Peri-implant infections

de Waal, Yvonne Catharina Maria

DIFFERENCES IN PERI-IMPLANT CONDITIONS BETWEEN FULLY AND PARTIALLY EDENTULOUS SUBJECTS: A SYSTEMATIC REVIEW

Y.C.M. de Waal
A.J. van Winkelhoff
H.J.A. Meijer
G.M. Raghoebar
E.G. Winkel

Edited version of: Journal of Clinical Periodontology 2013; 40: 266-286

ABSTRACT

Aim

The aim of the study was to compare peri-implant conditions between fully edentulous (FES) and partially edentulous subjects (PES).

Material and methods

A systematic review was conducted. The MEDLINE, EMBASE and CENTRAL databases were searched for publications up to January 1st 2012. Studies reporting on the bleeding tendency of the peri-implant mucosa and/or studies reporting on the prevalence of peri-implant mucositis and/or peri-implantitis were considered.

Results

55 publications describing 46 studies were selected. One study described both FES and PES; all other studies described either FES or PES. Subgroup analyses were performed according to dental status (fully/partially edentulous), follow-up time (≥ 5 years and ≥ 10 years) and study design (prospective/cross-sectional). FES harbored more plaque at their implants than PES. Modified bleeding index scores were significantly higher in FES, but no differences in bleeding on probing, implant loss and probing pocket depth were observed between FES and PES. No meta-analysis could be performed on prevalence of peri-implant mucositis and peri-implantitis. Overall prevalence of peri-implantitis was 0-3.4% after 5 years and 5.8-16.9% after 10 years of implant evaluation.

Conclusion

FES and PES show comparable implant survival rates. However, no conclusion can be drawn regarding differences in prevalence of peri-implant mucositis and peri-implantitis between FES and PES.

CLINICAL RELEVANCE

Scientific rationale for study

Implant therapy has developed into a successful treatment option, both for full and partial edentulism. It is unknown whether differences exist in peri-implant conditions between fully edentulous and partially edentulous subjects and whether both groups should be regarded similar when evaluating long-term implant treatment.

Principal finding

Fully edentulous subjects harbored more plaque than partially edentulous subjects. No differences in implant loss were found. No comparison on prevalence of peri-implant mucositis and peri-implantitis could be made.

Practical implications

The long-term implant survival rate of fully edentulous and partially edentulous subjects seems comparable. However, the association between edentulism and prevalence of peri-implant disease remains unclear.

INTRODUCTION

Implant therapy has developed into a successful treatment option, both for full and partial edentulism. High survival rates of dental implants are generally reported (Berglundh et al. 2002, Pjetursson et al. 2004, Jung et al. 2008). Although implant survival rate is often used as primary outcome for evaluation of implant treatment, reporting on the clinical condition of surviving implants, *i.e.* implant success, would be more meaningful. A crucial aspect of long-term implant success is the establishment and maintenance of healthy peri-implant tissues. Disturbance of the balance between the microbiological challenge and host response may result in peri-implant infection. Infection limited to the peri-implant mucosa is called peri-implant mucositis. Peri-implantitis is characterized by the additional loss of supporting bone (Zitzmann & Berglundh 2008). If peri-implant infection is left untreated it may ultimately lead to implant loss. In addition, inflammation of the oral tissues can be a threat for general health (Persson & Persson 2008).

The prevalence of peri-implant mucositis is reported to be as much as 42% for implants in function for 9 to 14 years (Roos-Jansåker et al. 2006a). Figures on the prevalence of peri-implantitis vary considerably, as can be concluded from the systematic reviews by Berglundh et al. (2002) (0.31% for single-tooth replacements to 6.47% for implants involved in fixed partial dentures after at least five years of follow-up) and Zitzmann & Berglundh (2008) (12 to 43% of the implants after at least five years of follow-up). It should be noted that these figures are based on small numbers of studies that show large variations in study design, patients/implants included and definitions used to define peri-implantitis.

Established factors that are related to peri-implant disease are poor oral hygiene, smoking and a history of periodontitis (Heitz-Mayfield 2008). The increased risk to

develop peri-implantitis in patients with a history of periodontitis might be two-fold: periodontitis patients generally harbor more putative periodontal pathogens than non-periodontitis patients (Van Winkelhoff et al. 2002) and/or they may have a higher genetic susceptibility to develop periodontal/peri-implant disease (Laine et al. 2006). Full-mouth tooth extraction eliminates caries and periodontal disease and may reduce the number of oral putative periodontal pathogens (Danser et al. 1994, Van Assche et al. 2009). Patients eligible for full-mouth tooth extraction generally have negative socio-behavioral factors *i.e.* poor oral hygiene, smoking, low socioeconomic status and/or high (genetic) susceptibility to destructive periodontal disease (Burt et al. 1990). Prevalence of full edentulism increases with age and concomitant declining mental and physical health, and divers between geographical regions and between groups with various background characteristics and lifestyle factors (Müller et al. 2007).
Many fully edentulous subjects (FES) receive dental implants to support fixed or removable prosthesis. However, most risk factors associated with full edentulism and related dental disease continue to be present and cannot be altered. It might be hypothesized that FES are at higher risk to develop peri-implant disease and should be regarded dissimilar to partially edentulous subjects (PES) when evaluating implant treatment.
The aim of the study was to compare the peri-implant conditions between fully edentulous (FES) and partially edentulous subjects (PES).

MATERIAL AND METHODS

Focused question

Do FES with dental implant supported reconstructions show a similar prevalence of peri-implant disease (*i.e.* peri-implant bleeding, peri-implant mucositis or peri-implantitis) compared to PES with dental implant supported reconstructions?

Eligibility criteria

Type of studies

Prospective studies with follow-up periods of at least five years or cross-sectional studies with implants in function for at least five years were considered. Retrospective studies (studies based on historic data only, in which subjects were not re-examined specifically for the purpose of the described study) were not included. Studies combining data on subjects with five year follow-up and data on subjects with shorter follow-up periods were only included if a breakdown of data corresponding to five years of observation could be made. Studies were excluded if less than five patients were evaluated at the final examination.

Type of patients

Studies reporting on FES and/or PES who were treated with implant supported reconstructions were considered. Studies not reporting on dental status or not allowing for breakdown of data corresponding to dental status were not included. In addition, studies evaluating implant therapy in specifically selected subsets of patients, *e.g.* diabetes patients, were not included.

Type of treatments
Studies describing treatments with titanium endosseous implants were considered. Consequently, studies of ceramic, submucosal, blade, transmandibular and zygoma implants were not included. In addition, studies evaluating immediate implant placement were not included.

Type of outcomes
Studies reporting on the bleeding tendency of the peri-implant mucosa using either bleeding on probing (BoP, scored on 4 or 6 sites per implant) or the modified bleeding index (mBI) (Mombelli et al. 1987) and/or studies reporting on the prevalence of peri-implant mucositis and/or peri-implantitis were considered. Peri-implant mucositis was defined as presence of inflammation in the peri-implant mucosa, as indicated by bleeding and/or pus on probing, without loss of supporting bone. Peri-implantitis was defined as presence of inflammation in the peri-implant mucosa, as indicated by bleeding and/or pus on probing, with loss of supporting bone (Zitzmann & Berglundh 2008).

Search strategy
Studies were identified by searching three electronic databases: MEDLINE (PubMed), CENTRAL (Cochrane Central Register of Controlled Trials) and EMBASE. No language restrictions were applied. The three databases were searched for studies published up to the 1st of January 2012. The search strategy is outlined in Table 1.

Study selection
Titles and abstracts of the identified publications were screened. Full-text articles were obtained for all potentially relevant studies and eligibility assessment was performed by two independent reviewers (Y.W. and H.S.). In addition, bibliographies of the selected publications and previously published reviews relevant to the present review were searched for eligible studies. In case of disagreement between the two reviewers, consensus was reached by discussion. If the dental status of the patients remained uncertain after full-text reading, but all other eligibility criteria were met, the authors of the selected studies were contacted for further clarification on dental status.

Data extraction
Data were extracted, in duplicate and independent by two reviewers, using a data extraction form containing the following items:
- Dental status (FES/PES);
- Number of patients/implants included, number of patients/implants at follow-up, drop-outs, follow-up period;
- Information regarding the treatment procedure (implant system, maxilla/mandible, bone augmentation, one-stage/two-stage implant placement, type of restoration);
- Information regarding patient variables (smoking, history of periodontitis, maintenance program);
- Data regarding the following outcome variables (outcomes were reported on subject, implant and/or site level):
    - *Peri-implantitis;*

- *Peri-implant mucositis;*
- *Bleeding on probing (BoP)*;
- *Modified bleeding index (mBI)* (Mombelli et al. 1987);
- *Presence of plaque (present/absent)*, scored on four or six sites per implant;
- *Modified plaque index (mPI)* (Mombelli et al. 1987);
- *Probing pocket depth (PPD)*;
- *Implants lost before loading*, represented as a percentage of the total number of implants placed;
- *Implants lost during function*, represented both as a percentage of the total number of implants placed and as a percentage of the number of implants evaluated at the final examination. Implants lost/removed as a result of fracture were not included in this figure.

Quality assessment

Methodological quality was assessed by two independent reviewers (Y.W. and H.S.) using specific study-design related forms designed by the Dutch Cochrane Collaboration. The quality of case series was assessed using the quality-assessment tool developed by Den Hartog et al. (2008). Studies scoring five of more 'plusses' were considered methodologically 'acceptable'.

Statistical analysis

Agreement between the two reviewers with regard to the study selection procedure was calculated using Cohen's κ statistics. The overall effects of the included studies were calculated using weighted rates/weighted mean values (weighted for study size) and random effects models. The statistical software package "Meta-analysis" was used [Comprehensive Meta-analysis Version 2.2, Biostat, Englewood NJ (2005), www.meta-analysis.com]. Subgroup analyses were performed according to dental status (FES/PES), follow-up time (≥ 5 years and mean follow up ≥ 10 years) and study design (prospective and cross-sectional). Heterogeneity within subgroups was assessed by I^2 statistic.

RESULTS

Study characteristics

The MEDLINE, EMBASE and Cochrane CENTRAL searches resulted in 9022, 1208 and 605 hits respectively. After extracting duplicate citations, 9757 remained to be screened (Figure 1). After screening of titles and abstracts, 440 publications were selected for full-text analysis. Screening of bibliographies of relevant reviews and selected publications revealed 2 additional publications. Of the 442 publications, 387 were excluded after full-text analysis and quality assessment. The κ-value for inter-assessor agreement was 0.86. Disagreements were easily resolved in a consensus meeting.
Of the 55 publications included, three, addressing different topics of the same study, reported on both FES and PES (Roos-Jansåker et al. 2006a,b,c). The 52 remaining publications reported either on FES or PES (Table 2). The results of three (Karoussis et al. 2004a,b, Brägger et al. 2005) and two publications (Roccuzzo et al. 2010, 2012)

Table 1. Search strategy

MEDLINE [MeSH terms / all subheadings] Dental Implants OR Dental Implantation OR [text words] Dental implants OR Dental implantation AND [MeSH terms / all subheadings] Periodontal Diseases OR [text words] periodontal diseases OR peri-implantitis OR periimplantitis OR peri-implant mucositis OR periimplant mucositis OR peri-implant disease OR periimplant disease OR complications OR controlled clinical trials OR cohort studies OR case control studies OR cross-sectional studies OR longitudinal OR prospective OR retrospective
EMBASE 'tooth implantation'/exp OR 'dental implants' OR 'dental implantation' AND 'periodontal disease'/exp OR 'periodontal disease' OR 'peri-implantitis' OR periimplantitis OR 'peri-implant mucositis' OR 'periimplant mucositis' OR 'peri-implant disease' OR 'periimplant disease' OR complications OR 'clinical study'/exp AND [embase]/lim
CENTRAL #1 search [MeSH terms / all subheadings] Dental Implants #2 search [MeSH terms / all subheadings] Dental Implantation #3 search 'dental implants' OR 'dental implantation' #4 search [MeSH terms / all subheadings] Periodontal Disease #5 search 'periodontal diseases' OR 'peri-implantitis' OR periimplantitis OR 'peri-implant mucositis' OR 'periimplant mucositis' OR 'peri-implant disease' OR 'peri-implant disease' OR complications #6 search (#1 OR #2 OR #3) AND (#4 OR #5)

respectively, addressing different topics of two studies, were grouped. Eight publications presented outcomes of the same studies but with different follow-up (Andersson et al. 1998b/Bergenblock et al. 2012, Meijer et al. 2000/Meijer et al. 2004b, Meijer et al. 2004a/Meijer et al. 2009b, Visser et al. 2005/Meijer et al. 2009a). The results are presented separately according to a follow-up period of ≥ 5 years (17 FES studies and 19 PES studies) and a mean follow up of ≥ 10 years (4 FES studies, 7 PES studies and 1 FES/PES study).

A total of 3493 implants in 1541 subjects were followed for ≥ 5 years and 2652 implants in 904 subjects had a mean follow-up of ≥ 10 years. The overall dropout rate of patients was 11.2% after 5 years of follow-up and 21.5% after a mean follow-up of 10 years.

In studies reporting on FES treatment mainly consisted of mandibular overdentures supported by two or four implants. Only Cordioli et al. (1997) and Gallucci et al. (2009) reported on different prosthetic treatments. In PES most implants were placed in the maxilla (53.9%) and treatment mainly consisted of implant-supported single crowns and fixed partial dentures.

None of the FES had received bone augmentation prior to implant placement, whereas 5 studies reporting on PES (also) included patients who needed some form of bone augmentation (Buser et al. 1996, Buser et al. 2002, Bornstein et al. 2008, Gatti et al. 2008, Bonde et al. 2010). Most implants were placed using a two-stage procedure (65.4%) and a conventional loading procedure (92.4%).

