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Systematic review of implant outcomes in treated periodontitis subjects

Constantine T. T. Ong[1], Saso Ivanovski[2], Ian G. Needleman[1], Maria Retzepi[1], David R. Moles, Maurizio S. Tonetti[3] and Nikolaos Donos[1]

[1]Unit of Periodontology & International Centre for Evidence-Based Oral Health, UCL Eastman Dental Institute, London, UK; [2]School of Dentistry and Oral health, Griffith University, Queensland, Australia; [3]European Research Group on Periodontology, Berne, Switzerland

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Abstract

Objectives: To determine implant outcomes in partially dentate patients who have been treated for periodontitis compared with periodontally healthy patients.

Material and Methods: All longitudinal studies (until March 2006) of endosseous dental implants of at least 6 months of loading were searched. Studies presented with one or more of the outcome measures (implant survival, success, bone-level change, peri-implantitis) were included. Screening, data abstraction and quality assessment were conducted independently and in duplicate.

Results: From 4448 citations, 546 full-text papers were screened and nine studies were included. Overall, the non-periodontitis patients demonstrated better outcomes than treated periodontitis patients. However, the strength of evidence showed that the studies included were at a medium to high risk of bias, with lack of appropriate reporting and analysis of outcomes plus lack of accounting for confounders, especially smoking. Furthermore, the studies showed variability in the definitions of treated and non-periodontitis, outcome criteria and quality of supportive periodontal therapy. Meta-analysis could not be performed due to heterogeneity of the chief study characteristics.

Conclusions: There is some evidence that patients treated for periodontitis may experience more implant loss and complications around implants than non-periodontitis patients. Evidence is stronger for implant survival than implant success; methodological issues limit the potential to draw robust conclusions.

Key words: implants; implant outcomes; periodontal disease; systematic review; treated periodontitis

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The dental endosseous implant is a widely recognized treatment option for replacing missing teeth (Esposito et al. 2005b). Failure of implant therapy resulting in loss of osseointegration sometimes occurs. When failure occurs, it can present as complications that take place either early following implant installation or late failure following periods of implant stability. Such late failures can be the result of excessive load (Isidor 1996, 1997) or infection such as peri-implantitis (van Steenberghe et al. 1993).

The prevalence of peri-implantitis varied between different dentate and edentulous treatment groups; Berglundh et al. (2002) estimated a mean value of 6.47% for fixed partial dentures. Several studies have identified similarities in the pathogenesis of periodontitis and peri-implantitis (Mombelli & Lang 1998, Lang et al. 2000). The same pathogenic bacteria in peri-implantitis have been implicated in the pathogenesis of periodontitis (Mombelli et al. 1987, Apse et al. 1989, Papaioannou et al. 1996). The results have shown that periodontal pathogens can translocate from periodontally involved teeth to the peri-implant sulci in partially dentate patients (Leonhardt et al. 1993, Mombelli et al. 1995, Quirynen et al. 2006). This has highlighted the importance of periodontal treatment of the residual dentition before placement of osseointegrated dental implants (Brägger 1994, Papaioannou et al. 1996).

The occurrence of peri-implantitis may be dependent on distinct individual susceptibility factors, e.g. immuno-inflammatory factors, interacting with molecular processes that are similar to periodontitis. Hence, it is important to

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ascertain whether patients with an increased susceptibility to periodontitis would have an increased susceptibility to peri-implantitis and implant loss (i.e. decreased survival or success rate of implants) even in partially dentate patients who have been treated for periodontitis. This is relevant because periodontitis is one of the leading causes of tooth loss and dental implants are increasingly used to replace missing teeth in such patients. Consequently, a history of past periodontitis may act as a prognostic factor for the future survival and success of dental implants.

Conversely, there are some studies that have shown successful osseointegration in patients with different types of periodontitis (Nevins & Langer 1995, Ellegaard et al. 1997). However, these reports did not offer comparative data between periodontally compromised patients who have been treated and periodontally healthy patients. Nevertheless, a systematic review by Van der Weijden et al. (2005) concluded that the outcome of implant therapy in periodontitis patients may be different compared with individuals without such a history in terms of loss of supporting bone and implant loss.

