Oral Implants Research* **13**, 144–153.

Esposito, M., Hirsch, J. M., Lekholm, U. & Thomsen, P. (1998) Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. *European Journal of Oral Sciences* **106**, 721–764.

Fielding, J. A. (1985) Smoking: health effects and control. *New England Journal of Medicine* **313**, 491–498.

Fleiss, J. L. (1981) *Statistical Methods for Rates and Proportions*, 2nd edition, pp. 61–67. New York: John Wiley.

Fox, N. L., Sexton, M., Hebel, J. R. & Thompson, B. (1989) The reliability of self-reports of smoking and alcohol consumption by pregnant women. *Addictive Behaviors* **14**, 187–195.

Gart, J. J. & Zweifel, J. R. (1967) On the bias of various estimators of the logit and its variance with application to quantal bioassay. *Biometrika* **54**, 181–187.

Hedges, L. V. (1992) Modeling publication selection effects in random effects models in meta-analysis. *Statistical Science* **7**, 246–255.

Heinikainen, M., Vehkalahti, M. & Murtomaa, H. (2002) Influence of patient characteristics on Finnish dentists' decision-making in implant therapy. *Implant Dentistry* **11**, 301–307.

Herrmann, I., Lekholm, U. & Holm, S. (2003) Statistical outcome of random versus selected withdrawal of dental implants. *International Journal of Prosthodontics* **16**, 25–30.

Herrmann, I., Lekholm, U., Holm, S. & Karlsson, S. (1999) Impact of implant interdependency when evaluating success rates: a statistical analysis of multicenter results. *International Journal of Prosthodontics* **12**, 160–166.

Hinode, D., Tanabe, S., Yokoyama, M., Fujisawa, K., Yamauchi, E. & Miyamoto, Y. (2006) Influence of smoking on osseointegrated implant failure: a meta-analysis. *Clinical Oral Implants Research* **17**, 473–478.

Jones, J. K. & Triplett, R. G. (1992) The relationship of cigarette smoking to impaired wound healing: a review of evidence and implications for patient care. *Journal of Oral and Maxillofacial Surgery* **50**, 237–239.

Jorgensen, L. N., Kallehave, F., Christensen, E., Siana, J. E. & Gottrup, F. (1998) Less collagen production in smokers. *Surgery* **123**, 450–455.

Kenney, E. B., Kraal, J. H., Saxe, S. R. & Jones, J. (1977) The effect of cigarette smoking on human PMN leukocytes. *Journal of Periodontal Research* **12**, 227–234.

La Veccia, C., Boyle, P. & Franceschi, S. (1991) Smoking and cancer with emphasis on Europe. *European Journal of Cancer* **27**, 94–104.

Lehr, H. A. (2000) Microcirculatory dysfunction induced by cigarette smoking. *Microcirculation* **7**, 367–384.

Lemons, J. E., Laskin, D. M., Roberts, W. E., Tarnow, D. P., Shipman, C. Jr., Paczkowski, C., Lorey, R. E. & English, C. (1997) Changes in patient screening for a clinical study of dental implants after increased awareness of tobacco use as a risk factor. *Journal of Oral and Maxillofacial Surgery* **55** (Suppl. 5), 72–75.

Levin, L. & Schwartz-Arad, D. (2005) The effect of cigarette smoking on dental implants and related surgery. *Implant Dentistry* **14**, 357–361.

Light, R. J. & Pillemer, D. B. (1984) *Summing-Up: The Science of Reviewing Research*. Cambridge: Harvard University Press.

MacFarlane, G. D., Hetzberg, M. C., Wolff, L. & Hardie, N. A. (1992) Refractory periodontitis associated with abnormal PMN leucocyte phagocytosis and cigarette smoking. *Journal of Periodontology* **63**, 908–913.

Macgregor, I. D. M. (1996) Efficacy of dental health advice as an aid to reducing cigarette smoking. *British Dental Journal* **180**, 292–296.

Meechan, J. G., Macgregor, I. D., Rogers, S. N., Hobson, R. S., Bate, J. P. & Dennison, M. (1988) The effect of smoking on immediate post-extraction socket filling with blood and on the incidence of painful socket. *British Journal of Oral and Maxillofacial Surgery* **26**, 402–409.

Miller, P. D. (1988) Regenerative and reconstructive periodontal plastic surgery. *Dental Clinics of North America* **32**, 287–312.

Misch, C. (1993) Implant success or failure: clinical assessment in implant dentistry. In: Misch, C. (ed). *Contemporary Implant Dentistry*, pp. 29–42. St. Louis: Mosby.

O'Loughlin, J., Tarasuk, J., Difranza, J. & Paradis, G. (2002) Reliability of selected measures of nicotine dependence in adolescents. *Annals of Epidemiology* **12**, 353–362.

Palmer, R. M., Wilson, R. F., Hasan, A. S. & Scott, D. A. (2005) Mechanisms of action of environmental factors – tobacco smoking. *Journal of Clinical Periodontology* **32** (Suppl. 6), 180–195.

Peto, R., Lopez, A. D., Boreham, J., Thun, M., Health, C. & Doll, R. (1996) Mortality from smoking worldwide. *British Medical Bulletin* **52**, 12–21.

Ramseier, C. A. (2005) Potential impact of subject-based risk factor control on periodontitis. *Journal of Clinical Periodontology* **32** (Suppl. 6), 283–290.