Table 2. Study/patient characteristics of included studies

authors	study design	dental status	implant system	follow-up	# initially included		# followed		age at start of study	smokers included	history periodon-titis	prosthesis type	maintenance program
					subj	impl (max/man)	subj	impl (max/man)					
Mericske-Stern et al. (1994)	P	FES	Strau	5 y	39	78 (0/78)	33	66 (0/66)	NR	NR	NR	OD	every 4-6 m
Cordioli et al. (1997)	P	FES	3i	5 y	21	21 (0/21)	15	15 (0/15)	74.2 (67-86)	NR	NR	OD, 1 implant	every year
Heijdenrijk et al. (1998)	CS	FES	IMZ	74 m (65-96)	43	86 (0/86)	40	83[3] (0/83)	55 (36-75)	NR	NR	OD	every 6 m
Kwakman et al. (1998)	CS	FES	IMZ	5 y	65	130 (0/130)	48	96 (0/96)	NR	NR	NR	OD	NR
Naert et al. (1998)	P	FES	NB	5 y	36	73 (0/73)	31	63[1] (0/63)	63 (36-85)	yes	NR	OD	every year
Deporter et al. (1999)	P	FES	Endopore	5-6 y	52	156 (0/156)	48	144 (0/144)	56	yes	NR	OD	NR
Meijer et al. (2000)	P	FES	NB	5 y	32	64 (0/64)	28	61[5] (0/61)	54.7	yes	NR	OD	strict oral hygiene regimen
			IMZ	5 y	29	58 (0/58)	28	59[3] (0/59)	59.4				
Stellingsma et al. (2000)	CS	FES	Strau (12 impl) IMZ (8 impl) NB (48 impl)	77 m (60-97)	17	68 (0/68)	17	68 (0/68)	65.0 (49-80)	yes	NR	OD	every 6 m
Meijer et al. (2001b)	P	FES	NB	6 y	17	34 (0/34)	16	33[1] (0/33)	54.5	yes	NR	OD	strict oral hygiene regimen
			IMZ	6 y	41	82 (0/82)	37	75[1] (0/75)	54.3				
Meijer et al. (2004a)	P	FES	Strau	5 y	30	60 (0/60)	27	54 (0/54)	52.8 (38-74)	yes	NR	OD	every 6 m or year
			NB	5 y	30	60 (0/60)	27	55[1] (0/55)	56.6 (35-79)				
Visser et al. (2005)	P	FES	IMZ, 2 impl	5 y	30	60 (0/60)	29	59[1] (0/59)	54.0 (38-77)	yes	NR	OD	every 6m or year
			IMZ, 4 impl	5 y	30	120 (0/120)	27	108 (0/108)	55.7 (35-79)				
Heijdenrijk et al. (2006)	P	FES	IMZ, 2-stage	5 y	20	40 (0/40)	19	39 (0/39)	58	yes	NR	OD	every year
			IMZ, 1-stage	5 y	20	40 (0/40)	19	38 (0/38)					
			Strau, 1-stage	5 y	20	40 (0/40)	18	36 (0/36)					
Cehreli et al. (2010)	P	FES	Strau	5 y	14	28 (0/28)	12	24 (0/24)	63.8	heavy smokers excl	NR	OD	every year
			NB	5 y	14	28 (0/28)	10	20 (0/20)					
Gallucci et al. (2009)	P	FES	Strau	5 y	45	237 (0/237)	45	237 (0/237)	59.6	moderate/ heavy smokers excl	NR	FFD	every year
Turkyilmaz et al. (2010)	P	FES	NB, imm. load	5 y	13	26 (0/26)	13	26 (0/26)	62.3 (50-76)	NR	NR	OD	every year
			NB, conv. load	5 y	13	26 (0/26)	13	26 (0/26)	63.2 (50-76)				

Weinländer et al. (2010)	P	FES	IMZ (20 impl) Camlog (28 impl), soldered bar, 2 impl	5 y	24	48 (0/48)	21	42 (0/42)					
			IMZ (88 impl) Frialoc (12 impl) soldered bar, 4 impl	5 y	25	100 (0/100)	22	88 (0/88)	59.6	NR	NR	OD	every year
			Camlog, milled bar, 4 impl	5 y	27	108 (0/108)	24	96 (0/96)					
Akoğlu et al. (2011)	P	FES	Strau (24 impl) SwissPlus (24 impl) Astra (24 impl)	5 y	36	72 (0/72)	36	72 (0/72)	NR (45-63)	yes	NR	OD	every year
Heckmann et al. (2004)	CS	FES	Strau	10.4 y (8-12.8)	41	82 (0/82)	23	46 (0/46)	NR	NR	NR	OD	NR
Meijer et al. (2004b)	P	FES	NB	10 y	32	64 (0/64)	25	55[5] (0/55)	54.7	yes	NR	OD	strict oral hygiene regimen
			IMZ	10 y	29	58 (0/58)	28	59[3] (0/59)	59.4				
Telleman et al. (2006)	CS	FES	Strau	10 y	38	115 (0/115)	38	115[1] (0/115)	NR	NR	NR	OD	every year
Roos-Jansåker et al. 2006a,b,c)	CS	FES	NB	10.8 y (9-14)	NR	NR	62	356	NR	yes	NR	NR	referred back to general dentist
Meijer et al. (2009b)	P	FES	Strau	10 y	30	60 (0/60)	27	54 (0/54)	52.8 (38-74)	yes	NR	OD	every 6 m or year
			NB	10 y	30	60 (0/60)	27	55[1] (0/55)	56.6 (35-79)				
Meijer et al. (2009a)	P	FES	IMZ, 2 impl	10 y	30	60 (0/60)	29	59[1] (0/59)	54.0 (38-77)	yes	NR	OD	every 6 m or year
			IMZ, 4 impl	10 y	30	120 (0/120)	23	92 (0/92)	55.7 (35-79)				
Buser et al. (1996)	P	PES	Strau	5 y	9	12 (5/7)	9	12 (5/7)	NR	NR	NR	SC (6 impl) FPD (6 impl)	maintenance care program or referred back to dentist
Andersson et al. (1998b)	P	PES	NB	5 y	57	65 (62/3)	50	56	31.8	yes	NR	SC	every year
Andersson et al. (1998a)	P	PES	NB, general practices	5 y	19	19 (19/0)	17	17 (17/0)	31 (20-45)	yes	NR	SC	every year
			NB, specialist clinic	5 y	19	19 (19/0)	17	17 (17/0)					
De Leonardis et al. (1999)	P	PES	Minimatic	5 y	63	100 (46/54)	62	98	NR	yes	NR	SC (30 impl) FPD (70 impl)	every 3 m
Weber et al. (2000)	P	PES	Strau	5 y	46	112	41	107	NR	NR	NR	SC / FPD	NR
Mericske-Stern et al. (2001)	P	PES	Strau	5-9 y	72	109 (48/61)	28	29	50.1 (19-82)	heavy smokers excl	NR	SC	every 4-6 m

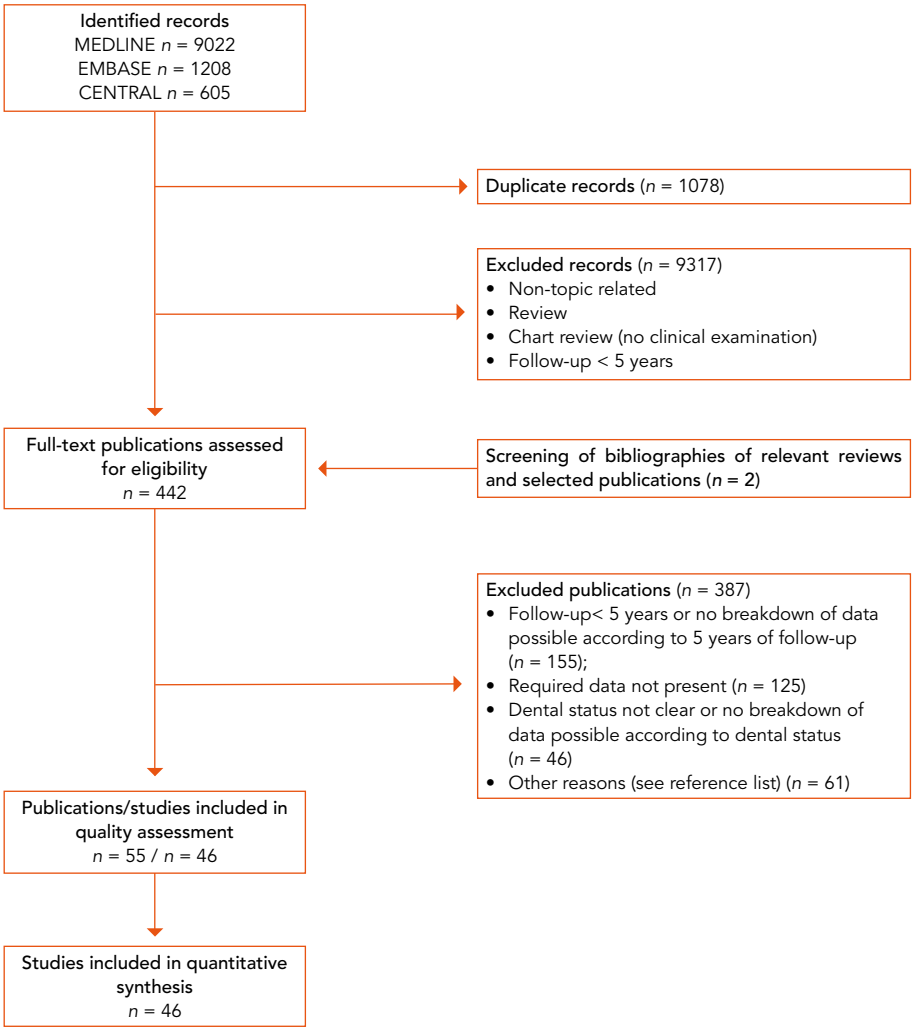
Table 2. Continued

authors	study design	dental status	implant system	follow-up	# initially included		# followed		age at start of study	smokers included	history periodontitis	prosthesis type	maintenance program
					subj	impl (max/man)	subj	impl (max/man)					
Buser et al. (2002)	P	PES	Strau	5 y	40	66	37	61	40 (16-73)	NR	NR	SC / FPD	every year
Davis et al. (2004)	P	PES	Calcitek Integral Omniloc	5 y	20	23 (22/1)	18	20	(18-61)	no	NR	SC	NR
Gotfredsen (2004)	P	PES	Astra	5 y	20	20 (20/0)	20	20 (20/0)	33 (18-59)	yes	NR, reason for tooth loss: root fracture, agenesi and trauma	SC	every year
Vigolo et al. (2004)	CS	PES	3i (small Ø)	7 y	165	192 (110/82)	165	192 (110/82)	39 (17-74)	yes	NR	SC (94 impl) FPD (98 impl)	every 3 m 1st year every 6 m thereafter
Wennström et al. (2004)	P	PES	Astra	5 y	51	149 (83/66)	47	141	59.5 (36-80)	yes	yes, all moderate to advanced chronic perio	FPD	every 4-6 m
Bornstein et al. (2005)	P	PES	Strau	5 y	51	104 (15/89)	49	101	NR	heavy smokers excl	NR	SC (39 impl) FPD (64 impl)	every year
Wennström et al. (2005)	P	PES	Astra	5 y	40	45 (40/5)	36	41	40.9 (20-71)	yes	NR	SC	every year
Bornstein et al. (2008)	P	PES	Strau	5 y	55	111 (111/0)	49	100 (100/0)	53.9 (19-74)	no	NR	SC (40 impl) FPD (71 impl)	NR
Gatti et al. (2008)	P	PES	NB, Zimmer, Mathys, Strau, Dentsply Friadent	5 y	29	72 (38/34)	27	67*	40 (18-61)		no		every 6 m
				5 y	7	26 (9/17)	5	19*	56 (42-70)	yes	yes, all moderate perio: pockets ≤ 5.5 mm before perio treatment	OD / FFD / FPD / SC	every 4 m
				5 y	26	129 (48/71)	24	119*	56 (35-85)		yes, all severe perio: pockets > 5.5 mm before perio treatment		every 3 m
Renvert et al. (2008)	CS	PES	NB (102 impl) Astra (132 impl)	7 y	76*	329	54	234	60.6 (27-75)	yes	yes, 44% needed implants because of perio, 24% received perio treatment	NR	referred back to general dentist
Roccuzzo et al. (2008)	P	PES	Strau, SLA	5 y	32	68	27	53	(26-59)	no	NR	SC / FPD	every 3 m 1st year every year thereafter
			Strau, TPS	5 y		68		53			NR		
Kehl et al. (2011)	P	PES	NB (43 impl) 3i (38 impl)	9.2y	17	81 (47/34)	17	81 (47/34)	46.94	yes	yes, all GAP	SC (4 impl) FPD (20 impl) TSOD (57 impl)	every 3 m
			NB (18 impl) 3i (20 impl)	5.7y	17	38 (16/22)	17	38 (16/22)	49.62		yes, all GCP	SC (12 impl) FPD (15 impl) TSOD (11 impl)	every 3 m