The purpose of this systematic review was therefore to determine the effect of a past history of periodontitis on the survival and success of dental implants in partially dentate patients. The focused question for this systematic review was, ''What are the survival and success rates (including bone level change or bone loss) and incidence of peri-implantitis for dental implants placed in partially dentate patients that have been treated for periodontitis ('treated periodontitis') compared with patients without a history or clinical or radiographic evidence of periodontitis ('non-periodontitis')?''

Material and Methods

Before commencement of the study, we developed a detailed protocol, agreed upon by all the authors.

Criteria for considering studies for this review

We included all longitudinal studies [i.e. randomized-controlled trials (RCTs), controlled clinical trials, cohort studies, case–control studies and case series] reporting on endosseous dental implant survival and/or success. To be included, case series studies needed to report on consecutive patients rather than a selected group of patients from the case series (e.g. based on bone quality or volume). Letters and reviews were explicitly excluded. Data syntheses were stratified by study design. Single arms (subgroup) of studies that presented data separately for treated periodontitis and non-periodontitis patients were also included. These data may be located in different types of studies including clinical trials (e.g. RCTs) and cohort studies, comparing different implant types.

Studies needed to report on implants with at least 6 months of loading. This was selected to allow biological complications during function to be observed rather than early implant failures (e.g. overheating the bone due to poor surgical technique, bone pathology).

Patients who were partially dentate received periodontal treatment with a comparison group of patients without a history of periodontitis or clinical or radiographic evidence. Studies included at least 10 patients, five with treated periodontitis and five non-periodontitis patients. This number was selected arbitrarily to exclude individual case reports. Studies on smokers were included. Studies that looked specifically at medically compromised individuals, e.g. cancer, uncontrolled diabetes mellitus or with specific bone or soft tissue grafts augmentation procedures were excluded.

Studies utilizing titanium endosseous implants including different types of surface modification were included. However, transmandibular implants (i.e. staple implants), zygomatic implants, implants used for anchorage in orthodontic therapy, facial prosthesis or any other non-dental use were excluded.

Studies presenting different type (e.g. aggressive or chronic periodontitis) and severity of periodontitis (e.g. mild, moderate or severe) as well as the different treatment modalities and effectiveness were considered. The comparison group was patients without a history or clinical or radiographic signs of periodontitis. Periodontal treatment was treatment undertaken by a suitably trained dentist or dental auxiliaries/dental care professionals (e.g. hygienists).

Types of outcome measures

Implant survival. All definitions of implant survival as described in the study included were considered. For example, this could be presented as a percentage cumulative ''survival'' rate indicating that a certain percentage of implants were still present in the mouth (censored) at the end of the observation period. The observation period could be classified into cumulative implant survival from placement or from loading (i.e. post-loading survival rate). The results could also be presented as incidence of implant loss (''failure'' rate), i.e. number of losses divided by the sum of lengths of time at risk for each implant.

Implant success. All definitions of implant success (including bone level change) were considered, particularly because there is a lack of consensus regarding a set of universally accepted success criteria. This could be based on the following clinical and radiographic criteria to define implant success (with an emphasis on the signs and symptoms of peri-implantitis) as defined by Albrektsson et al. (1986) and adapted by Buser et al. (1997) as well as Karoussis et al. (2004):

1. Absence of mobility (Buser et al. 1990).
2. Absence of persistent subjective complaints (pain, foreign-body sensation and/or dysaesthesia) (Buser et al. 1990).
3. Absence of recurrent peri-implant infection with suppuration (Buser et al. 1990).
4. Absence of a continuous radiolucency around the implant (Buser et al. 1990).
5. No pocket probing depth (PPD) >5 mm (Mombelli & Lang 1994, Bragger et al. 2001).
6. No PPD $\geqslant 5$ mm and bleeding on probing (BOP) (Mombelli & Lang 1994).
7. After the first year of service, the annual vertical bone loss should not exceed 0.2 mm (mesially or distally) (Albrektsson et al. 1986, Albrektsson & Isidor 1994).

The success rate could be based on the number of successful implants divided by the total time at risk for each implant.

Peri-implantitis. All definitions of peri-implantitis were considered. This could be defined as an incidence of PPD $\geqslant 5$ mm with BOP and radiographic signs of bone loss (Karoussis et al. 2003). Incidence is the number of cases

of peri-implantitis among the subjects of a population during a time period (observation period), divided by the sum of the length of time for each subject of the study population during which each subject is in danger of presenting with peri-implantitis.