Reichart, P. A., Kirchheim, A. & Löchte, K.-H. (2000) Tobacco and oral health. Questionnaire about knowledge, practices and opinions among dentists in Berlin. *Mund-, Kiefer- und Gesichtschirurgie* **4**, 45–49, (article in German).

Roos, J., Sennerby, L., lekholm, U., Jemt, T., Gröndahl, K. & Albrektsson, T. (1997) A qualitative and quantitative method for evaluating implant success: a 5-year retrospective analysis of the Brånemark implant. *International Journal of Oral and Maxillofacial Implants* **12**, 504–514.

Sands, T., Pynn, B. R. & Nenniger, S. (1993) Third molar surgery: current concepts and controversies. Part 2. *Oral Health* **83**, 19–21, 27–30.

Schubert, U., Kleber, B.-M., Strietzel, F. P. & Dörfling, P. (2001) CrossLaps and β-glucuronidase in peri-implant and gingival crevicular fluid. *International Journal of Oral and Maxillofacial Implants* **16**, 252–258.

Sennerby, L. & Roos, J. (1998) Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. *International Journal of Prosthodontics* **11**, 408–420.

Sham, A. S., Cheung, L. K., Jin, L. J. & Corbet, E. F. (2003) The effects of tobacco use on oral health. *Hong Kong Medical Journal* **9**, 271–277.

Smith, D. E. & Zarb, G. A. (1989) Criteria for success of osseointegrated endosseous implants. *Journal of Prosthetic Dentistry* **62**, 567–572.

Strietzel, F. P. (2003) Patient's informed consent prior to implant-prosthetic treatment: a retrospective analysis of expert opinions. *International Journal of Oral and Maxillofacial Implants* **18**, 433–439.

WHO (2005) Tobacco and Health. The role of health professionals in tobacco control. WHO Library Catalogue-in-Publication, pp. 7–8. www.who.int/tobacco/resources/publications

Wood, M. R. & Vermilyea, S. G. (2004) A review of selected dental literature on evidence-based treatment planning for dental implants: report of the committee on Research in Fixed Prosthodontics of the Academy of Fixed Prosthodontics. *Journal of Prosthetic Dentistry* **92**, 447–462.

References included into meta-analysis

Bain, C. A. (1996) Smoking and implant failure – benefits from a smoking cessation protocol. *International Journal of Oral and Maxillofacial Implants* **11**, 756–759.

Bain, C. A. & Moy, P. E. (1993) The association between the failure of dental implants and cigarette smoking. *International Journal of Oral and Maxillofacial Implants* **8**, 609–615.

Balshi, T. J. & Wolfinger, G. J. (1999) Dental implants in the diabetic patient: a retrospective study. *Implant Dentistry* **8**, 355–359.

Berge, T. I. & Grønningsaeter, A. G. (2000) Survival of single crystal sapphire implants supporting mandibular overdentures. *Clinical Oral Implants Research* **11**, 154–162.

Beschnidt, S. M., Muche, R., Krausse, A. & Strub, J. R. (2003) Implant survival and success rates in partially edentulous patients. Part 1. *Schweizerische Monatsschrift für Zahnmedizin* **113**, 396–403.

De Bruyn, H. & Collaert, B. (1994) The effect of smoking on early implant failure. *Clinical Oral Implants Research* **5**, 260–264.

De Bruyn, H., Collaert, B., Lindén, U., Johansson, C. & Albrektsson, T. (1999) Clinical outcome of screw vent implants. A 7-year prospective follow-up study. *Clinical Oral Implants Research* **10**, 139–148.

Geurs, N. C., Wang, I.-C., Shulman, L. B. & Jeffcoat, M. K. (2001) Retrospective radiographic analysis of sinus graft and implant placement procedures from the Academy of Osseointegration consensus conference on sinus grafts. *International Journal of Periodontics and Restorative Dentistry* **21**, 517–523.

Gorman, L. M., Lambert, P. M., Morris, H. F., Ochi, S. & Winkler, S. (1994) The effect of smoking on implant survival at second stage surgery: DICRG interim report No. 5. *Implant Dentistry* **3**, 165–168.

Grunder, U., Gaberthuel, T., Boitel, N., Imoberdorf, M., Meyenberg, K., Andreoni, C. & Meier, T. (1999) Evaluating the clinical performance of the Osseotite implant: defining the prosthetic predictability. *Compendium of Continuing Education in Dentistry* **20**, 628–640.

Jones, J. D., Lupori, J., Van Sickels, J. E. & Gardner, W. (1999) A 5-year comparison of hydroxyapatite-coated titanium plasma-sprayed and titanium plasma-sprayed cylinder dental implants. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* **87**, 649–652.

Kan, J. Y. K., Rungcharassaeng, K., Kim, J., Lozada, J. L. & Goodachre, C. J. (2002) Factors affecting the survival of implants placed in grafted maxillary sinuses: a clinical report. *Journal of Prosthetic Dentistry* **87**, 485–489.

Karoussis, I. K., Salvi, G. E., Heitz-Mayfield, L. A. J., Brägger, U., Hämmerle, C. H. F. & Lang, N. P. (2003) Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10-year prospective cohort study of the ITI dental implant system. *Clinical Oral Implants Research* **14**, 329–339.