Rodrigo et al. (2012)	P	PES	Strau, delayed loading group	5	22	34	22	34	59.3 (33-76)	yes, 36% smokers	yes, 68% periodontally treated	NR	every year, in periodontitis patients more often
Lekholm et al. (1999)	P	PES	NB	10 y	127	461 (185/276)	89	338	50 (18-70)	NR	NR	FPD	every year
Gunne et al. (1999)	P	PES	NB	10 y	23	69 (0/69)	20	60 (0/60)	57.7	NR	NR	I-I FPD (46 impl) I-T FPD (23 impl)	NR
Leonhardt et al. (2002)	P	PES	NB	10 y	19	63	15	57 (31/26)	(21-71)	NR	yes, all advanced perio	NR	regularly
Karoussis et al. (2004a,b), Brägger et al. (2005)	P	PES	Strau	10 y (8-12)	127	258	89	179 (104/75)	49.3 (19-78)	NR	yes, some	SC (69 impl) I-I FPD (69 impl) I-T FPD (22 impl)	every 3-6 m
Roos-Jansåker et al. (2006a,b,c)	CS	PES	NB	10.8 y (9-14)	NR	NR	156	643	NR	yes	yes, 60% of patients had 31-100% of remaining teeth with bone loss ≥ 4 mm	NR	referred back to general dentist
Bonde et al. (2010)	CS	PES	NB	10 y (7.5-12)	51	55 (49/6)	48	52	43 (19-79)	yes	yes, 9% perio as reason for tooth loss	SC	no systematic maintenance program
Simonis et al. (2010)	CS	PES	Strau	10-16 y	76	162	55	131 (66/65)	NR	yes	yes, 26% perio as reason for tooth loss	SC (36 impl) I-I FPD (70 impl) I-T FPD (25 impl)	NR
Bergenblock et al. (2012)	P	PES	NB	18.4 y (17-19)	57	65 (62/3)	49	55	31.9 (15-57)	yes	NR	SC	every year during first five years, thereafter no follow-up program
Roccuzzo et al. (2010, 2012)	P	PES	Strau	10 y	32		28	61	45	yes, 11% smokers	periodontally healthy	single crown FPD	individually tailored maintenance care program
					42	264	37	95	49	yes, 27% smokers	moderately periodontally compromised		
					38		36	90	44	yes, 14% smokers	severely periodontally compromised		

P = prospective study; CS = cross-sectional study; FES = fully edentulous subjects; PES = partially edentulous subjects; Strau = Straumann/ITI; IMZ = IMZ implant system, NB= Nobel Biocare/Brånemark; impl = implants; imm. load = immediate loading protocol; conv. load = conventional loading protocol; SLA = sandblasted, large-grit, acid-etched implant surface; TPS = titanium plasma sprayed implant surface; y = years; m = months; subj = subjects; * = # is estimated based on mean # of implants per subject at follow-up; NR = not reported; max = maxilla; man = mandibula; [1,3,5] = # implants included replacing implants lost before loading; excl = excluded; perio = periodontitis; mm = millimeters; GAP = generalized aggressive periodontitis; GCP = generalized chronic periodontitis; OD = overdenture; FFD = fixed full denture; SC = single crown; FPD = fixed partial denture; TSOD = telescopic crown overdenture; I-I FPD = implant retained fixed partial denture; I-T FPD = implant-tooth retained fixed partial denture

Figure 1. Study selection procedure



Outcome variables

The outcomes of the studies are listed in Tables 3-6 and are summarized below. Weighted rates/mean values and 95% confidence intervals are summarized in Table 7.

Implant loss

No statistically significant differences in early and late implant loss were observed between FES and PES in ≥ 5 year and ≥ 10 year follow-up studies. However, in prospective studies, after 10 years of follow-up a significantly higher late implant loss could be observed in PES compared to 5 years of follow-up (1.4%, 95% CI [0.8, 2.2] versus 5.2%, 95% CI [3.5, 7.7]), whereas no significant difference could be observed in FES between 5 and 10 years of follow-up (1.9%, 95% CI [1.3, 2.9] versus 2.9%, 95% CI [1.3, 6.4]).

Probing pocket depth

No statistical differences in probing pocket depth were observed between FES and PES at both time intervals and within the PES group comparing both time intervals. Only for prospective studies on FES a difference could be observed between ≥ 5 year and ≥ 10 year follow-up studies (2.81 mm, 95% CI [2.45, 3.17] versus 3.66 mm, 95% CI [3.23, 4.09]).

Modified plaque index (mPI) / presence of plaque

After ≥ 5 years of follow-up, FES generally harbored more plaque than PES as indicated both by the mPI (0.65, 95% CI [0.53, 0.78] versus 0.36, 95% CI [0.27, 0.44]) and the percentages of sites harboring plaque (49.0%, 95% CI [42.6, 55.5] versus 15.1%, 95% CI [8.2, 26.2]). The mean mPI could be extracted from 49% of the studies. Although reporting a mean mPI value to represent the four different observations per implant is actually not correct (since mPI is an ordinal parameter), it is widely used. More meaningful would be to report on the presence of plaque on site, implant and/or subject level. From some studies data regarding presence of plaque could be recalculated from mPI data.

Modified bleeding index (mBI) / bleeding on probing (BoP)

Since mBI is an ordinal variable (see mPI) it is actually not correctly represented by a mean value. However, the mean mBI value is often reported. Using this parameter, FES showed a higher bleeding tendency of the peri-implant mucosa than PES both in prospective studies reporting ≥ 5 years of follow-up (0.61, 95% CI [0.44, 0.79] versus 0.33, 95% CI [0.25, 0.41]) and studies reporting ≥ 10 years of follow-up (0.57, 95% CI [0.28, 0.86] versus 0.19, 95% CI [0.15, 0.23]). Most studies on FES used the mBI to quantify the bleeding tendency of the peri-implant mucosa, whereas in PES studies BoP score was most frequently used. In most of these studies pocket probing was performed at four sites per implant. Only Bonde et al. (2010), Simonis et al. (2010) and Rodrigo et al. (2012) measured at six sites per implant. It was assumed that probing at four or six sites per implant would not affect outcomes.

The mBI measures the bleeding tendency after running a periodontal probe through the marginal sulcus (1 mm deep) around an implant, whereas BoP scores the bleeding tendency after probing the peri-implant pockets. Although both parameters use

Table 3. Outcomes of studies reporting on fully edentulous subjects (follow up period ≥ 5 years)

	authors	# clin evaluated		outcomes								
		subj	impl	% impl lost before loading	% impl lost during function (fractures excluded)	PPD (SD)	mPI (SD)	presence of plaque % sites/impl/subj	mBI (SD)	bleeding on probing % sites/impl/subj	peri-implant mucositis % impl/subj	peri-implantitis % impl/subj
Prospective studies	Mericske-Stern et al. (1994)	33	64	0	1.3/1.5	3.16 (0.8) 2.93 (0.7)	0.50 (NR)	NR	0.25 (NR)	26.2/54.7/69.7	NR	NR
	Cordioli et al. (1997)	15	15	0	0/0	2.7 (NR)	2.50 (NR)	NR	0.30 (NR)	NR	NR	NR
	Naert et al. (1998)	31	62	1.4	0/0	NR	NR	54.2/NR/NR	NR	28.2/NR/NR	NR	NR
	Deporter et al. (1999)	46	134	3.2	3.2/3.5	2.9 (NR)	0.42 (0.49)	NR	0.21 (0.24)	20.9/NR/NR	NR	NR
	Meijer et al. (2000)	28	52	7.8	6.3/6.6	3.3 (0.9)	0.50 (0.8)	NR	0.10 (0.3)	NR	NR	NR
		28	55	5.2	1.7/1.7	3.7 (1.0)	0.70 (0.7)	NR	0.10 (0.3)	NR	NR	NR
	Meijer et al. (2001b)	16	32	2.9	0/0	3.1 (NR)	0.90 (NR)	NR	0.50 (NR)	NR	NR	NR
		37	73	1.2	1.2/1.3	4.8 (NR)	0.80 (NR)	NR	0.50 (NR)	NR	NR	NR
	Meijer et al. (2004a)	27	54	0	0/0	2.4 (0.7)	0.40 (0.8)	NR	0.70 (0.8)	NR	NR	NR
		27	54	1.7	0/0	3.0 (0.6)	0.80 (1.0)	NR	0.70 (0.5)	NR	NR	NR
	Visser et al. (2005)	29	58	1.7	0/0	4.2 (1.3)	0.50 (0.7)	NR	0.90 (0.6)	NR	NR	NR
		27	108	0	0/0	4.0 (1.1)	0.40 (0.7)	NR	1.20 (0.7)	NR	NR	NR
	Heijdenrijk et al. (2006)	19	38	0	2.5/2.6	NR	NR	NR/34.2/NR	NR	NR/*23.7*/NR	NR	NR
		19	37	0	2.5/2.6	NR	NR	NR/24.3/NR	NR	NR/*27.0*/NR	NR	NR
		19	36	0	0/0	NR	NR	NR/33.3/NR	NR	NR/*22.2*/NR	NR	NR
	Gallucci et al. (2009)	45	237	0	0/0	NR	0.33 (NR)	NR	0.16 (NR)	NR	NR	NR
	Cehreli et al. (2010)	12	24	0	0/0	NR	0.08 (NR)	NR	0.08 (NR)	NR	NR	NR
		10	20	0	0/0	NR	0.60 (NR)	NR	0.20 (NR)	NR	NR	NR
	Turkyilmaz et al. (2010)	13	26	0	0/0	1.84 (0.4)	1.22 (0.4)	NR	1.03 (0.3)	NR	NR	NR
		13	26	0	0/0	1.83 (0.4)	1.17 (0.5)	NR	0.95 (0.4)	NR	NR	NR
	Weinländer et al. (2010)	21	42	0	0/0	3.2 (1.3)	0.60 (0.4)	NR	0.40 (0.3)	NR	NR	NR
		22	88	0	0/0	3.1 (1.5)	0.60 (0.4)	NR	0.50 (0.3)	NR	NR	NR
		24	96	0	0/0	3.0 (1.4)	0.60 (0.3)	NR	0.60 (0.2)	NR	NR	NR
	Akoğlu et al. (2011)	36	72	0	0/0	1.50 (0.42) 1.73 (0.53) 2.39 (0.43)	0.46 (NR)	45.8/NR/NR	0.10 (NR)	*10.1*/NR/NR	NR	NR

Cross-sectional studies	Heijdenrijk et al. (1998)	40	79	3.5	1.2/1.2	3.1 (1.0)	NR	NR/34.2/NR	NR	NR/*13.9*/NR	NR	NR
	Kwakman et al. (1998)	48	96	0	0/0	NR	NR	NR/NR/47.0	NR	NR/NR/10.4	NR	NR
	Stellingsma et al. (2000)	17	60	10.3	1.5/1.5	3.0 (0.9)	0.63 (0.8)	NR	0.36 (0.5)	*35.8*/NR/NR	NR	NR
All studies		mean (SD)		1.65 (2.87)	0.81/0.86 (1.24)/(1.31)	3.01 (0.73)	0.72 (0.58)	50.0/32.4/47.0 (5.9)/(2.5)/(-)	0.42 (0.33)	24.3/28.6/39.9 (9.6)/(15.4)/ (42.2)	- / -	- / -
		range		0-10.3	0-6.3/0-6.6	1.83-4.8	0.08-2.5	45.8-54.2/ 24.8-34.5/-	0.08-1.20	10.1-36.0/ 13.9-54.7/ 10.0-69.7	- / -	- / -
Prospective studies		weighted mean		2.4	1.9/2.1	2.81	0.65	49.0/30.8/-	0.61	20.5/31.6/-	-	-
		95% CI		1.6-3.6	1.3-2.9/ 1.4-3.2	2.45-3.17	0.53-0.78	42.6-55.5/ 22.9-40.1/-	0.44-0.79	14.2-28.7/ 17.6-50.1/-	-	-
		I^2		*0*	*0/0*	*98.7*	*91.7*	*56.7/0/-*	*98.3*	*90.2/81.0/-*	-	-
Cross-sectional studies		weighted mean		3.9	1.0/1.1	3.05	-	-	-	-	-	-
		95% CI		1.0-14.6	0.3-3.5/ 0.3-3.7	2.89-3.21	-	-	-	-	-	-
		I^2		*71.4*	*0/0*	*0*	-	-	-	-	-	-

clin evaluated = clinically evaluated; subj = subjects; impl = implants; SD = standard deviation; 95% CI = 95% confidence interval; PPD = probing pocket depth; NR = not reported; mPI = mean modified plaque index (Mombelli et al. 1987) measured at 4 sites per implant; mBI = mean modified bleeding index (Mombelli et al. 1987) measured at 4 sites per implant; *italic* = value recalculated from modified bleeding index data