Search strategy

The search strategy incorporated searching of electronic databases, supplemented by checking bibliographies of review articles. A search of Ovid MEDLINE and EMBASE was conducted up to and including March 2006.

A comprehensive search strategy was developed that aimed to identify all longitudinal studies reporting on endosseous dental implant survival and/or success. This highly sensitive search (i.e. greatest chance of finding relevant studies) was employed as we anticipated that studies involving periodontitis patients might be difficult to locate if the periodontitis was not the focus of the study.

The search strategy for MEDLINE and EMBASE used a combination MeSH terms and text words. The initial electronic search strategies formulated for MEDLINE were adapted from Esposito et al. (2005a) and later modified as appropriate for EMBASE. The details of the electronic search strategy were as follows:

Population/exposure

''DENTAL IMPLANTS'' OR ''DENTAL IMPLANTATION'' OR ''((osseointegrated adj implant$) and (dental or oral))'' OR ''dental implant$'' OR ''(implant$ adj5 dent$)'' OR ''dental-implant$'' OR ''implant supported dental prosthesis'' OR ''((endosseous adj5 implant$) and (dental or oral))'' OR ''((dental or oral) adj5 implant$)''.

Outcome

''INCIDENCE'' OR ''prognos$'' OR ''predict$'' OR ''course'' OR ''surviv$'' OR ''success''.

Types of studies

''FOLLOW-UP STUDIES'' OR ''longitudinal'' OR ''cohort'' OR ''CLINICAL TRIALS'' OR ''RESEARCH DESIGN'' OR ''randomized controlled trial.pt'' OR ''clinical trial.pt''

These were combined as:

Population/exposure AND (outcome OR types of studies)

We attempted to clarify ambiguous or incomplete data by contacting the authors. In addition, bibliographies of all the articles included and the bibliographies of relevant review articles were screened for possible inclusion. Unpublished data, ''in press'' manuscripts were requested from the *British Dental Journal*, *Clinical Oral Implants Research*, *Journal of Clinical Periodontology* and *Journal of Periodontology*. There were no language restrictions to studies.

Study eligibility assessment including quality assurance

Owing to the large volume of literature on these topics as a result of the comprehensive nature of the search, a three-stage screening was carried out independently and in duplicate to increase precision. At each stage, any disagreement was resolved by discussion and where consensus on excluding an article was not reached, the article was included in the next stage of screening.

The first-stage screening of titles (C. O., S. I. and M. R.) was carried out to eliminate clearly irrelevant materials, e.g. reviews, animal studies, studies on non-dental or non-endosseous implants and studies that clearly did not report on our outcome measures.

The second-stage screening of titles and abstracts (S. I. and C. O.) excluded studies based on the number of partially dentate patients, the length of follow-up, the outcome measures and the nature of the study population. Nevertheless, the presence of treated periodontitis and non-periodontitis patients was determined from the third-stage screening of the full-text articles. The exception to this was the non-English articles where inclusion in the next stage was determined from the titles and abstracts. If the title and abstract of non-English articles were not in English, translation into English or screening by translators was carried out.

The third-stage screening of the full-text articles (S. I. and C. O.) was carried out using a data screening and abstraction form to verify the study eligibility based on the inclusion/exclusion criteria; to carry out the methodological quality assessment; and to abstract data on study characteristics and outcomes for the studies included.

The level of agreement concerning study inclusion was calculated using κ statistics for the second-stage screening and for 50 randomly selected articles in the third-stage screening. The latter was done because of the quantity of full-text articles for screening and logistic difficulties for the reviewers. Any disagreement was resolved by discussion and, if necessary, a third reviewer was consulted. Additionally, the authors of the studies were contacted to provide missing data.

Data extraction methods

Independent duplicate data extraction was performed by three reviewers (C. O., M. R. and N. D.) on a specifically designed data extraction form. As a quality assurance measure, forms were piloted and amended before being used for assessing the papers included.

Data recorded from the studies included were based directly on the focus of the research question including details of the population, interventions/comparisons, outcomes and study characteristics. The four categories of data were extracted namely study, population, intervention and outcome characteristics.