Keller, E. E., Tolman, D. E. & Eckert, S. E. (1999) Maxillary antral-nasal inlay autogenous bone graft reconstruction of compromised maxilla: a 12-year retrospective study. *International Journal of Oral and Maxillofacial Implants* **14**, 707–721.

Kronström, M., Svenson, B., Hellman, M. & Persson, G. R. (2001) Early implant failures in patients treated with Brånemark system titanium dental implants: a retrospective study. *International Journal of Oral and Maxillofacial Implants* **16**, 201–207.

Kumar, A., Jaffin, R. A. & Berman, C. (2002) The effect of smoking on achieving osseointegration of surface-modified implants: a clinical report. *International Journal of Oral and Maxillofacial Implants* **17**, 816–819.

Lambert, P. M., Morris, H. F. & Ochi, S. (2000) The influence of smoking on 3-year clinical success of osseointegrated dental implants. *Annals of Periodontology – The American Academy of Periodontology* **5**, 79–89.

Mayfield, L., Skoglund, A., Hising, P., Lang, N. P. & Attström, R. (2001) Evaluation following functional loading of titanium fixtures placed in ridges augmented by deproteinized bone mineral. *Clinical Oral Implants Research* **12**, 508–514.

Minsk, L. & Polson, A. M. (1998) Dental implant outcomes in postmenopasusal women undergoing hormone replacement. *Compendium of Continuing Education in Dentistry* **19**, 859–866.

Moheng, P. & Feryn, J. M. (2005) Clinical and biological factors related to oral implant failure: a 2-year follow-up study. *Implant Dentistry* **14**, 281–288.

Olson, J. W., Dent, C. D., Morris, H. F. & Ochi, S. (2000a) Long-term assessment (5 to 71 months) of endosseous dental implants placed in the augmented maxillary sinus. *Annals of Periodontology – The American Academy of Periodontology* **5**, 152–156.

Örtorp, A. & Jemt, T. (2002) Clinical experience of CNC-milled titanium frameworks supported by implants in the edentulous jaw: a 3-year interim report. *Clinical Implant Dentistry and Related Research* **4**, 104–109.

Penarrocha, M., Guarinos, J., Sanchis, J. M. & Balaguer, J. (2002) A retrospective study (1994–1999) of 441 ITI(r) implants in 114 patients followed-up during an average of 23 years. *Medicina Oral* **7**, 144–155.

Schwartz-Arad, D., Grossmann, Y. & Chaushu, G. (2000) The clinical effectiveness of implants placed immediately into fresh extraction sites of molar teeth. *Journal of Periodontology* **71**, 839–844.

Schwartz-Arad, D., Samet, N., Samet, N. & Mamlider, A. (2002) Smoking and complications of endosseous dental implants. *Journal of Periodontology* **73**, 153–157.

van Steenberghe, D., Jacobs, R., Desnyder, M., Maffei, G. & Quirynen, M. (2002) The relative impact of local and endogenous patient-related factors on implant failure up to the abutment stage. *Clinical Oral Implants Research* **13**, 617–622.

van Steenberghe, D., Molly, L., Jacobs, R., Vandekerckhove, B., Quirynen, M. & Naert, I. (2004) The immediate rehabilitation by means of a ready-made final fixed prosthesis in the edentulous mandible: a 1-year follow-up study on 50 consecutive patients. *Clinical Oral Implants Research* **15**, 360–365.

Wallace, R. H. (2000) The relationship between cigarette smoking and dental implant failure. *European Journal of Prosthodontics and Restorative Dentistry* **8**, 103–106.

Widmark, G., Andersson, B., Carlsson, G. E., Lindvall, A.-M. & Ivanoff, C.-J. (2001) Rehabilitation of patients with severely resorbed maxillae by means of implants with or without bone grafts: a 3- to 5-year follow-up clinical report. *International Journal of Oral and Maxillofacial Implants* **16**, 73–79.

References included for systematic review

Aalam, A.-A. & Nowzari, H. (2005) Clinical evaluation of dental implants with surfaces roughened by anodic oxidation, dual acid-etched implants, and machined implants. *International Journal of Oral and Maxillofacial Implants* **20**, 793–798.

Ataoglu, H., Alptekin, N. O., Haliloglu, S., Gursel, M., Ataoglu, T., Serpek, B. & Durmus, E. (2002) Interleukin-1beta, tumor necrosis factor-alpha levels and neutrophil elastase activity in peri-implant crevicular fluid. *Clinical Oral Implants Research* **13**, 470–476.

Attard, N. J. & Zarb, G. A. (2002) A study of dental implants in medically treated hypothyroid patients. *Clinical Implant Dentistry and Related Research* **4**, 220–231.

Baelum, V. & Ellegaard, B. (2004) Implant survival in periodontally compromised patients. *Journal of Periodontology* **75**, 1404–1412.

Bain, C. A., Weng, D., Meltzer, A., Kohles, S. S. & Stach, R. M. (2002) A meta-analysis evaluating the risk for implant failure in patients who smoke. *Compendium of Continuing Education in Dentistry* **23**, 695–699.

Carlsson, G. E., Lindquist, L. W. & Jemt, T. (2000) Long-term marginal periimplant bone loss in edentulous patients. *International Journal of Prosthodontics* **13**, 295–302.

Chuang, S.-K., Tian, L., Wei, L. J. & Dodson, T. B. (2002b) Risk factors for dental implant failure: a strategy for the analysis of clustered failure-time observations. *Journal of Dental Research* **81**, 572–577.