Table 4. Outcomes of studies reporting on fully edentulous subjects (follow up period ≥ 10 years)

	authors	# clin evaluated		outcomes								
		subj	impl	% impl lost before loading	% impl lost during function (fractures excluded)	PPD (SD)	mPI (SD)	presence of plaque % sites/impl/subj	mBI (SD)	bleeding on probing % sites/impl/subj	peri-implant mucositis % impl/subj	peri-implantitis % impl/subj
Prospective studies	Meijer et al. (2004b)	25	46	7.8	6.3/7.3	3.4 (1.0)	0.80 (1.0)	NR	0.60 (0.6)	NR	NR	NR
		28	55	5.2	1.7/1.7	4.7 (1.8)	0.80 (1.0)	NR	0.70 (0.7)	NR	NR	NR
	Meijer et al. (2009a)	27	55	1.7	5.0/5.1	3.8 (1.3)	0.40 (0.8)	NR	0.50 (0.6)	NR	NR	NR
		23	92	0	0/0	3.9 (1.3)	0.60 (1.0)	NR	1.00 (0.3)	NR	NR	NR
	Meijer et al. (2009b)	27	54	0	0/0	3.3 (1.0)	0.40 (0.7)	NR	0.30 (0.6)	NR	NR	NR
		27	54	1.7	0/0	3.0 (0.5)	0.60 (0.9)	NR	0.30 (0.5)	NR	NR	NR
Cross-sectional studies	Heckmann et al. (2004)	23	46	0	0/0	2.15 (0.96)	0.82 (NR)	55.4/NR/NR	0.36 (NR)	*29.3*/NR/NR	NR	NR
	Telleman et al. (2006)	38	111	0.9	2.6/2.6	3.3 (1.3)	NR	NR/NR/*68.4*	NR	NR/NR/*71.1*	NR	NR
	Roos-Jansåker et al. (2006a,b,c)	62	356 (m) 344 (pi)	NR	NR	NR	NR	NR	NR	NR	39.6/NR (criteria: PPD ≥ 4mm and BoP+)	5.8/NR (criteria: BoP+ and/or suppuration and bone loss ≥ 3 threads between 1 year and final examination)
All studies		mean (SD)		2.77 (3.04)	1.67/2.25 (1.76)/(1.81)	3.31 (0.76)	0.66 (0.17)	55.4/ - /68.4 (-)/(-)/(-)	0.53 (0.24)	29.3/ - /71.1 (-)/(-)/(-)	39.6 (-)	5.8/ - (-)/(-)
		range		0-7.8	0-6.3/0-7.3	2.15-4.7	0.40-0.82	- / - / -	0.30-1.00	- / - / -	- / -	- / -
Prospective studies		weighted mean		3.1	2.9/3.2	3.66	0.58	-	0.57	-	-	-
		95% CI		1.3-7.0	1.3-6.4/ 1.4-7.0	3.23-4.09	0.44-0.72	-	0.28-0.86	-	-	-
		I^2		*38.0*	*26.6/26.3*	*93.8*	*54.9*	-	*96.7*	-	-	-
Cross-sectional studies		weighted mean		0.8	2.1/2.3	2.73	-	-	-	-	-	-
		95% CI		0.2-3.7	0.7-5.9/ 0.8-6.3	1.60-3.85	-	-	-	-	-	-
		I^2		*0*	*0/0*	*97.3*	-	-	-	-	-	-

clin evaluated = clinically evaluated; subj = subjects; impl = implants; (m) = peri-implant mucositis analysis; (pi) = peri-implantitis analysis; SD = standard deviation; 95% CI = 95% confidence interval; NR = not reported; PPD = probing pocket depth; mPI = mean modified plaque index (Mombelli et al. 1987) measured at 4 sites per implant; mBI = mean modified bleeding index (Mombelli et al. 1987) measured at 4 sites per implant; mm = millimeters; BoP+ = bleeding on probing; *italic* = value recalculated from modified bleeding index data

different methods, it was assumed that both parameters are more or less interchangeable. Therefore, whenever possible, data regarding BoP were recalculated from mBI data. No differences in BoP were found between FES and PES after ≥ 5 years of follow-up (20.5% of sites, 95% CI [14.2, 28.7] versus 20.9% of sites, 95% CI [15.3, 27.9]). No sufficient data were available for a comparison of the ≥ 10 year follow-up studies.

Peri-implant mucositis
Two studies reported on the prevalence of peri-implant mucositis (Roos-Jansåker et al. 2006c, Rodrigo et al. 2012), both using the criteria of BoP+, PPD ≥ 4 mm and no bone loss. Rodrigo et al. (2012) reported a prevalence of peri-implant mucositis in PES of 20.6% of the implants after a 5-year observation period. After a mean observation period of 10.8 years, Roos-Jansåker et al. (2006c) found a lower prevalence of peri-implant mucositis in FES than in PES (39.6% versus 52.3%).

Peri-implantitis
One study reported on the prevalence of peri-implantitis in FES and PES (Roos-Jansåker et al. 2006a,b,c). Five other studies reported on the prevalence of peri-implantitis in PES only (Brägger et al. 2005, Gatti et al. 2008, Simonis et al. 2010, Roccuzzo et al. 2012, Rodrigo et al. 2012). Different criteria were used to define peri-implantitis, making a meta-analysis impossible (Table 8). Roos-Jansåker et al. (2006a,b,c) found a lower prevalence of peri-implantitis in FES (5.8% of the implants) compared to PES (7.2% of the implants). After an observation period of 5 years, Gatti et al. (2008) observed peri-implantitis in 3.4% of the implants in patients with a history of severe periodontitis, whereas no implants were affected in non-periodontitis patients or patients with a history of moderate periodontitis. Rodrigo et al. (2012) reported a prevalence of peri-implantitis of 2.9% of the implants after 5 years of follow-up. In the study described by Karoussis et al. (2004a,b) and Brägger et al. (2005) peri-implantitis occurred in 15.4% of the implants after a mean observation period of 10 years. Simonis et al. (2010) reported a peri-implantitis prevalence of 16.9% after an observation period of 10-16 years. They found a remarkable difference between patients with a history of periodontitis (37.9%) and patients without a history of periodontitis (10.5%). In contrast to the abovementioned studies, Roccuzzo et al. (2012) reported the prevalence of peri-implantitis on subject level. It was found that 47.2% of the severely periodontally compromised subjects, 27.0% of the moderately periodontally compromised subjects and 10.7% of the periodontally healthy subjects required peri-implantitis treatment during an observation period of 10 years (Mombelli & Lang 1998).

FES/PES study
Since Roos-Jansåker et al. (2006a,b,c) was the only study describing both FES and PES, this study is considered in more detail. The percentage of subjects with implant loss was lower in the FES group than the PES group (6.5% versus 11.5%). No distinction was made between early and late implant loss. The prevalence of peri-implant mucositis and peri-implantitis was lower in FES compared to PES (only implant-based data available; peri-implant mucositis: 39.6% versus 52.3%; peri-implantitis: 5.8% versus 7.2%). The PES group included more smokers than the FES group. After correction

Table 5. Outcomes of studies reporting on partially edentulous subjects (follow up period ≥ 5 years)

	authors	# clin. evaluated		outcomes								
		subj	impl	% impl lost before loading	% impl lost during function (fractures excluded)	PPD (SD)	mPI (SD)	presence of plaque % sites/impl/subj	mBI (SD)	bleeding on probing % sites/impl/subj	peri-implant mucositis % impl/subj	peri-implantitis % impl/subj
Prospective studies	Buser et al. (1996)	9	12	0	0/0	3.44 (1.33)	0.06 (0.32)	4.2/16.7/22.2	0.50 (0.77)	*33.3/91.7/88.9*	NR	NR
	Andersson et al. (1998b)	49	55	0	1.5/1.8	NR	NR	NR	NR	NR/5.5/NR	NR	NR
	Andersson et al. (1998a)	17	17	0	0/0	NR	NR	NR	NR	NR/11.8/NR	NR	NR
		17	17	0	0/0	NR	NR	NR	NR	NR/ 0/NR	NR	NR
	De Leonardis et al. (1999)	61	97	0	0/0	2.77 (0.85)	0.53 (0.64)	36.1/NR/NR	0.51 (0.62)	*35.1*/NR/NR	NR	NR
	Weber et al. (2000)	41	106	0	0.9/0.9	3.0 (NR)	0.45 (NR)	38.0/NR/NR	0.42 (NR)	*23.1*/NR/NR	NR	NR
	Mericske-Stern et al. (2001)	26	26	0	1.8/6.9	3.3 (1.2)	0.60 (0.5)	NR	0.40 (0.5)	NR	NR	NR
	Buser et al. (2002)	37	61	0	0/0	4.43 (1.24)	0.25 (0.29)	NR	0.25 (0.43)	NR	NR	NR
	Davis et al. (2004)	18	20	0	0/0	NR	NR	10.0/NR/NR	NR	23.8/NR/NR	NR	NR
	Gotfredsen (2004)	20	20	0	0/0	NR	NR	21.3/NR/NR	NR	*37.5*/NR/NR	NR	NR
	Wennström et al. (2004)	47	137	0.7	0/0	3.1 (0.8)	NR	5.3/NR/NR	NR	4.9/NR/NR	NR	NR
	Bornstein et al. (2005)	48	100	1.0	0/0	4.02 (CI: 3.86-4.18)	0.26 (CI: 0.20-0.32)	NR	0.25 (CI: 0.21-0.29)	NR	NR	NR
	Wennström et al. (2005)	36	40	0	2.2/2.4	3.5 (NR)	NR	8.1/NR/NR	NR	11.9/NR/NR	NR	NR
	Bornstein et al. (2008)	49	98	0	1.8/2.0	4.14 (SEM:0.11)	0.27 (SEM:0.03)	NR	0.29 (SEM:0.04)	NR	NR	NR
	Gatti et al. (2008)	21	67	0	0/0	NR	NR	NR	NR	NR	NR	0/0
		5	19	0	0/0	NR	NR	NR	NR	NR	NR	0/0
		24	117	0	1.6/1.7	NR	NR	NR	NR	NR	NR	3.4/8.3 (4 implants in 2 subjects: 2 treated, 2 lost. Criteria: PPD > 5 mm, pus or other sign of infection, bone loss > 2 mm)
	Roccuzzo et al. (2008)	27	53	0	0/0	3.2 (1.0)	0.27 (0.56)	NR	NR	28.8/NR/NR	NR	NR
			53	0	0/0	3.2 (1.0)	0.32 (0.54)	NR	NR	32.1/NR/NR	NR	NR
	Kehl et al. (2011)	17	81	0	0/0	3.06 (0.82)	0.74 (1.00)	NR	NR	17.9/NR/NR	NR	NR
		17	38	0	0/0	2.80 (0.66)	0.52 (0.87)	NR	NR	13.2/NR/NR	NR	NR
	Rodrigo et al. (2012)	22	34	0	0/0	NR	NR	20.0/NR/NR 6 sites	NR	13.7/NR/NR 6 sites	20.6/NR (criteria: BoP+, PPD ≥ 4mm, no significant bone loss)	2.9/NR (criteria: BoP+, PPD ≥ 4 mm, significant bone loss)

Cross-sectional studies	Vigolo et al. (2004)	9	12	0	0/0	3.44 (1.33)	0.06 (0.32)	4.2/16.7/22.2	0.50 (0.77)	*33.3/91.7/88.9*	NR	NR
	Renvert et al. (2008)	54	234	NR	NR	NR	NR	NR/NR/87.0	NR	NR/NR/88.9	NR	NR
All studies		mean (SD)	0.21 (0.55)	0.65/0.98 (0.92)/(1.75)	3.36 (0.59)	0.38 (0.20)	17.9/16.7/54.8 (12.5)/ - /(46.0)	0.37 (0.11)	21.6/34.2/89.3 (11.5)/(49.8)/ (0.5)	20.6/ - (-)/(-)	2.4/3.6 (0.6)/ (-)	
		range	0-2.1	0-2.6/0-6.9	2.4-4.43	0.06-0.74	4.2-38.0/ - / 22.2-87.3	0.25-0.51	4.9-38.0/ 0-91.7/ 88.9-89.6	- / -	0-3.4/ -	
Prospective studies		weighted mean	1.0	1.4/1.7	3.40	0.36	15.1/-/-	0.33	20.9/18.3/-	-	-	
		95% CI	0.5-1.7	0.8-2.2/ 1.1-2.7	3.06-3.74	0.27-0.44	8.2-26.2/ -/ -	0.25-0.41	15.3-27.9/ 2.2-68.8/ -	-	-	
		I^2	*0*	*0/0*	*96.2*	*82.5*	*96.3/-/-*	*72.8*	*93.3/85.6/-*	-	-	
Cross-sectional studies		weighted mean	-	-	-	-	-	-	-	-	-	
		95% CI	-	-	-	-	-	-	-	-	-	
		I^2	-	-	-	-	-	-	-	-	-	

clin evaluated = clinically evaluated; subj = subjects; impl = implants; SD = standard deviation; 95% CI = 95% confidence interval; NR = not reported; PPD = probing pocket depth; SEM = standard error of the mean; mPI = mean modified plaque index (Mombelli et al. 1987) measured at 4 sites per implant; mBI = mean modified bleeding index (Mombelli et al. 1987) measured at 4 sites per implant; mm = millimeters; BoP+ = bleeding on probing; *italic* = value recalculated from modified bleeding index data

Table 6. Outcomes of studies reporting on partially edentulous subjects (follow up period ≥ 10 years)

	authors	# clin. evaluated		outcomes								
		subj	impl	% impl lost before loading	% impl lost during function (fractures excluded)	PPD (SD)	mPI (SD)	presence of plaque % sites/impl/subj	mBI (SD)	bleeding on probing % sites/impl/subj	peri-implant mucositis % impl/subj	peri-implantitis % impl/subj
Prospective studies	Lekholm et al. (1999)	89	304	3.5	3.3/4.4	NR	NR	NR	NR	10.4/NR/NR	NR	NR
	Gunne et al. (1999)	20	52	1.4	10.1/11.7	NR	NR	NR	NR	NR/5.8/NR	NR	NR
	Leonhardt et al. (2002)	15	54	0	4.8/5.3	NR	NR	NR/NR/46.7	NR	60.6/NR/NR	NR	NR
	Karoussis et al. (2004a,b), Brägger et al. (2005)	89	166	0	5.0/7.3	2.60 (0.41) 3.14 (1.36) 3.12 (1.07)	0.35 (0.41) 0.42 (0.35) 0.18 (0.21)	NR	0.19 (0.28) 0.19 (0.27) 0.21 (0.34)	38.1/NR/NR 51.8/NR/NR 45.6/NR/NR	NR	15.4/NR (criteria: PPD ≥ 5mm, BoP+, radiographic signs of bone loss between 1 year and final examination)
	Bergenblock et al. (2012)	47	52	0	1.5/1.8	NR	NR	NR	NR	10.7/17.3/NR	NR	NR
	Roccuzzo et al. (2010, 2012)	28	59	0	3.3	3.1 (0.5)	NR	16.1/NR/NR	NR	12.3/NR/NR	NR	NR/10.7
		37	88	0	6.8 7.4	3.5 (0.9)	NR	29.0/NR/NR	NR	31.0/NR/NR	NR	NR/27.0
		36	81	0	10	3.9 (0.7)	NR	23.1/NR/NR	NR	30.9/NR/NR	NR	NR/47.2 (criteria: treatment C or D of CIST protocol = BoP+, PPD > 5 mm, bone loss)
Cross-sectional studies	Roos-Jansåker et al. (2006a,b,c)	156	642 (m) 643 (pi)	NR	NR	NR	NR	NR	NR	NR	52.3/NR (criteria: PPD ≥ 4 mm and BoP+)	7.2/NR (criteria: BoP+ and/or suppuration and bone loss ≥ 3 threads between 1 year and final examination)
	Bonde et al. (2010)	45	49	5.5	0/0	4.8 (NR) 6 sites	NR	NR	NR	55.1/93.9/95.6 6 sites	NR	NR
	Simonis et al. (2010)	55	109	1.9	9.3/11.5	2.73 (0.81) 6 sites	NR	52.5/NR/NR 6 sites	NR	15.8/NR/NR 6 sites	NR	16.9/NR (criteria: PPD ≥ 5 mm, BoP+ and/or suppuration, radiographic bone loss ≥ 2.5 mm or bone loss extending ≥ 3 threads, 10.5% in patients without history of perio, 37.9% in patients with history of perio)