Methodological quality assessment

Quality assessment of all the studies included was conducted independently and in duplicate by three reviewers (C. O., M. R. and N. D.) as part of the data extraction process.

The methodological quality assessment of the studies included was adapted from Khan et al. (2001). It assessed components of the study methodology shown to affect the study outcomes such as similarity of baseline characteristics between the test and control groups; masking of outcome assessors to patient's periodontal status; completeness of follow-up; and reasons, rates of drop-out and explicitness of the inclusion criteria (Tables 5a and 5b). Although masking of outcome assessors is difficult for evaluation of implant success (including bone-level change) and peri-implantitis as a history of periodontal disease may be apparent at clinical examination or radiographic examination, masking of assessors for implant survival is possible as the survival rate can be collected without reviewing the clinical or radiographic features. This has been taken into account when categorizing the risk of

bias in each study with regard to masking of assessors. An overall risk of bias was classified into three categories: low, medium or high. This was classified by the reviewers based on the fulfilment of the number of components of the study methodology. A low risk of bias is classified as fulfilment of all the assessed components and, conversely, a high risk of bias is based on studies that have either not fulfilled or only fulfilled a limited number of the assessed components.

Confounding factors

Factors such as smoking, systemic disease (e.g. diabetes mellitus, osteoporosis), medications (e.g. anticoagulant medications, long-standing steroid medication) and radiotherapy or chemotherapy were also assessed to determine whether they were reported and adjusted in the analysis, e.g. multivariate analysis.

Data synthesis and analysis

Data were collated into evidence tables and grouped according to the study design (cohort study or case series). Descriptive analysis (summary) was initially performed to determine the quantity of data, checking further for study variations in terms of study characteristics (i.e. populations, interventions, outcomes, design, quality and results). In addition, this step was used to determine the similarity of studies for possible meta-analysis. Meta-analysis was not carried out due to marked heterogeneity as evident in many aspects of the study characteristics. Synthesis of data was determined from the evidence tables alone.

Results

Study characteristics

The search resulted in 4448 studies. Following first-stage screening of titles, 1421 potentially relevant publications were identified. Independent screening of titles and abstracts (second-stage screening) resulted in further consideration of 546 for possible inclusion. Ten publications of nine studies met the defined inclusion criteria (Fig. 1). The 536 excluded publications and reasons for exclusion are presented in Appendix A.

The κ value for inter-reviewer agreement for study inclusion was 0.71 (titles and abstracts) and 1.0 (full-text articles), indicating strong agreement (Fig. 2).

The nine studies included consisted of two cohort studies (Karoussis et al. 2003, Mengel & Flores-de-Jacoby 2005), four case series with a control group or retrospective cohort studies (Hardt et al. 2002, Evian et al. 2004, Rosenberg et al. 2004, Roos-Jansåker et al. 2006a, b) and three studies where subgroup comparisons between treated and non-periodontitis were carried out. The latter comprises of subgroups of one cohort study (Watson et al. 1999) and two case series (Brocard et al. 2000, Hänggi et al. 2005). Two publications (Roos-Jansåker et al. 2006a, b) were on the same patient material and study period but reporting on different outcomes. There was considerable variation in the study design and data presentation among the studies.

Bibliographies of all included articles and the bibliographies of a systematic review on this subject (Van der Weijden et al. 2005) were screened but this did not result in further articles for inclusion. No additional studies were also identified from the journals contacted, due to absence of relevant studies or lack of response.

Patient characteristics (Tables 1a and 1b)

In the two cohort studies and a further cohort study subgroup, 148 implants (54 patients) were placed in the treated periodontitis group and 147 implants (64 patients) were placed in the non-periodontitis group. For the case series and subgroup of case series, the total numbers were not combinable due to lack of stratification of implants into treated and non-periodontitis groups (Hänggi et al. 2005) and reported on a combination of partially dentate and completely edentulous patients rather than solely partially dentate patients for the non-periodontitis group (Brocard et al. 2000).