Eckert, S. E., Meraw, S. J., Weaver, A. L. & Lohse, C. M. (2001) Early experience with wide-platform Mk II implants. Part I: implant survival. Part II: Evaluation of risk factors involving implant survival. *International Journal of Oral and Maxillofacial Implants* **16**, 208–216.

Feloutzis, A., Lang, N. P., Tonetti, M. S., Burgin, W., Bragger, U., Buser, D., Duff, G. W. & Kornman, K. S. (2003) IL-1 gene polymorphism and smoking as risk factors for peri-implant bone loss in a well-maintained population. *Clinical Oral Implants Research* **14**, 10–17.

Galindo-Moreno, P., Fauri, M., Ávila-Ortiz, G., Fernández-Barbero, J. E., Cabrera-León, A. & Sánchez-Fernández, E. (2005) Influence of alcohol and tobacco habits on peri-implant marginal bone loss: a prospective study. *Clinical Oral Implants Research* **16**, 579–586.

Gruica, B., Wang, H.-Y., Lang, N. P. & Buser, D. (2004) Impact of IL-1 genotype and smoking on the prognosis of osseointegrated implants. *Clinical Oral Implants Research* **15**, 393–400.

Haas, R., Haimbock, W., Mailath, G. & Watzek, G. (1996) The relationship of smoking on peri-implant tissue: a retrospective study. *Journal of Prosthetic Dentistry* **76**, 592–596.

Karoussis, I. K., Müller, S., Salvi, G. E., Heitz-Mayfield, L. J., Brägger, U. & Lang, N. P. (2004) Association between periodontal and peri-implant conditions: a 10-year prospective study. *Clinical Oral Implants Research* **15**, 1–7.

Kourtis, S. G., Sotiriadou, S., Voliotis, S. & Challas, A. (2004) Private practice results of dental implants. Part I: survival and evaluation of risk factors – Part II: surgical and prosthetic complications. *Implant Dentistry* **13**, 373–385.

Lemmerman, K. J. & Lemmerman, N. E. (2005) Osseointegrated dental implants in private practice: a long-term case series study. *Journal of Periodontology* **76**, 310–319.

Leonhardt, Å., Dahlén, G. & Renvert, S. (2003) Five-year clinical, microbiological, and radiological outcome following treatment of peri-implantitis in man. *Journal of Periodontology* **74**, 1415–1422.

Levin, L., Herzberg, R., Dolev, E. & Schwartz-Arad, D. (2004) Smoking and complications of onlay bone grafts and sinus lift operations. *International Journal of Oral and Maxillofacial Implants* **19**, 369–373.

Lindquist, L. W., Carlsson, G. E. & Jemt, T. (1996) A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. *Clinical Oral Implants Research* **7**, 329–336.

Lindquist, L. W., Carlsson, G. E. & Jemt, T. (1997) Association between marginal bone loss around osseointegrated mandibular implants and smoking habits: a 10-year follow-up study. *Journal of Dental Research* **76**, 1667–1674.

Mc Dermott, N. E., Chuang, S.-K., Woo, V. V. & Dodson, T. B. (2003) Complications of dental implants: identification, frequency, and associated risk factors. *International Journal of Oral and Maxillofacial Implants* **18**, 848–855.

Moy, P. K., Medina, D., Shetty, V. & Aghaloo, T. L. (2005) Dental implant failure rates and associated risk factors. *International Journal of Oral and Maxillofacial Implants* **20**, 569–577.

Nitzan, D., Mamlider, A., Levin, L. & Schwartz-Arad, D. (2005) Impact of smoking on marginal bone loss. *International Journal of Oral and Maxillofacial Implants* **20**, 605–609.

Oates, T. W., Caraway, D. & Jones, J. (2004) Relation between smoking and biomarkers of bone resorption associated with dental endosseous implants. *Implant Dentistry* **13**, 352–357.

Örtorp, A. & Jemt, T. (2004) Clinical experiences of computer numeric-control milled titanium frameworks supported by implants in the edentulous jaw: a 5-year prospective study. *Clinical Implant Dentistry and Related Research* **6**, 199–209.

Penarrocha, M., Palomar, M., Sanchis, J. M., Guarinos, J. & Balaguer, J. (2004) Radiologic study of marginal bone loss around 108 dental implants and its relationship to smoking, implant location, and morphology. *International Journal of Oral and Maxillofacial Implants* **19**, 861–867.

Schwartz-Arad, D., Kidron, N. & Dolev, E. (2005a) A long-term study of implants supporting overdentures as a model for implant success. *Journal of Periodontology* **76**, 1431–1435.

Schwartz-Arad, D., Levin, L. & Sigal, L. (2005b) Surgical success of intraoral autogenous block on lay bone grafting for alveolar ridge augmentation. *Implant Dentistry* **14**, 131–138.

Strietzel, F. P. (2001) Risks and complications of membrane-guided bone regeneration. *Mund-, Kiefer- und Gesichtschirurgie* **5**, 28–32.

Strietzel, F. P. (2004) Sinus floor elevation and augmentation. Evidence-based analysis of prognosis and risk factors. *Mund-, Kiefer- und Gesichtschirurgie* **8**, 93–105.