All studies	mean (SD)	1.54 (2.04)	5.10/6.16 (3.54)/(4.18)	3.47 (0.96)	0.35 (-)	38.1/ - /46.7 (20.4)/(-)/(-)	0.19 (-)	31.5/39.0/95.6 (21.2)/(47.9)/(-)	52.3/ - (-)/(-)	13.2/28.3 (5.2)/(18.3)
	range	0-5.5	0-10.1/ 0-11.7	2.60-4.8	-	- / - / -	-	10.2-60.6/ 5.8-93.9/-	- / -	7.2-16.9/10.7-47.2
Prospective studies	weighted mean	1.0	5.2/6.6	3.23	0.32	22.6/ - /-	0.19	29.4/11.0/-	-	-
	95% CI	0.3-3.3	3.5-7.7/ 4.8-9.1	2.81-3.66	0.19-0.45	16.4-30.4/ -/-	0.15-0.23	18.4-43.4/ 3.6-29.0/-	-	-
	I^2	*50.8*	*48.6/28.5*	*96.4*	*82.7*	*84.4*	*0*	*97.8/67.7/-*	-	-
Cross-sectional studies	weighted mean	3.2	4.3/4.8	-	-	-	-	32.4/-/-	-	-
	95% CI	1.1-8.9	0.5-29.9/ 0.4-37.1	-	-	-	-	7.1-75.1/-/-	-	-
	I^2	*44.6*	*64.5/69.2*	-	-	-	-	*98.9/-/-*	-	-

clin evaluated = clinically evaluated; subj = subjects; impl = implants; (m) = peri-implant mucositis analysis; (pi) = peri-implantitis analysis; SD = standard deviation; 95% CI = 95% confidence interval; NR = not reported; PPD = probing pocket depth; 6 sites = measured at six sites around the implants; mPI = mean modified plaque index (Mombelli et al. 1987) measured at 4 sites per implant; mBI = mean modified bleeding index (Mombelli et al. 1987) measured at 4 sites per implant; mm = millimeters; BoP+ = bleeding on probing; perio = periodontitis; CIST = cumulative interceptive supportive therapy

Table 7. Weighted rates/mean values of considered parameters for subgroup analyses

Prospective Studies	% impl lost before loading	% impl lost during function (fractures excluded)	PPD (SD)	mPI (SD)	presence of plaque % sites/impl/subj	mBI (SD)	bleeding on probing % sites/impl/subj
Fully edentulous, ≥ 5 year follow-up							
weighted mean	2.4	1.9/2.1	2.81	0.65	49.0/30.8/-	0.61	20.5/31.6/-
95% CI	1.6-3.6	1.3-2.9/ 1.4-3.2	2.45-3.17	0.53-0.78	42.6-55.5/ 22.9-40.1/-	0.44-0.79	14.2-28.7/ 17.6-50.1/-
Partially edentulous, ≥ 5 year follow- up							
weighted mean	1.0	1.4/1.7	3.40	0.36	15.1/-/-	0.33	20.9/18.3/-
95% CI	0.5-1.7	0.8-2.2/ 1.1-2.7	3.06-3.74	0.27-0.44	8.2-26.2/ -/-	0.25-0.41	15.3-27.9/ 2.2-68.8/-
Fully edentulous, ≥ 10 year follow-up							
weighted mean	3.1	2.9/3.2	3.66	0.58	-	0.57	-
95% CI	1.3-7.0	1.3-6.4/ 1.4-7.0	3.23-4.09	0.44-0.72	-	0.28-0.86	-
Partially edentulous, ≥ 10 year follow- up							
weighted mean	1.0	5.2/6.6	3.23	0.32	22.6/ - /-	0.19	29.4/11.0/-
95% CI	0.3-3.3	3.5-7.7/ 4.8-9.1	2.81-3.66	0.19-0.45	16.4-30.4/ -/-	0.15-0.23	18.4-43.4/ 3.6-29.0/-
Cross-Sectional Studies	% impl lost before loading	% impl lost during function (fractures excluded)	PPD (SD)	mPI (SD)	presence of plaque % sites/impl/subj	mBI (SD)	bleeding on probing % sites/impl/subj
Fully edentulous, ≥ 5 year follow-up							
weighted mean	3.9	1.0/1.1	3.05	-	-	-	-
95% CI	1.0-14.6	0.3-3.5/ 0.3-3.7	2.89-3.21	-	-	-	-
Partially edentulous, ≥ 5 year follow- up							
weighted mean	-	-	-	-	-	-	-
95% CI	-	-	-	-	-	-	-
Fully edentulous, ≥ 10 year follow-up							
weighted mean	0.8	2.1/2.3	2.73	-	-	-	-
95% CI	0.2-3.7	0.7-5.9/ 0.8-6.3	1.60-3.85	-	-	-	-
Partially edentulous, ≥ 10 year follow- up							
weighted mean	3.2	4.3/4.8	-	-	-	-	32.4/-/-
95% CI	1.1-8.9	0.5-29.9/ 0.4-37.1	-	-	-	-	7.1-75.1/-/-

95% CI = 95% confidence interval; impl = implants; PPD = probing pocket depth; SD = standard deviation; mPI = mean modified plaque index (Mombelli et al. 1987) measured at 4 sites per implant; subj = subjects; mBI = mean modified bleeding index (Mombelli et al. 1987) measured at 4 sites per implant

for variations in smoking no differences in the number of implants affected by peri-implantitis between FES and PES were observed. In both groups smokers showed a substantially higher prevalence of peri-implantitis than never-smokers and ex-smokers (FES: smokers 16.1%, ex-smokers 1.5%, never-smokers 3.4%; PES: smokers 15.3%, ex-smokers 2.0%, never-smokers 4.4%). Thus, smoking appeared to be a substantial risk factor for developing peri-implantitis in both FES and PES. No such corrections could be made for the prevalence of peri-implant mucositis or implant loss.
The PES group was subdivided in subjects with and without a history of periodontitis. This revealed a much higher occurrence of implant loss and much higher prevalence of peri-implantitis in the periodontitis patients compared to the non-periodontitis patients (implant loss: 17.0% versus 3.2%; peri-implantitis: 9.2% versus 2.2%). The occurrence of implant loss and the prevalence of peri-implantitis in FES was higher than in the non-periodontitis PES group, but lower than the periodontitis PES group.

DISCUSSION

In this review the clinical outcomes of implant treatment were compared between FES and PES. The results of this systematic review were based on one cross-sectional study evaluating implant treatment in both FES and PES and 36 prospective studies and 9 cross-sectional studies evaluating either FES or PES.
In PES the majority of the implants were placed in the maxilla (53.9%), whereas in FES 100% of the implants were placed in the mandibula. Higher failure rates (Esposito et al. 1998, Berglundh et al. 2002) and a higher prevalence of detectable (but not overt) peri-implantitis (Koldsland et al. 2011) have been reported for implants placed in the maxilla, which may partly be explained by a lower bone quality generally found in the maxilla as compared to the mandible. However, we found no differences regarding early implant loss between FES and PES despite the difference in maxilla/mandibula ratio.
The results also indicate that FES generally show higher plaque levels than PES. It might be hypothesized that FES are less accustomed in maintaining proper oral hygiene levels, because they did not (need to) do so before receiving oral implants. A second explanation could be that plaque around implants supporting overdentures is more persistent than plaque around implants supporting single crowns and partial bridges, because it is less accessible for natural cleaning by tongue, lip, cheek and saliva. The higher plaque levels in FES might also partly be explained by the fact that, on average, the FES were older than the PES (mean age: 57.7 versus 46.1 years). It has been shown that older patients generally have more oral hygiene problems than younger patients (Meijer et al. 2001a, Engfors et al. 2004). Older patients generally experience higher morbidity and, as a consequence, have a higher daily medication intake. This might negatively influence the capability of performing oral hygiene measures and other factors such as salivary flow, and might thereby increase the risk of oral health problems. With this in mind it could be expected that, besides higher plaque levels, the generally older FES would also experience more implant loss, show higher probing pocket depths, more peri-implant mucosal bleeding and an increased prevalence of peri-implantitis. However, this could not be substantiated by this syste-

Table 8. Peri-implantitis criteria and prevalence

authors	dental status	follow-up	peri-implantitis criteria			peri-implantitis prevalence	
			inflammation	PPD	radiographic bone loss	% implants	% subjects
Gatti et al. (2008)	PES	5 y	suppuration or other signs of infection	> 5 mm	> 2 mm between implant loading and final examination	0 (no perio); 0 (moderate perio); 3.4 (severe perio)	0 (no perio); 0 (moderate perio); 8.3 (severe perio)
Rodrigo et al. (2012)	PES	5 y	BoP+	≥ 4 mm	significant bone loss	2.9	NR
Karoussis et al. (2004a,b), Brägger et al. (2005)	PES	10 y	BoP+	≥ 5 mm	bone loss between 1 year and final examination	15.4	NR
Roos-Jansåker et al. (2006a,b,c)	FES/ PES	10.8 y	BoP+ and/or suppuration		bone loss ≥ 3 threads (= 1.8 mm) between final and 1 year examination	5.8 (FES); 7.2 (PES; 9.2% in perio patients, 2.2% in non-perio patients)	NR
Simonis et al. (2010)	PES	10-16 y	BoP+ and/or suppuration	≥ 5 mm	≥ 2.5 mm or extending ≥ 3 threads	16.9 (37.9% in perio patients, 10.5% in non-perio patients)	NR
Roccuzzo et al. (2010, 2012)	PES	10 y	patients requiring, during SPT, treatment C or D of CIST protocol (Mombelli & Lang 1998):			NR	10.7 (no perio); 27.0 (moderate perio); 47.2 (severe perio)
			BoP+	> 5 mm	bone loss between implant loading and follow-up examination		

PES = partially edentulous subjects; FES = fully edentulous subjects; y = years; BoP+ = bleeding on probing; SPT = supporting periodontal therapy; CIST = cumulative interceptive supportive therapy; PPD = probing pocket depth; mm = millimeters; perio = periodontitis

matic review. No differences were found in implant loss and probing pocket depth and the outcomes on mucosal bleeding were inconsistent. Although mBI-scores were significantly higher in FES, no differences in BoP were observed between FES and PES. Due to lack of data, no comparison could be made regarding prevalence of peri-implant mucositis and peri-implantitis. However, the only study describing both FES and PES tended to show favorable results for FES, both with regard to survival rate and prevalence of peri-implant mucositis and peri-implantitis. From the abovementioned, it might be hypothesized that the quantity of the plaque plays a less predominant role in the development of peri-implant disease than the quality of the plaque, *i.e.* the microbial composition.

Peri-implant mucositis represents the obvious precursor of peri-implantitis, as does gingivitis for periodontitis (Lang et al. 2011). It has been shown that the progression from peri-implant mucositis to peri-implantitis is significantly associated with lack of preventive maintenance (Costa et al. 2012). Furthermore, attendance in a structured maintenance program, as compared to only an annual implant examination, has been strongly related to implant survival (Anner et al. 2010). Therefore, prevention and treatment of mucositis is mandatory for the prevention of peri-implantitis. In the studies evaluated in this systematic review maintenance frequency ranged from one to four times a year, with most patients being examined once every year. In many studies recall frequency was either not reported, not specified or unknown because patients were referred back to their general dentist.