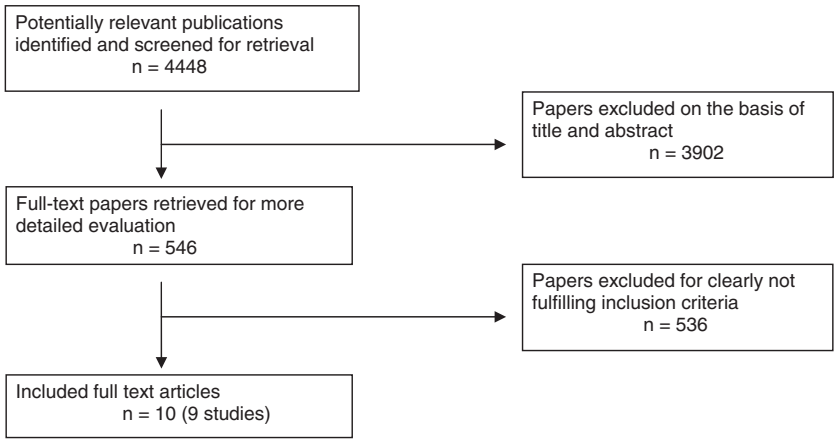

Fig. 1. Flow of studies through the review.

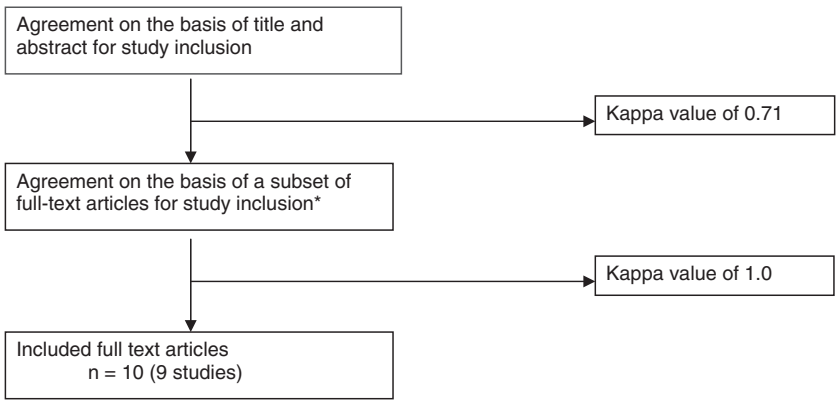

Fig. 2. κ scores for inter-reviewer agreement.

Table 1a. Patient characteristics of selected cohort studies

Study	Methods	Participants: 1. Number 2. Age range 3. Drop-outs 4. Source of recruitment 5. Smoking habits	Implants (numbers)	Follow-up in years	Inclusion/exclusion criteria (e.g. general health)	Trial characteristics: 1. Location 2. Number of centre 3. Source of funding	1. Classification of periodontitis 2. Definition of treated periodontitis and non-periodontitis groups 3. Type of treatment carried out on periodontitis patients 4. Periodontal condition of dentition during study
Karoussis et al. (2003)	Cohort study – prospective longitudinal study	1. Test* – 8 Control – 45 2. Age range – not reported 3. Drop-outs – no 4. Recruited from uni/hospital 5. Smokers included, mixed population (number in each group was not reported) Smokers were defined as heavy smokers	Test – 21 Control – 91	10	No	1. Switzerland 2. 1 centre (uni) 3. Funding – academic	1. Classification – chronic periodontitis 2. Treated periodontitis defined as patients with history of chronic periodontitis who lost their teeth due to periodontitis and were treated according to Lang (1988) Non-periodontitis defined as without a history of chronic periodontitis, replacing teeth lost due to other reasons such as caries, fractures, anodontia or trauma 3. Periodontal treatment – treated according to a comprehensive treatment strategy Lang (1988) 4. Periodontal condition – not reported
Mengel & Flores-de-Jacoby (2005)	Cohort study – prospective longitudinal study	1. Test – 27 (12 – GCP; 15 – GAgP) Control – 12 2. Age range – 19–59 (Mean – GAgP- 32; GCP – 34; control –31) 3. Drop-outs – no 4. Recruited from uni/hospital 5. Non-smokers	Test – 120 (43 – GCP; 77 – GAgP) Control – 30 (GAgP – 52 MK II/ 25 osseotite; GCP – 17 MK II/26 osseotite; control – 14 MKII/16 osseotite)	3	Inclusion – no systemic disease, no pregnancy, no orthodontic therapy, no myoarthropathies, no extensive carious lesions, no medication or psychiatric disorders	1. Germany 2. 1 centre (uni) 3. Unclear	1. Classification – generalized aggressive periodontitis and generalized chronic periodontitis Armitage (1999) 2. Treated periodontitis defined as when PD $\leqslant$ 3 mm with no BOP at all teeth Non-periodontitis defined as periodontally healthy with PD $\leqslant$ 3 mm without BOP on all teeth 3. Periodontal treatment – periodontal surgery and SRP of sites $>$ 4 mm and BOP 4. Gingival index (GI), Plaque index (PI), Probing depth (PD), Attachment loss (AL) and bone loss of teeth reported from baseline to 3 years: GI (range) – GAgP – 0.08–0.13; GCP – 0.14–0.25; non-periodontitis – 0.01–0.15 PI (range) – GAgP – 0.38–0.53; GCP – 0.27–0.41; non-periodontitis – 0.22–0.55 PD (range) – GAgP – 2.67–3.21; GCP – 2.57–2.84; non-periodontitis – 2.50–2.59 AL (range) – GAgP – 4.07–4.87; GCP – 3.90–3.93; non-periodontitis – 2.80–2.96