Wennström, J., Zurdo, J., Karlsson, S., Ekestubbe, A., Gröndahl, K. & Lindhe, J. (2004a) Bone level change at implant-supported fixed partial dentures with and without cantilever extension after 5 years in function. *Journal of Clinical Periodontology* **31**, 1077–1083.

Wennström, J. L., Ekestubbe, A., Gröndahl, K., Karlsson, S. & Lindhe, J. (2004b) Oral rehabilitation with implant-supported fixed partial dentures in periodontitis-susceptible subjects. A 5-year prospective study. *Journal of Clinical Periodontology* **31**, 713–724.

Weyant, R. J. (1994) Characteristics associated with the loss and peri-implant tissue health of endosseous dental implants. *International Journal of Oral and Maxillofacial Implants* **9**, 95–102.

Wilson, T. G. Jr. & Nunn, M. (1999) The relationship between the interleukin-1 periodontal genotype and implant loss. Initial data. *Journal of Periodontology* **70**, 724–729.

Woo, V. V., Chuang, S.-K., Daher, S., Muftu, A. & Dodson, T. B. (2004) Dentoalveolar reconstructive procedures as a risk factor for implant failure. *Journal of Oral and Maxillofacial Surgery* **62**, 773–780.

Zitzmann, N. U., Schärer, P. & Marinello, C. P. (1999) Factors influencing the success of GBR. Smoking, timing of implant placement, implant location, bone quality and provisional restoration. *Journal of Clinical Periodontology* **26**, 673–682.

References excluded from meta-analysis and/or systematic review

Al-Nawas, B., Wegener, J., Bender, C. & Wagner, W. (2004) Critical soft tissue parameters of the zygomatic implant. *Journal of Clinical Periodontology* **31**, 497–500. No analysis of the implant failure related to the group of smoking patients.

August, M., Chung, K., Chang, Y. & Glowacki, J. (2001) Influence of estrogen status on endosseous implant osseointegration. *Journal of Oral and Maxillofacial Surgery* **59**, 1285–1289. Publication not matching focused question.

Bain, C. A. (1997) Influences of smoking on the periodontium and dental implants. *Dental Update* **24**, 328–330. Publication not matching inclusion criteria.

Bain, C. A. (2003) Implant installation in the smoking patient. *Periodontology 2000* **33**, 185–193. Publication not matching inclusion criteria.

Brisman, D. L., Brisman, A. S. & Moses, M. S. (2001) Implant failures associated with asymptomatic endodontically treated teeth. *Journal of the American Dental Association* **132**, 191–195.

Campos, M. I., Santos, M. C., Trevilatto, P. C., Scarel-Caminaga, R. M., Bezerra, F. J. & Line, S. R. (2005) Evaluation of the relationship between Interleukin-1 gene cluster polymorphisms and early implant failure in non-smoking patients. *Clinical Oral Implants Research* **16**, 194–201. Publication not matching the focused question.

Cesar-Neto, J. B., Benatti, B. B., Sallum, E. A. & Nociti, F. H. Jr. (2005a) Bone filling around titanium implants may benefit from smoking cessation: a histologic study in rats. *International Journal of Oral and Maxillofacial Implants* **20**, 713–719. Publication not matching inclusion criteria.

Cesar-Neto, J. B., Benatti, B. B., Sallum, E. A., Sallum, A. W. & Nociti, F. H. Jr. (2005b) Bone filling around titanium implants may benefit from smoking cessation: a histologic study in rats. *Journal of Periodontology* **76**, 1476–1481. Publication not matching inclusion criteria.

Chuang, S. K., Cai, T., Douglass, C. W., Wei, L. J. & Dodson, T. B. (2005) Frailty approach for the analysis of clustered failure time observations in dental research. *Journal of Dental Research* **84**, 54–58. Publication not matching the focused question.

Chuang, S. K., Tian, L., Wei, L. J. & Dodson, T. B. (2001) Kaplan-Meier analysis of dental implant survival: a strategy for estimating survival with clustered observations. *Journal of Dental Research* **80**, 2016–2020. Publication not matching the focused question.

Chuang, S. K., Tian, L., Wei, L. J. & Dodson, T. B. (2002a) Predicting dental implant survival by use of the marginal approach of the semi-parametric survival methods for clustered observations. *Journal of Dental Research* **81**, 851–855. Publication not matching the focused question.

Clapp, C., Wheeler, J. C., Martof, A. B. & Levine, P. A. (1996) Oral squamous cell carcinoma in association with dental osseointegrated implants. An unusual occurrence. *Archives of Otolaryngology, Head- and Neck Surgery* **122**, 1402–1403. Publication not matching the focused question.

Collaert, B. & De Bruyn, H. (1998) Comparison of Brånemark fixture integration and short-term survival using one-stage or two-stage surgery in completely and partially edentulous mandibles. *Clinical Oral Implants Research* **9**, 131–135. No quantitative characterization of the cohort of smokers and non-smokers provided. No assessment of the effects of smoking on dental implant failures.

Cooper, L., Felton, D. A., Kugelberg, C. F., Ellner, S., Chaffee, N., Molina, A. L., Moriarty, J. D., Paquette, D. & Palmqvist, U. (2001) A multicenter 12-month evaluation of single-tooth implants restored 3 weeks after 1-stage surgery. *International Journal of Oral and Maxillofacial Implants* **16**, 182–192. Publication not matching focused question.