Only six of the evaluated studies reported on the prevalence of peri-implantitis and used well defined criteria to diagnose it. Unfortunately these criteria differentiated between the studies, making a comparison difficult. Koldsland et al. (2010) showed that using different thresholds to define peri-implant disease results in substantial variance in prevalence. They reported, based on a cross-sectional study evaluating implants in function from 1 to 16 years, a peri-implantitis prevalence ranging from 5.4% (implant level, 11.3% on subject level, threshold: BoP+, PPD ≥ 6 mm and bone loss ≥ 3 mm) to 11.4% (implant level, 20.4% on subject level, threshold: BoP+, PPD ≥ 4 mm and bone loss ≥ 2 mm) depending on the definition used. In the present systematic review, peri-implantitis prevalence reported on implant level ranged from 0% to 3.4% after an observation period of 5 years and from 5.8% to 16.9% after an observation period of ≥ 10 years. On subject level the prevalence of peri-implantitis ranged from 10.7% to 47.2% after 10 years of observation. Apparently, peri-implantitis is not very likely to occur within the first five years of implant functioning, whereas after this period it is a frequently observed problem. A higher prevalence is reported in smokers (Roos-Jansåker et al. 2006b,c) and patients with a history of periodontitis (Roos-Jansåker et al. 2006c, Gatti et al. 2008, Simonis et al. 2010, Roccuzzo et al. 2012). FES seem to exhibit less peri-implantitis than PES with a history of periodontitis but more than non-periodontitis PES (Roos-Jansåker et al. 2006c). The latter might by explained by the high probability of the FES group containing a substantial number of subjects with a history of periodontitis. Although full-mouth tooth extraction might reduce the number of periodontal pathogens present in the oral cavity (Danser et al. 1994, Van Assche et al. 2009) it will not alter the potential genetic susceptibility for periodontal disease and lifestyle factors. Figures on the number of FES being ex-periodontitis patients

were not available in any of the studies, probable because this information is difficult to gather and often not reliable since depending mostly on self-reporting.
It is desirable that future reports on the prevalence of peri-implant disease clearly specify the threshold values used to diagnose peri-implant disease and specify the distribution of FES/PES, smokers/non-smokers and patients with/without a history of periodontitis (also in FES).

Conclusions

Within the limits of this systematic review, it can be concluded that:

- FES generally harbor more plaque at their implants than PES;
- No differences can be observed between FES and PES regarding implant loss and mean probing pocket depth. Inconsistent data exists regarding peri-implant mucosal bleeding.
- As of yet, no comparison on prevalence of peri-implant mucositis and peri-implantitis can be made between FES and PES;
- Peri-implantitis prevalence reported on implant level ranges from 0% to 3.4% after an observation period of 5 years and from 5.8% to 16.9% after an observation period of ≥ 10 years.
- PES with a history of periodontitis show a higher prevalence of peri-implantitis than FES, which, in turn, show a higher prevalence of peri-implantitis than PES without a history of periodontitis. No data are available to allow for a comparison between FES with and without a history of periodontitis;
- Smoking seems to be a risk indicator for the development of peri-implantitis both in FES and PES.

Acknowledgements

The authors wish to thank Dr. H.J. Santing for his assistance in the study selection procedure.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interest. The study was self-funded by the authors and their institution.

References

Anner R., Grossmann Y., Anner Y. & Levin L. (2010) Smoking, diabetes mellitus, periodontitis, and supportive periodontal treatment as factors associated with dental implant survival: a long-term retrospective evaluation of patients followed for up to 10 years. *Implant Dentistry* 19, 57-64.

Berglundh T., Persson L. & Klinge B. (2002) A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *Journal of Clinical Periodontology* 29 Suppl 3, 197-212; discussion 232-233.

Burt B.A., Ismail A.I., Morrison E.C. & Beltran E.D. (1990) Risk factors for tooth loss over a 28-year period. *Journal of Dental Research* 69, 1126-1130.

Costa F.O., Takenaka-Martinez S., Cota L.O., Ferreira S.D., Silva G.L. & Costa J.E. (2012) Peri-implant disease in subjects with and without preventive maintenance: a 5-year follow-up. *Journal of Clinical Periodontology* 39, 173-181.

Danser M.M., Van Winkelhoff A.J., De Graaff J., Loos B.G. & Van der Velden U. (1994) Short-term effect of full-mouth extraction on periodontal pathogens colonizing the oral mucous membranes. *Journal of Clinical Periodontology* 21, 484-489.

Den Hartog L., Huddleston Slater J.J., Vissink A., Meijer H.J., Raghoebar G.M. (2008) Treatment outcome of immediate, early and conventional single-tooth implants in the aesthetic zone: a systematic review to survival, bone level, soft-tissue, aesthetics and patient satisfaction. *Journal of Clinical Periodontology* 35, 1073-1086.

Engfors I., Örtorp A. & Jemt T. (2004) Fixed implant-supported prostheses in elderly patients: a 5-year retrospective study of 133 edentulous patients older than 79 years. *Clinical Implant Dentistry and Related Research* 6, 190-198.

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.

Heitz-Mayfield L.J. (2008) Peri-implant diseases: diagnosis and risk indicators. *Journal of Clinical Periodontology* 35, 292-304.

Jung R.E., Pjetursson B.E., Glauser R., Zembic A., Zwahlen M. & Lang N.P. (2008) A systematic review of the 5-year survival and complication rates of implant-supported single crowns. *Clinical Oral Implant Research* 19, 119-130.

Koldsland O.C., Scheie A.A. & Aass A.M. (2011) The association between selected risk indicators and severity of peri-implantitis using mixed model analyses. *Journal of Clinical Periodontology* 38, 285-292.

Koldsland O.C., Scheie A.A. & Aass A.M. (2010) Prevalence of peri-implantitis related to severity of the disease with different degrees of bone loss. *Journal of Periodontology* 81, 231-238.

Laine M.L., Leonhardt Å., Roos-Jansåker A.M., Peña A.S., Van Winkelhoff A.J., Winkel E.G. & Renvert S. (2006) IL-1RN gene polymorphism is associated with peri-implantitis. *Clinical Oral Implant Research* 17, 380-385.

Lang N.P., Bosshardt D.D. & Lulic M. (2011) Do mucositis lesions around implants differ from gingivitis lesions around teeth? *Journal of Clinical Periodontology* 38, 182-187.

Meijer H.J., Batenburg R.H. & Raghoebar G.M. (2001a) Influence of patient age on the success rate of dental implants supporting an overdenture in an edentulous mandible: a 3-year prospective study. *International Journal of Oral and Maxillofacial Implants* 16, 522-526.

Mombelli A. & Lang N.P. (1998) The diagnosis and treatment of peri-implantitis. *Periodontology 2000* 17, 63-76.

Mombelli A., Van Oosten M.A., Schurch E.,Jr & Land N.P. (1987) The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiology and Immunology* 2, 145-151.

Müller F., Naharro M. & Carlsson G.E. (2007) What are the prevalence and incidence of tooth loss in the adult and elderly population in Europe? *Clinical Oral Implant Research* 18 Suppl 3, 2-14.

Persson G.R. & Persson R.E. (2008) Cardiovascular disease and periodontitis: and update on the associtations and risk. *Journal of Clinical Periodontology* 35, 362-79

Pjetursson B.E., Tan K., Lang N.P., Brägger U., Egger M. & Zwahlen M. (2004) A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clinical Oral Implant Research* 15, 625-642.

Rams T.E., Roberts T.W., Tatum H.,Jr & Keyes P.H. (1984) The subgingival microbial flora associated with human dental implants. *Journal of Prosthetic*

Dentistry 51, 529-534.

Van Assche N., Van Essche M., Pauwels M., Teughels W. & Quirynen M. (2009) Do periodontopathogens disappear after full-mouth tooth extraction? *Journal of Clinical Periodontology* 36, 1043-1047.

Van Winkelhoff A.J., Loos B.G., Van der Reijden W.A. & Van der Velden U. (2002) *Porphyromonas gingivalis, Bacteroides forsythus* and other putative periodontal pathogens in subjects with and without periodontal destruction. *Journal of Clinical Periodontology* 29, 1023-1028.

Zitzmann N.U. & Berglundh T. (2008) Definition and prevalence of peri-implant diseases. *Journal of Clinical Periodontology* 35, 286-291.

Included studies

Akoglu B., Uçankale M., Özkan Y. & Kulak-Özkan Y. (2011) Five-year treatment outcomes with three brands of implants supporting mandibular overdentures. *International Journal of Oral and Maxillofacial Implants* 26, 188-194.

Andersson B., Ödman P., Lindvall A.M. & Brånemark P.I. (1998a) Five-year prospective study of prosthodontic and surgical single-tooth implant treatment in general practices and at a specialist clinic. *International Journal of Prosthodontics* 11, 351-355.

Andersson B., Ödman P., Lindvall A.M. & Brånemark P.I. (1998b) Cemented single crowns on osseointegrated implants after 5 years: results from a prospective study on CeraOne. *International Journal of Prosthodontics* 11, 212-218.

Bergenblock S., Andersson B., Fürst B. & Jemt T. (2012) Long-Term Follow-Up of CeraOne Single-Implant Restorations: An 18-Year Follow-Up Study Based on a Prospective Patient Cohort. *Clinical Implant Dentistry and Related Research* 14, 471-479.

Bonde M.J., Stokholm R., Isidor F. & Schou S. (2010) Outcome of implant-supported single-tooth replacements performed by dental students. A 10-year clinical and radiographic retrospective study. *European Journal of Oral Implantology* 3, 37-46.

Bornstein M.M., Chappuis V., Von Arx T. & Buser D. (2008) Performance of dental implants after staged sinus floor elevation procedures: 5-year results of a prospective study in partially edentulous patients. *Clinical Oral Implant Research* 19, 1034-1043.

Bornstein M.M., Schmid B., Belser U.C., Lussi A. & Buser D. (2005) Early loading of non-submerged titanium implants with a sandblasted and acid-etched surface. 5-year results of a prospective study in partially edentulous patients. *Clinical Oral Implant Research* 16, 631-638.

Brägger U., Karoussis I., Persson R., Pjetursson B., Salvi G. & Lang N.P. (2005) Technical and biological complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study. *Clinical Oral Implant Research* 16, 326-334.

Buser D., Ingimarsson S., Dula K., Lussi A., Hirt H.P. & Belser U.C. (2002) Long-term stability of osseointegrated implants in augmented bone: a 5-year prospective study in partially edentulous patients. *International Journal of Periodontics & Restorative Dentistry* 22, 109-117.

Buser D., Dula K., Lang N.P. & Nyman S. (1996) Long-term stability of osseointegrated implants in bone regenerated with the membrane technique. 5-year results of a prospective study with 12 implants. *Clinical Oral Implant Research* 7, 175-183.

Cehreli M.C., Uysal S. & Akca K. (2010) Marginal bone level changes and prosthetic maintenance of mandibular overdentures supported by 2 implants: a 5-year randomized clinical trial. *Clinical Implant Dentistry and Related Research* 12, 114-121.

Cordioli G., Majzoub Z. & Castagna S. (1997) Mandibular overdentures anchored to single implants: a five-year prospective study. *Journal of Prosthetic Dentistry* 78, 159-165.

Davis D.M., Watson R.M. & Packer M.E. (2004) Single tooth crowns supported on hydroxyapatite coated endosseous dental implants: a prospective 5-year study on twenty subjects. *International Dental Journal* 54, 201-205.

De Leonardis D., Garg A.K. & Pecora G.E. (1999) Osseointegration of rough acid-etched titanium implants: 5-year follow-up of 100 minimatic implants. *International Journal of Oral and Maxillofacial Implants* 14, 384-391.

Deporter D., Watson P., Pharoah M., Levy D. & Todescan R. (1999) Five- to six-year results of a prospective clinical trial using the Endopore dental implant and a mandibular overdenture. *Clinical Oral Implant Research* 10, 95-102.

Gallucci G.O., Doughtie C.B., Hwang J.W., Fiorellini J.P. & Weber H.P. (2009) Five-year results of fixed implant-supported rehabilitations with distal cantilevers for the edentulous mandible. *Clinical Oral Implant Research* 20, 601-607.

Gatti C., Gatti F., Chiapasco M. & Esposito M. (2008) Outcome of dental implants in partially edentulous patients with and without a history of periodontitis: a 5-year interim analysis of a cohort study. *European Journal of Oral Implantology* 1, 45-51.

Gotfredsen K. (2004) A 5-year prospective study of single-tooth replacements supported by the Astra Tech implant: a pilot study. *Clinical Implant Dentistry and Related Research* 6, 1-8.

Gunne J., Astrand P., Lindh T., Borg K. & Olsson M. (1999) Tooth-implant and implant supported fixed partial dentures: a 10-year report. *International Journal of Prosthodontics* 12, 216-221.

Heckmann S. M., Schrott A., Graef F., Wichmann M.G. & Weber H.P. (2004) Mandibular two-implant telescopic overdentures. *Clinical Oral Implant Research* 15, 560-569.

Heijdenrijk K., Raghoebar G.M., Meijer H.J., Stegenga B. & Van der Reijden W.A. (2006) Feasibility and influence of the microgap of two implants placed in a non-submerged procedure: a five-year follow-up clinical trial. *Journal of Periodontology* 77, 1051-1060.

Heijdenrijk K., Batenburg R.H., Raghoebar G.M., Meijer H.J., Van Oort R.P. & Stegenga B. (1998) Overdentures stabilised by two IMZ implants in the lower jaw--a 5-8 year retrospective study. *European Journal of Prosthodontics and Restorative Dentistry* 6, 19-24.

Karoussis I. K., Brägger U., Salvi G.E., Bürgin W. & Lang N.P. (2004a) Effect of implant design on survival and success rates of titanium oral implants: a 10-year prospective cohort study of the ITI Dental Implant System. *Clinical Oral Implant Research* 15, 8-17.

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

Kehl M., Swierkot K. & Mengel R. (2011) Three-dimensional measurement of bone loss at implants in patients with periodontal disease. *Journal of Periodontology* 82, 689-699.

Kwakman J.M., Voorsmit R.A. & Freihofer H.P. (1998) Treatment of the edentulous mandible with a vestibuloplasty combined with Intramobil Zylinder implants: a 5-year follow-up. *British Journal of Oral and Maxillofacial Surgery* 36, 296-300.

Lekholm U., Gunne J., Henry P., Higuchi K., Lindén U., Bergström C. & Van Steenberghe D. (1999) Survival of the Brånemark implant in partially edentulous jaws: a 10-year prospective multicenter study. *International Journal of Oral and Maxillofacial Implants* 14, 639-645.