Table 1a. (Contd.)

Study	Methods	Participants: 1. Number 2. Age range 3. Drop-outs 4. Source of recruitment 5. Smoking habits	Implants (numbers)	Follow-up in years	Inclusion/exclusion criteria (e.g. general health)	Trial characteristics: 1. Location 2. Number of centre 3. Source of funding	1. Classification of periodontitis 2. Definition of treated periodontitis and non-periodontitis groups 3. Type of treatment carried out on periodontitis patients 4. Periodontal condition of dentition during study
Watson et al. (1999)	Subgroup of cohort study – prospective longitudinal study	1. Test – 7 Control – 19 2. Age range – 22–63 3. Drop-outs – reported but unclear of the reasons 4. Recruited from uni 5. Smokers included – mixed population (number in each group was not reported)	Test – 7 Control – 26	4	Exclude medically compromised, poor oral hygiene, heavy smoker, inadequate bone volume or psychiatric disorders	1. UK 2. 1 centre (uni) 3. Academic, govt and industry	1. Classification – chronic periodontitis (pockets $\geqslant$4 mm & radiographic bone loss) 2. Treated periodontitis – not defined (treatment was not defined) Non-periodontitis group was not defined 3. Periodontal treatment – not reported 4. Periodontal condition – not reported

*Definition – test: treated periodontitis patients; control: non-periodontitis patients.

BOP, bleeding on probing; GAgP, generalized aggressive periodontitis; GCP, generalized chronic periodontitis; govt, government; pts, patients; uni, university; PD, probing depth; SRP, scaling and root planing.

Table 1b. Patient characteristics of selected case series

Study	Methods	Participants: 1. Number 2. Age range 3. Drop-outs 4. Source of recruitment 5. Smoking habits	Implants (numbers)	Follow-up in years	Inclusion/exclusion criteria (e.g. general health)	Trial characteristics: 1. Location 2. Number of centre 3. Source of funding	1. Classification of periodontitis 2. Definition of treated periodontitis and non-periodontitis groups 3. Type of treatment carried out on periodontitis patients 4. Periodontal condition of dentition during study
Brocard et al. (2000)	Subgroup of case series	1. Test – 147 Control – unclear (293 – combination of partially dentate and complete edentulous) 2. Age range – reported but unclear for test and control (mixed dentate and edentulous population) 3. Drop-outs – reported but unclear for test and control (mixed dentate and edentulous population) 4. Recruited from periodontal practice 5. Smokers included, mixed population (numbers in each group not reported). Smokers were mostly light smokers – no more than 5 cigarettes/day	Test – 375 Control – unclear (647 – mixture of partially dentate and complete edentulous)	7	Exclusion – subjects with untreated systemic disease	1. France 2. 10 centres (10 private periodontal practices) 3. Funding – unclear	1. Periodontitis – not classified 2. Treated periodontitis – all patients in a periodontal maintenance program with regular professional plaque control Non-periodontitis – healthy patients (unclear) 3. Periodontal treatment – hygienic phase consisting of SRP, oral hygiene instructions (OHI) and some cases by periodontal surgery. 4. Periodontal condition – unclear

Table 1b. (Contd.)