Crews, K. M., Cobb, G. W., Seago, D. & Williams, N. (1999) Tobacco and dental implants. *General Dentistry* **47**, 484–488. Publication not matching the inclusion criteria.

Cullen, R. (1998) The oral-burn syndrome and its effects on dental implants. *Journal of Oral Implantology* **24**, 219–221. Publication not matching the focused question and inclusion criteria.

Deem, L. P., Bassiouny, M. A. & Deem, T. E. (2002) The sequential failure of osseointegrated submerged implants. *Implant Dentistry* **11**, 243–248. Publication not matching the inclusion criteria.

Eger, D. E., Gunsolley, J. C. & Feldman, S. (2000) Comparison of angled and standard abutments and their effect on clinical outcomes: a preliminary report. *International Journal of Oral and Maxillofacial Implants* **15**, 819–823. Publication not matching the focused question.

Ekfeldt, A., Christiansson, U., Eriksson, T., Linden, U., Lundqvist, S., Rundcrantz, T., Johansson, L. A., Nilner, K. & Billstrom, C. A. (2001) Retrospective analysis of factors associated with multiple implant failures in maxillae. *Clinical Oral Implants Research* **12**, 462–467. Publication not matching the inclusion criteria. Influence of smoking on implant failure was not assessed and no related quantitative data were reported.

El Askary, A. S., Meffert, R. M. & Griffin, T. (1999) Why do dental implants fail? Part I. *Implant Dentistry* **8**, 173–185. Publication not matching the inclusion criteria.

Ellen, R. P. (1994) Periodontal care for community-dwelling older adults. *Journal of Prosthetic Dentistry* **72**, 500–506. Publication not matching the focused question.

Ericsson, I., Nilson, H., Lindh, T., Nilner, K. & Randow, K. (2000) Immediate functional loading of Brånemark single tooth implants. An 18 months' clinical pilot follow-up study. *Clinical Oral Implants Research* **11**, 26–33. Publication not matching the inclusion criteria.

Esposito, M., Hirsch, J. M., Lekholm, U. & Thomsen, P. (1998) Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. *European Journal of Oral Sciences* **106**, 721–764. Publication not matching the inclusion criteria.

Fartash, B., Tangerud, T., Silness, J. & Arvidson, K. (1996) Rehabilitation of mandibular edentulism by single crystal sapphire implants and overdentures: 3-12 year results in 86 patients. A dual center international study. *Clinical Oral Implants Research* **7**, 220–229. No quantitative characterization of the cohort of smokers and non-smokers provided.

Feldman, S., Boitel, N., Wenig, D., Kohles, S. S. & Stach, R. M. (2004) Five-year survival distributions of short-length (10 mm or less) machined-surfaced and Osseotite implants. *Clinical Implant Dentistry and Related Research* **6**, 16–23. Publication not matching the focused question.

Ganeles, J. & Wismeijer, D. (2004) Early and immediately restored and loaded dental implants for single-tooth and partial-arch applications. *International Journal of Oral and Maxillofacial Implants* **19** (Suppl), 92–102. Publication not matching the focused question.

Goene, R., Bianchesi, C., Hürzeler, M., Del-Lupo, R., Testori, T., Davarpanah, M. & Jalbout, Z. (2005) Performance of short implants in partial restorations: 3-year follow-up of Osseotite implants. *Implant Dentistry* **14**, 274–280. No quantitative characterization of the cohort of smokers and non-smokers in relation to successful and failed implants provided.

Granström, G. (2005) Osseointegration in irradiated cancer patients: an analysis with respect to implant failures. *Journal of Oral and Maxillofacial Surgery* **63**, 579–585. Publication not matching the focused question and excluded due to confounding factors.

Greenstein, G. & Hart, T. C. (2002) Clinical utility of a genetic susceptibility test for severe chronic periodontitis: a critical evaluation. *Journal of the American Dental Association* **133**, 452–459. Publication not matching the focused question.

Heinikainen, M., Vehkalahti, M. & Murtomaa, H. (2002) Influence of patient characteristics on Finnish dentists' decision-making in implant therapy. *Implant Dentistry* **11**, 301–307. Publication not matching the focused question.

Henry, P. J. (2002) A review of guidelines for implant rehabilitation of the edentulous maxilla. *Journal of Prosthetic Dentistry* **87**, 281–288. Publication not matching the inclusion criteria.

Hirsch, J. M. & Ericsson, I. (1991) Maxillary sinus augmentation using mandibular bone grafts and simultaneous installation of implants. A surgical technique. *Clinical Oral Implants Research* **2**, 91–96. Smoking patients were excluded from the study.

Hultin, M., Fischer, J., Gustafsson, A., Kallus, T. & Klinge, B. (2000) Factors affecting late fixture loss and marginal bone loss around teeth and dental implants. *Clinical Implant Dentistry and Related Research* **2**, 203–208. Publication not matching the focused question.

Ibanez, J. C., Tahhan, M. J., Zamar, J. A., Menendez, A. B., Juaneda, A. M., Zamar, N. J. & Monqaut, J. L. (2005) Immediate occlusal loading of double acid-etched surface titanium implants in 41 consecutive full-arch cases in the mandible and maxilla: 6- to 74-month results. *Journal of Periodontology* **76**, 1972–1981. No quantitative characterization of the cohort of smokers and non-smokers in relation to successful and failed implants provided.