Leonhardt Å., Gröndahl K., Bergström C. & Lekholm U. (2002) Long-term follow-up of osseointegrated titanium implants using clinical, radiographic and microbiological parameters. *Clinical Oral Implant Research* 13, 127-132.

Meijer H.J., Raghoebar G.M., Batenburg R.H., Visser A. & Vissink A. (2009a) Mandibular overdentures supported by two or four endosseous implants: a 10-year clinical trial. *Clinical Oral Implant Research* 20, 722-728.

Meijer H.J., Raghoebar G.M., Batenburg R.H. & Vissink A. (2009b) Mandibular overdentures supported by two Brånemark, IMZ or ITI implants: a ten-year prospective randomized study. *Journal of Clinical Periodontology* 36, 799-806.

Meijer H.J., Batenburg R.H., Raghoebar G.M. & Vissink A. (2004a) Mandibular overdentures supported by two Brånemark, IMZ or ITI implants: a 5-year prospective study. *Journal of Clinical Periodontology* 31, 522-526.

Meijer H.J., Raghoebar G.M., Van't Hof M.A. & Visser A. (2004b) A controlled clinical trial of implant-retained mandibular overdentures: 10 years' results of clinical aspects and aftercare of IMZ implants and Brånemark implants. *Clinical Oral Implant Research* 15, 421-427.

Meijer H.J., Geertman M.E., Raghoebar G.M. & Kwakman J.M. (2001b) Implant-retained mandibular overdentures: 6-year results of a multicenter clinical trial on 3 different implant systems. *Journal of Oral and Maxillofacial surgery* 59, 1260-1268; discussion 1269-1270.

Meijer H.J., Raghoebar G.M., Van 't Hof M.A., Visser A., Geertman M.E. & Van Oort R.P. (2000) A controlled clinical trial of implant-retained mandibular overdentures; five-years' results of clinical aspects and aftercare of IMZ implants and Brånemark implants. *Clinical Oral Implant Research* 11, 441-447.

Mericske-Stern R., Grütter L., Rösch R. & Mericske E. (2001) Clinical evaluation and prosthetic complications of single tooth replacements by non-submerged implants. *Clinical Oral Implant Research* 12, 309-318.

Mericske-Stern R., Steinlin Schaffner T., Marti P. &

Geering A.H. (1994) Peri-implant mucosal aspects of ITI implants supporting overdentures. A five-year longitudinal study. *Clinical Oral Implant Research* 5, 9-18.

Naert I., Gizani S., Vuylsteke M. & Van Steenberghe D. (1998) A 5-year randomized clinical trial on the influence of splinted and unsplinted oral implants in the mandibular overdenture therapy. Part I: Peri-implant outcome. *Clinical Oral Implant Research* 9, 170-177.

Renvert S., Lindahl C., Renvert H. & Persson G.R. (2008) Clinical and microbiological analysis of subjects treated with Brånemark or AstraTech implants: a 7-year follow-up study. *Clinical Oral Implant Research* 19, 342-347.

Roccuzzo M., Bonino F., Aglietta M. & Dalmasso P. (2012) Ten-year results of a three arms prospective cohort study on implants in periodontally compromised patients. Part 2: clinical results. *Clinical Oral Implant Research* 23, 389-395.

Roccuzzo M., De Angelis N., Bonino L. & Aglietta M. (2010) Ten-year results of a three-arm prospective cohort study on implants in periodontally compromised patients. Part 1: implant loss and radiographic bone loss. *Clinical Oral Implant Research* 21, 490-496.

Roccuzzo M., Aglietta M., Bunino M. & Bonino L. (2008) Early loading of sandblasted and acid-etched implants: a randomized-controlled double-blind split-mouth study. Five-year results. *Clinical Oral Implant Research* 19, 148-152.

Rodrigo D., Martin C. & Sanz M. (2012) Biological complications and peri-implant clinical and radiographic changes at immediately placed dental implants. A prospective 5-year cohort study. *Clinical Oral Implant Research* 23, 1224-1234.

Roos-Jansåker A.M., Lindahl C., Renvert H. & Renvert S. (2006a) Nine- to fourteen-year follow-up of implant treatment. Part II: presence of peri-implant lesions. *Journal of Clinical Periodontology* 33, 290-295.

Roos-Jansåker A.M., Lindahl C., Renvert H. & Renvert S. (2006b) Nine- to fourteen-year follow-up of implant treatment. Part I: implant loss and associations to various factors. *Journal of Clinical Periodontology* 33, 283-289.

Roos-Jansåker A.M., Renvert H., Lindahl C. & Renvert S. (2006c) Nine- to fourteen-year follow-up of implant treatment. Part III: factors associated with peri-implant lesions. *Journal of Clinical Periodontology* 33, 296-301.

Simonis P., Dufour T. & Tenenbaum H. (2010) Long-term implant survival and success: a 10-16-year follow-up of non-submerged dental implants. *Clinical Oral Implant Research* 21, 772-777.

Stellingsma C., Meijer H.J. & Raghoebar G.M. (2000) Use of short endosseous implants and an overdenture in the extremely resorbed mandible: a five-year retrospective study. *Journal of Oral and Maxillofacial Surgery* 58, 382-387; discussion 387-388.

Telleman G., Meijer H.J. & Raghoebar G.M. (2006) Long-term evaluation of hollow screw and hollow cylinder dental implants: clinical and radiographic results after 10 years. *Journal of Periodontology* 77, 203-210.

Turkyilmaz I., Tozum T.F. & Tumer C. (2010) Early versus delayed loading of mandibular implant-supported overdentures: 5-year results. *Clinical Implant Dentistry and Related Research* 12 Suppl 1, 39-46.

Vigolo P., Givani A., Majzoub Z. & Cordioli G. (2004) Clinical evaluation of small-diameter implants in single-tooth and multiple-implant restorations: a 7-year retrospective study. *International Journal of Oral and Maxillofacial Implants* 19, 703-709.

Visser A., Raghoebar G.M., Meijer H.J., Batenburg R.H. & Vissink A. (2005) Mandibular overdentures supported by two or four endosseous implants. A 5-year prospective study. *Clinical Oral Implant Research* 16, 19-25.

Weber H.P., Crohin C.C. & Fiorellini J.P. (2000) A 5-year prospective clinical and radiographic study of non-submerged dental implants. *Clinical Oral Implant Research* 11, 144-153.

Weinländer M., Piehslinger E. & Krennmair G. (2010) Removable implant-prosthodontic rehabilitation of the edentulous mandible: five-year results of different prosthetic anchorage concepts. *International Journal of Oral and Maxillofacial Implants* 25, 589-597.

Wennström J.L., Ekestubbe A., Gröndahl K., Karlsson S. & Lindhe J. (2005) Implant-supported single-tooth restorations: a 5-year prospective study. *Journal of Clinical Periodontology* 32, 567-574.

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

Excluded studies

Aloufi F., Bissada N., Ficara A., Faddoul F. & Al-Zahrani M.S. (2009) Clinical assessment of peri-implant tissues in patients with varying severity of chronic periodontitis. *Clinical Implant Dentistry and Related Research* 11, 37-40. *Exclusion criterion: Follow-up period not clear*

Andersson B., Glauser R., Maglione M. & Taylor Å. (2003) Ceramic implant abutments for short-span FPDs: a prospective 5-year multicenter study. *International Journal of Prosthodontics* 16, 640-646. *Exclusion criterion: Reporting on BoP but not clear how measeured; no information on # implants at 5-year follow-up*

Arvidson K., Bystedt H., Frykholm A., Von Konow L. & Lothigius E. (1998) Five-year prospective follow-up report of the Astra Tech Dental Implant System in the treatment of edentulous mandibles. *Clinical Oral Implant Research* 9, 225-234. *Exclusion criterion: Status of opposing jaw not clear*

Astrand P., Engquist B., Dahlgren S., Gröndahl K., Engquist E. & Feldmann H. (2004) Astra Tech and Brånemark system implants: a 5-year prospective study of marginal bone reactions. *Clinical Oral Implant Research* 15, 413-420. *Exclusion criterion: Reporting median BoP values*

Baelum V. & Ellegaard B. (2004) Implant survival in periodontally compromised patients. *Journal of Periodontology* 75, 1404-1412. *Exclusion criterion: Reporting time-to first event BoP (% implants not having experienced BoP at any time (1-year, 5-year and 10-year evaluation) during 10 year follow-up period*

Behneke A., Behneke N. & D'Hoedt B. (2002) A 5-year longitudinal study of the clinical effectiveness of ITI solid-screw implants in the treatment of mandibular edentulism. *International Journal of Oral and Maxillofacial Implants* 17, 799-810. *Exclusion criterion: Reporting on peri-implant mucositis and peri-implantitis, but not clearly defined; mBI only scored on buccal and lingual implant sites (not approximal)*

Behneke A., Behneke N. & D'Hoedt B. (2000) The longitudinal clinical effectiveness of ITI solid-screw implants in partially edentulous patients: a 5-year follow-up report. *International Journal of Oral and Maxillofacial Implants* 15, 633-645. *Exclusion criterion: mBI only scored on buccal and lingual implant sites (not approximal)*

Binahmed A., Stoykewych A., Hussain A., Love B. & Pruthi V. (2007) Long-term follow-up of hydroxyapatite-coated dental implants - a clinical trial. *International Journal of Oral and Maxillofacial Implants* 22, 963-968. *Exclusion criterion: Both fully and partially edentulous patients included, no breakdown of data possible (confirmed by the author)*

Blake F., Bubenheim M., Heiland M., Pohlenz P., Schmelzle R. & Gbara A. (2008) Retrospective assessment of the peri-implant mucosa of implants inserted in reanastomosed or free bone grafts from the fibula or iliac crest. *International Journal of Oral and Maxillofacial Implants* 23, 1102-1108. *Exclusion criterion: Reporting on peri-implant mucositis and peri-implantitis, but not clearly defined*

Blanes R.J., Bernard J.P., Blanes Z.M. & Belser U.C. (2007) A 10-year prospective study of ITI dental implants placed in the posterior region. I: Clinical and radiographic results. *Clinical Oral Implant Research* 18, 699-706. *Exclusion criterion: No data extraction on mBI possible*

Botticelli D., Renzi A., Lindhe J. & Berglundh T. (2008) Implants in fresh extraction sockets: a prospective 5-year follow-up clinical study. *Clinical Oral Implant Research* 19, 1226-1232. *Exclusion criterion: Immediate implant placement*

Chung W.E., Rubenstein J.E., Phillips K.M. & Raigrodski A.J. (2009) Outcomes assessment of patients treated with osseointegrated dental implants at the University of Washington Graduate Prosthodontic Program, 1988 to 2000. *International Journal of Oral and Maxillofacial Implants* 24, 927-935. *Exclusion criterion: No data extraction on BoP possible*

Costa F.O., Takenaka-Martinez S., Cota L.O., Ferreira S.D., Silva G.L. & Costa J.E. (2012) Peri-implant disease in subjects with and without preventive maintenance: a 5-year follow-up. *Journal of Clinical Periodontology* 39, 173-181. *Exclusion criterion: Preselected group: patients with peri-implant mucositis at the evaluation 5 years earlier*

Cochran D.L., Jackson J.M., Bernard J.P., Ten Bruggenkate C.M., Buser D., Taylor T.D., Weingart D., Schoolfield J.D., Jones A.A. & Oates T.W. (2011) A 5-year prospective multicenter study of early loaded titanium implants with a sandblasted and acid-etched surface. *International Journal of Oral and Maxillofacial Implants* 26, 1324-1332. *Exclusion criterion: Both fully and partially edentulous patients included, no breakdown of data possible (confirmed by the author)*

Cune M., Burgers M., Van Kampen F., De Putter C. & Van der Bilt A. (2010) Mandibular overdentures re-

tained by two implants: 10-year results from a cross-over clinical trial comparing ball-socket and bar-clip attachments. *International Journal of Prosthodontics* 23, 310-317. *Exclusion criterion: No data extraction on BoP possible*

Davis D.M. & Packer M.E. (1999) Mandibular overdentures stabilized by Astra Tech implants with either ball attachments or magnets: 5-year results. *International Journal of Prosthodontics* 12, 222-229. *Exclusion criterion: Reporting on BoP in combination with erythema and edema, no breakdown of data possible on separate parameters*

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 Implant Research* 10, 139-148. *Exclusion criterion: Screw Vent Implant system used, does not meet success criteria proposed by the European Academy for Periodontology*

Degidi M. & Piattelli A. (2005) 7-Year Follow-Up of 93 Immediately Loaded Titanium Dental Implants. *Journal of Oral Implantology* 31, 25-31. *Exclusion criterion: Reporting on peri-implant mucositis, but not clearly defined (obvious clinical signs of inflammation and hyperplasia)*

Ekelund J.A., Lindquist L.W., Carlsson G.E. & Jemt T. (2003) Implant treatment in the edentulous mandible: a prospective study on Brånemark system implants over more than 20 years. *International Journal of Prosthodontics* 16, 602-608. *Exclusion criterion: Reporting on peri-implantitis, but not clearly defined (combination of inflammation, pain and obvious continuous bone loss)*

Ellegaard B., Baelum V. & Kolsen-Petersen J. (2006) Non-grafted sinus implants in periodontally compromised patients: a time-to-event analysis. *Clinical Oral Implant Research* 17, 156-164. *Exclusion criterion: Reporting time-to first event BoP (% implants not having experienced BoP at any time (1-year, 5-year and 10-year evaluation) during 10 year follow-up period);no information on #implants/subjects at follow-up*

Ellegaard B., Baelum V. & Karring T. (1997) Implant therapy in periodontally compromised patients. *Clinical Oral Implant Research* 8, 180-188. *Exclusion criterion: Reporting time-to first event BoP (% implants not having experienced BoP at any time (1-year and 5-year evaluation) during 5 year follow-up period)*