Jansson, H., Hamberg, K., De Bruyn, H. & Bratthall, G. (2005) Clinical consequences of IL-1 genotype on early implant failures in patients under periodontal maintenance. *Clinical Implant Dentistry and Related Research* **7**, 51–59. Publication not matching the focused question.

Jones, J. D., Saigusa, M., van Sickels, J. E., Tiner, B. D. & Gardner, W. A. (1997) Clinical evaluation of hydroxyapatite-coated titanium plasma-sprayed and titanium plasma-sprayed cylinder dental implants. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* **84**, 137–141. Results are reported later for 5-year evaluation (see Jones et al. 1999).

Jones, R. B. (2000) Tobacco or oral health: past progress, impending challenge. *Journal of the American Dental Association* **131**, 1130–1136. Publication not matching the inclusion criteria.

Kan, J. Y., Rungcharassaeng, K., Lozada, J. L. & Goodacre, C. J. (1999) Effects of smoking on implant success in grafted maxillary sinuses. *Journal of Prosthetic Dentistry* **82**, 307–311. Results will be reported later (see Kan et al. 2002).

Klinge, B., Hultin, M. & Berglundh, T. (2005) Peri-implantitis. *Dental Clinics of North America* **49**, 661–676. Publication not matching the inclusion criteria.

Krauser, J. (2005) Etiology and management of implant complications. Interview. *Dental Implantology Update* **16**, 25–31. Publication not matching the inclusion criteria.

Lemons, J. E., Laskin, D. M., Roberts, W. E., Tarnow, D. P., Shipman, C. Jr., Paczkowski, C., Lorey, R. E. & English, C. (1997) Changes in patient screening for a clinical study of dental implants after increased awareness of tobacco use as a risk factor. *Journal of Oral and Maxillofacial Surgery* **55** (Suppl. 5), 72–75. Publication not matching the focused question.

Levin, L. & Schwartz-Arad, D. (2005) The effect of cigarette smoking on dental implants and related surgery. *Implant Dentistry* **14**, 357–361. Publication not matching the inclusion criteria.

Levin, L., Schwartz-Arad, D. & Nitzan, D. (2005) (Smoking as a risk factor for dental implants and implant-related surgery). *Refuat Hapeh Vehashinayim* **22**, 37–43. (Publication in Hebrew) Publication not matching the inclusion criteria.

Manz, M. C. (2000) Factors associated with radiographic vertical bone loss around implants placed in a clinical study. *Annals of Periodontology – The American Academy of Periodontology* **5**, 137–151. No quantitative characterization of the cohort of smokers and non-smokers and no statistical assessment of effects of smoking on implant failure rate or peri-implant tissues provided.

Minsk, L., Polson, A. M., Weisgold, A., Rose, L. F., Sanavi, F., Baumgarten, H. & Listgarten, M. A. (1996) Outcome failures of endosseous implants from a clinical training center. *Compendium of Continuing Education in Dentistry* **17**, 848–854. Publication not matching the focused question.

Morris, H. F. & Ochi, S. (1998) Hydroxyapatite-coated implants: a case for their use. *Journal of Oral and Maxillofacial Surgery* **56**, 1303–1311.

Naert, I. E. (1997) Success of implants in the moderately resorbed edentate maxilla. *Nederlands Tijdschrift voor Tandheelkunde* **104**, 251–252. (Publication in Dutch) Publication not matching the inclusion criteria.

Nociti, F. H. Jr., Cesar, N. J., Carvalho, M. D. & Sallum, E. A. (2002) Bone density around titanium implants may be influenced by intermittent cigarette smoke inhalation: a histometric study in rats. *International Journal of Oral and Maxillofacial Implants* **17**, 347–352. Publication not matching the inclusion criteria.

Nosaka, Y., Tachi, Y., Shimpuku, H., Kawamura, T. & Ohura, K. (2002) Association of calcitonin receptor gene polymorphism with early marginal bone loss around endosseous implants. *International Journal of Oral and Maxillofacial Implants* **17**, 38–43. Publication not matching the focused question.

Oikarinen, K., Raustia, A. M. & Hartikainen, M. (1995) General and local contraindications for endosseal implants – an epidemiological panoramic radiograph study in 65-year-old subjects. *Community Dentistry and Oral Epidemiology* **23**, 114–118. Publication not matching the focused question.

Olson, J. W., Shernoff, A. F., Tarlow, J. L., Colwell, J. A., Scheetz, J. P. & Bingham, S. F. (2000) Dental endosseous implant assessments in a type 2 diabetic population: a prospective study. *International Journal of Oral and Maxillofacial Implants* **15**, 811–818. No data for assessment of the effects of smoking on dental implant failures provided.

O'Mahony, A., MacNeill, S. R. & Cobb, C. M. (2000) Design features that may influence bacterial plaque retention: a retrospective analysis of failed implants. *Quintessence International* **31**, 249–256. Publication not matching the focused question.

Porter, J. A. & von Fraunhofer, J. A. (2005) Success or failure of dental implants? A literature review with treatment considerations. *General Dentistry* **53**, 423–432. Publication not matching the inclusion criteria.

Quirynen, M., De Soete, M. & van Steenberghe, D. (2002) Infectious risks for oral implants: a review of the literature. *Clinical Oral Implants Research* **13**, 1–19. Publication not matching the focused question.

Quirynen, M., Peeters, W., Naert, I., Coucke, W. & van Steenberghe, D. (2001) Peri-implant health around screw-shaped c.p. titanium machined implants in partially edentulous patients with or without ongoing periodontitis. *Clinical Oral Implants Research* **12**, 589–594. Publication not matching the focused question.

Randow, K., Ericsson, I., Nilner, K., Petersson, A. & Glantz, P. O. (1999) Immediate functional loading of Brånemark dental implants. An 18-month clinical follow-up study. *Clinical Oral Implants Research* **10**, 8–15. Smokers excluded from the study.

Rocci, A., Martignoni, M. & Gottlow, J. (2003) Immediate loading of Brånemark system TiUnite and machined-surface implants in the posterior mandible: a randomized open-ended clinical trial. *Clinical Implant Dentistry and Related Research* **5** (Suppl. 1), 57–63. No quantitative characterization of the cohort of failed implants in smokers and non-smokers provided.

Rodriquez, G. P., Claus-Walker, J. & Reed, G. (1992) A study of osteoporosis as it relates to metabolic manifestations in edentulous women. *Journal of Oral Implantology* **18**,

379–382. Publication not matching the focused question.
Romanos, G. E. & Johansson, C. B. (2005) Immediate loading with complete implant-supported restorations in an edentulous heavy smoker: histologic and histomorphometric analyses. *International Journal of Oral and Maxillofacial Implants* **20**, 282–290. Publication not matching the inclusion criteria.
Sbordone, L., Barone, A., Ciaglia, R. N., Ramaglia, L. & Iacono, V. J. (1999) Longitudinal study of dental implants in a periodontally compromised population. *Journal of Periodontology* **70**, 1322–1329. Publication not matching the focused question.
Schug, T. & Dumbach, J. (1999) Dislocation of endossous implants into the sinus – a rare complication in implant dentistry. *Zeitschrift für Zahnärztliche Implantologie* **15**, 224–228. Publication not matching the inclusion criteria.
Schwartz, Z., Nasazky, E. & Boyan, B. D. (2005) Surface microtopography regulates osteointegration: the role of implant surface microtopography in osteointegration. *The Alpha Omegan* **98**, 9–19. Publication not matching the focused question.
Sennerby, L. & Roos, J. (1998) Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. *International Journal of Prosthodontics* **11**, 408–420. Publication not matching the inclusion criteria.
Sham, A. S., Cheung, L. K., Jin, L. J. & Corbet, E. F. (2003) The effects of tobacco use on oral health. *Hong Kong Medical Journal* **9**, 271–277. Publication not matching the inclusion criteria.
Shimpuku, H., Nosaka, Y., Kawamura, T., Tachi, Y., Shinohara, M. & Ohura, K. (2003) Genetic polymorphisms of the interleukin-1 gene and early marginal bone loss around endosseous dental implants. *Clinical Oral Implants Research* **14**, 423–429. Publication not matching the focused question.
Tomson, P. L., Butterworth, C. J. & Walmsley, A. D. (2004) Management of peri-implant bone loss using guided bone regeneration: a clinical report. *Journal of Prosthetic Dentistry* **92**, 12–16. Publication not matching the focused question and inclusion criteria.
Tonetti, M. S. (1998) Cigarette smoking and periodontal diseases: etiology and management of disease. *Annals of Periodontology – The American Academy of Periodontology* **3**, 88–101. Publication not matching the focused question.
Vachiramon, A., Wang, W. C. & Vachiramon, T. (2004) The use of acupuncture in implant dentistry. *Implant Dentistry* **13**, 58–64. Publication not matching the focused question.
van Steenberghe, D. (2003) The use of oral implants in compromised patients. *Periodontology 2000* **33**, 9–11. Publication not matching the focused question.
Vehemente, V. A., Chuang, S.-K., Daher, S., Muftu, A. & Dodson, T. B. (2002) Risk factors affecting dental implant survival. *Journal of Oral Implantology* **28**, 74–81. Data published also in Chuang et al., (2002b).
Wallace, S. S. & Froum, S. J. (2003) Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Annals of Periodontology – The American Academy of Periodontology* **8**, 328–343. No data available for detection of the influence of smoking on implants and maxillary sinus augmentation outcomes.
Wang, I. C., Reddy, M. S., Geurs, N. C. & Jeffcoat, M. K. (1996) Risk factors in dental implant failure. *Journal of Long Term Effects of Medical Implants* **6**, 103–117. Publication not matching the focused question.
Wilson, T. G. Jr. & Higginbottom, F. L. (1998) Periodontal diseases and dental implants in older adults. *Journal of Esthetic Dentistry* **10**, 265–271. Publication not matching the inclusion criteria.
Wood, M. R. & Vermilyea, S. G. (2004) A review of selected dental literature on evidence-based treatment planning for dental implants: report of the Committee on Research in Fixed Prosthodontics of the Academy of Fixed Prosthodontics. *Journal of Prosthetic Dentistry* **92**, 447–462. Publication not matching the inclusion criteria.
Zechner, W., Trinkl, N., Watzak, G., Busenlechner, D., Tepper, G., Haas, R. & Watzek, G. (2004) Radiologic follow-up of peri-implant bone loss around machine-surfaced and rough-surfaced interforaminal implants in the mandible functionally loaded for 3 to 7 years. *International Journal of Oral and Maxillofacial Implants* **19**, 216–221. Publication not matching the focused question.

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.