Fransson C., Wennström J. & Berglundh T. (2008) Clinical characteristics at implants with a history of progressive bone loss. *Clinical Oral Implant Research* 19, 142-147. *Exclusion criterion: Pre-selected group: patients with at least one implant with progressive bone loss; fully edentulous patients included, no breakdown of data possible (confirmed by the author)*

Friberg B., Raghoebar G.M., Grunert I., Hobkirk J.A. & Tepper G. (2008) A 5-year prospective multicenter study on 1-stage smooth-surface Brånemark System implants with early loading in edentulous mandibles. *International Journal of Oral and Maxillofacial Implants* 23, 481-486. *Exclusion criterion: Both fully and partially edentulous patients included, no breakdown of data possible (confirmed by the author)*

Glauser R. (2013) Implants with an Oxidized Surface Placed Predominately in Soft Bone Quality and Subjected to Immediate Occlusal Loading: Results from a 7-Year Clinical Follow-Up. *Clinical Implant Dentistry and Related Research* 15, 322-331. *Exclusion criterion: BoP only scored on buccal and lingual implant sites*

Gotfredsen K. & Holm B. (2000) Implant-supported mandibular overdentures retained with ball or bar attachments: a randomized prospective 5-year study. *International Journal of Prosthodontics* 13, 125-130. *Exclusion criterion: Reporting on peri-implant mucositis, but not clearly defined*

Hellem S., Karlsson U., Almfeldt I., Brunell G., Hamp S.E. & Astrand P. (2001) Nonsubmerged implants in the treatment of the edentulous lower jaw: a 5-year prospective longitudinal study of ITI hollow screws. *Clinical Implant Dentistry and Related Research* 3, 20-29. *Exclusion criterion: Both fully and partially edentulous patients included, no breakdown of data possible (confirmed by the author)*

Henry P.J., Laney W.R., Jemt T., Harris D., Krogh P. H., Polizzi G., Zarb G.A. & Herrmann I. (1996) Osseointegrated implants for single-tooth replacement: a prospective 5-year multicenter study. *International Journal of Oral and Maxillofacial Implants* 11, 450-455. *Exclusion criterion: Sulcus Bleeding Index by Mühlemann and Son used, no transformation to BoP possible*

Hultin M., Gustafsson A. & Klinge B. (2000) Long-term evaluation of osseointegrated dental implants in the treatment of partly edentulous patients. *Journal of Clinical Periodontology* 27, 128-133. *Exclusion criterion: Group is part of bigger cohort study described by Lekholm et al. (1994) and Lekholm et al. (1999)*

Jacobs R., Pittayapat P., Van Steenberghe D., De Mars G., Gijbels F., Van der Donck A., Li L., Liang X., Van Assche N., Quirynen M. & Naert I. (2010) A split-mouth comparative study up to 16 years of two screw-shaped titanium implant systems. *Journal of Clinical Periodontology* 37, 1119-1127. *Exclusion criterion: Sulcus Bleeding Index by Mühlemann and Son used, no transformation to/no data extraction on BoP possible*

Jemt T., Henry P., Lindén B., Naert I., Weber H. & Wendelhag I. (2003) Implant-supported laser-welded titanium and conventional cast frameworks in the partially edentulous law: a 5-year prospective multicenter study. *International Journal of Prosthodontics* 16, 415-421. *Exclusion criterion: Sulcus Bleeding Index by Mühlemann used, no transformation to BoP possible*

Jung R.E., Windisch S.I., Eggenschwiler A.M., Thoma D.S., Weber F.E. & Hämmerle C.H. (2009) A randomized-controlled clinical trial evaluating clinical and radiological outcomes after 3 and 5 years of dental implants placed in bone regenerated by means of GBR techniques with or without the addition of BMP-2. *Clinical Oral Implant Research* 20, 660-666. *Exclusion criterion: No data extraction on BoP possible*

Juodzbalys G., Raustia A.M. & Kubilius R. (2007) A 5-year follow-up study on one-stage implants inserted concomitantly with localized alveolar ridge augmentation. *Journal of Oral Rehabilitation* 34, 781-789. *Exclusion criterion: Pre-selected group: implants with bone dehiscence at implant placement*

Karoussis I.K., Salvi G.E., Heitz-Mayfield L.J., Brägger U., Hämmerle C.H. & 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 Implant Research* 14, 329-339. *Exclusion criterion: Group is part of bigger cohort study described by Brägger et al. (2005), Karoussis et al. (2004a,b)*

Kim D.M., Badovinac R.L., Lorenz R.L., Fiorellini J.P. & Weber H.P. (2008) A 10-year prospective clinical and radiographic study of one-stage dental implants. *Clinical Oral Implant Research* 19, 254-258. *Exclusion criterion: No data extraction on mBI possible*

Lekholm U., Van Steenberghe D., Herrmann I., Bolender C., Folmer T., Gunne J., Henry P., Higuchi K., Laney W.R. & Lindén U. (1994) Osseointegrated implant in the treatment of partially edentulous jaws: a prospective 5-year multicenter study. *International Journal of Oral and Maxillofacial Implants* 9, 627-635. *Exclusion criterion: Sulcus Bleeding Index by Mühlemann used, no transformation to BoP possible*

Lethaus B., Kälber J., Petrin G., Brandstätter A. & Weingart D. (2011) Early loading of sandblasted and acid-etched titanium implants in the edentulous mandible: a prospective 5-year study. *International Journal of Oral and Maxillofacial Implants* 26, 887-892. *Exclusion criterion: Both fully and partially edentulous patients included, no breakdown of data possible (confirmed by the author)*

Meijer H.J., Raghoebar G.M. & Van 't Hof M.A. (2003) Comparison of implant-retained mandibular overdentures and conventional complete dentures: a 10-year prospective study of clinical aspects and patient satisfaction. *International Journal of Oral and Maxillofacial Implants* 18, 879-885. *Exclusion criterion: Same group as reported by Meijer et al. (2004a)*

Meijer H.J., Raghoebar G.M., Van't Hof M.A., Geertman M.E. & Van Oort R.P. (1999) Implant-retained mandibular overdentures compared with complete dentures; a 5-years' follow-up study of clinical aspects and patient satisfaction. *Clinical Oral Implant Research* 10, 238-244. *Exclusion criterion: Same group as reported by Meijer et al. (2000)*

Mengel R., Behle M. & Flores-de-Jacoby L. (2007) Osseointegrated implants in subjects treated for generalized aggressive periodontitis: 10-year results of a prospective, long-term cohort study. *Journal of Periodontology* 78, 2229-2237. *Exclusion criterion: No data extraction on BoP possible*

Naert I., Alsaadi G., Van Steenberghe D. & Quirynen M. (2004) A 10-year randomized clinical trial on the influence of splinted and unsplinted oral implants retaining mandibular overdentures: peri-implant outcome. *International Journal of Oral and Maxillofacial Implants* 19, 695-702. *Exclusion criterion: No data extraction on BoP possible*

Oetterli M., Kiener P. & Mericske-Stern R. (2001) A longitudinal study on mandibular implants supporting an overdenture: the influence of retention mechanism and anatomic-prosthetic variables on periimplant parameters. *International Journal of Prosthodontics* 14, 536-542.*Exclusion criterion: Preselected group, selection criteria not clearly defined*

Özkan Y., Akoglu B. & Kulak-Özkan Y. (2011) Five-year treatment outcomes with four types of implants in the posterior maxilla and mandible in partially edentulous patients: a retrospective study. *International Journal of Oral and Maxillofacial Implants* 26, 639-647. *Exclusion criterion: No data extraction on mBI possible*

Polizzi G., Grunder U., Goené R., Hatano N., Henry P., Jackson W.J., Kawamura K., Renouard F., Rosenberg R., Triplett G., Werbitt M. & Lithner B. (2000) Immediate and delayed implant placement into extraction sockets: a 5-year report. *Clinical Implant Dentistry and Related Research* 2, 93-99. *Exclusion criterion: Immediate implant placement*

Quirynen M., Alsaadi G., Pauwels M., Haffajee A., Van Steenberghe D. & Naert I. (2005) Microbiological and clinical outcomes and patient satisfaction for two treatment options in the edentulous lower jaw after 10 years of function. *Clinical Oral Implant Research* 16, 277-287. *Exclusion criterion: No data extraction on BoP possible, since # implants at follow-up not clear*

Rasmusson L., Roos J. & Bystedt H. (2005) A 10-year follow-up study of titanium dioxide-blasted implants. *Clinical Implant Dentistry and Related Research* 7, 36-42. *Exclusion criterion: No data extraction on BoP possible*

Renvert S., Roos-Jansåker A.M., Lindahl C., Renvert H. & Persson R.G. (2007) Infection at titanium implants with or without a clinical diagnosis of inflammation. *Clinical Oral Implant Research* 18, 509-516. *Exclusion criterion: Same group as reported by Roos-Jansåker et al. (2006a,b,c); subjects included in fully edentulous group who lost their remaining dentition after implant placement*

Ricci G., Aimetti M., Stablum W. & Guasti A. (2004) Crestal bone resorption 5 years after implant loading: clinical and radiologic results with a 2-stage implant system. *International Journal of Oral and Maxillofacial Implants* 19, 597-602. *Exclusion criterion: No distinction between immediate implant placement and non-immediate placement*

Roccuzzo M., De Angelis N., Bonino L. & Aglietta M. (2010) Ten-year results of a three-arm prospective cohort study on implants in periodontally compromised patients. Part 1: implant loss and radiographic bone loss. *Clinical Oral Implant Research* 21, 490-496. *Exclusion criterion: No data extraction on BoP possible*

Rosén A. & Gynther G. (2007) Implant treatment without bone grafting in edentulous severely resorbed maxillas: a long-term follow-up study. *Journal of Oral and Maxillofacial surgery* 65, 1010-1016. *Exclusion criterion: Reporting on peri-implant mucositis, but not clearly defined*

Sánchez-Pérez A., Moya-Villaescusa M.J. & Caffesse R.G. (2007) Tobacco as a risk factor for survival of dental implants. *Journal of Periodontology* 78, 351-359. *Exclusion criterion: Papillar bleeding index by Saxer and Mühlemann used, no transformation to BoP possible*

Scheller H., Urgell J.P., Kultje C., Klineberg I., Goldberg P. V., Stevenson-Moore P., Alonso J.M., Schaller M., Corria R.M., Engquist B., Toreskog S., Kastenbaum F. & Smith C.R. (1998) A 5-year multicenter study on implant-supported single crown restorations. *International Journal of Oral and Maxillofacial Implants* 13, 212-218. *Exclusion criterion: BoP only scored on mesial and distal implant sites*

Schrott A.R., Jimenez M., Hwang J.W., Fiorellini J. & Weber H.P. (2009) Five-year evaluation of the influence of keratinized mucosa on peri-implant soft-tissue health and stability around implants supporting full-arch mandibular fixed prostheses. *Clinical Oral Implant Research* 20, 1170-1177. *Exclusion criterion: mBI only scored on the buccal and lingual implant sites (not approximal)*

Smedberg J.I., Nilner K. & Frykholm A. (1999) A six-year follow-up study of maxillary overdentures on osseointegrated implants. *European Journal of Prosthodontics and Restorative Dentistry* 7, 51-56. *Exclusion criterion: Not clear which bleeding index is used*

Tsai E.S., Crohin C.C. & Weber H.P. (2000) A five-year evaluation of implants placed in extraction sockets. *Journal of the Western Society of Periodontology/ Periodontal abstracts* 48, 37-47. *Exclusion criterion: Immediate implant placement; control group is part of bigger cohort described by Weber et al. (2000)*

Van Assche N., Pittayapat P., Jacobs R., Pauwels M., Teughels W. & Quirynen M. (2011) Microbiological outcome of two screw-shaped titanium implant systems placed following a split-mouth randomised protocol, at the 12th year of follow-up after loading. *European Journal of Oral Implantology* 4, 103-116. *Exclusion criterion: Not clear if BoP data are reported on site level or implant level*

Vroom M.G., Sipos P., De Lange G.L., Grundemann L.J., Timmerman M.F., Loos B.G. & Van der Velden U. (2009) Effect of surface topography of screw-shaped titanium implants in humans on clinical and radiographic parameters: a 12-year prospective study. *Clinical Oral Implant Research* 20, 1231-1239. *Exclusion criterion: Angular bleeding index used, no transformation to BoP possible*

Weng D., Jacobson Z., Tarnow D., Hürzeler M.B., Faehn O., Sanavi F., Barkvoll P. & Stach R.M. (2003) A

prospective multicenter clinical trial of 3i machined-surface implants: results after 6 years of follow-up. *International Journal of Oral and Maxillofacial Implants* 18, 417-423. *Exclusion criterion: No data extraction on BoP possible*

Wennström J.L., Bengazi F. & Lekholm U. (1994) The influence of the masticatory mucosa on the peri-implant soft tissue condition. *Clinical Oral Implant Research* 5, 1-8. *Exclusion criterion: BoP only scored on the facial and approximal implant sites (not lingual)*

Zafiropoulos G.G., Deli G., Bartee B.K. & Hoffmann O. (2010) Single-tooth implant placement and loading in fresh and regenerated extraction sockets. Five-year results: a case series using two different implant designs. *Journal of Periodontology* 81, 604-615. *Exclusion criterion: No data extraction on BoP possible*

Zetterqvist L., Feldman S., Rotter B., Vincenzi G., Wennström J.L., Chierico A., Stach R.M. & Kenealy J.N. (2010) A prospective, multicenter, randomized-controlled 5-year study of hybrid and fully etched implants for the incidence of peri-implantitis. *Journal of Periodontology* 81, 493-501. *Exclusion criterion: No data extraction on mBI possible*