Study	Methods	Participants: 1. Number 2. Age range 3. Drop-outs 4. Source of recruitment 5. Smoking habits	Implants (numbers)	Follow-up in years	Inclusion/exclusion criteria (e.g. general health)	Trial characteristics: 1. Location 2. Number of centre 3. Source of funding	1. Classification of periodontitis 2. Definition of treated periodontitis and non-periodontitis groups 3. Type of treatment carried out on periodontitis patients 4. Periodontal condition of dentition during study
Evian et al. (2004)	Case series – retrospective descriptive longitudinal study (consecutive patients)	1. Test – 77 Control – 72 (each patient had a single implant placed). 2. Age range – unclear 3. Drop-outs – no (based on available data-retrospective chart review) 4. Recruited from periodontal practice 5. Unclear	Test – 77 Control – 72	Unclear (censored *implants observed for a mean of 943 days (SD – 932, range 35–4030) and failed implants observed for a mean of 722 days (SD – 1026, range 18–3458)	Exclusion – patients with contraindicating diseases-controlled endocrine disorders. Require certification by physician. Exclude multiple implants. Included data that were recorded for patients who received a single implant. Specific periodontal disease as defined	1. USA 2. 1 centre (1 periodontal practice) 3. Funding – unclear	1. Periodontitis were classified as patients where the periodontal disease was 5 mm or greater and associated with radiographic signs of bone loss. Patients who exhibited 1 or more teeth with periodontal disease or who originally lost their teeth as a result of periodontitis were considered to have periodontal disease 2. Treated periodontitis was not defined. Non-periodontitis was defined as those with no history or current manifestations of periodontal disease 3. Periodontal treatment – unclear (some had periodontal surgery performed before or in conjunction with implant placement) 4. Periodontal condition – not reported
Hänggi et al. (2005)	Subgroup of case series – retrospective longitudinal study	1. Test – 49 [33 – chronic periodontitis (CP); 16 aggressive periodontitis (AgP)] Control – 19 2. Age range – 28–83 3. Drop-outs – no (only report on available data) 4. Recruited from periodontal practice 5. Smokers included, mixed population (number in each group was not reported)	Unclear	3	Based on available data. No mention of medical health of population	1. Switzerland 2. 1 centre (private periodontal/ periodontal practice) 3. Unclear	1. Chronic periodontitis and Aggressive periodontitis Armitage (1999) 2. Treated periodontitis defined as gingivitis/ periodontitis eliminated or reduced with maintenance care Non-periodontitis defined as no history of periodontitis 3. Periodontal treatment – unclear. All sources of inflammation were eliminated or reduced 4. Periodontal condition-based on dental hygiene classification – good – 17 pts; adequate – 42 pts; poor – 9 pts

Table 1b. (Contd.)

Study	Methods	Participants: 1. Number 2. Age range 3. Drop-outs 4. Source of recruitment 5. Smoking habits	Implants (numbers)	Follow-up in years	Inclusion/exclusion criteria (e.g. general health)	Trial characteristics: 1. Location 2. Number of centre 3. Source of funding	1. Classification of periodontitis 2. Definition of treated periodontitis and non-periodontitis groups 3. Type of treatment carried out on periodontitis patients 4. Periodontal condition of dentition during study
Hardt et al. (2002)	Case series – retrospective longitudinal study	1. Test – 25; Control – 25 2. Age range – 20–83 (Mean – 57.6; SD – 14.6) 3. Drop-outs – unclear 4. Recruited from uni 5. Unclear	Test – 100 Control – 92	5	Inclusion – patients were systematically healthy; Implant-supported prosthesis without posterior cantilever in canine to molar region (maxilla). Intra-oral radiographs of the implants after abutment connection, bridge insertion and 1 and 5 years of follow-up. Exclusion – subjects with bone augmentation procedures and single implant cases	1. Sweden 2. 1 centre (1 govt) 3. Funding – unclear	1. Periodontitis – not classified 2. Treated periodontitis – defined as an age-related bone loss score. The two end quartiles of the distribution were defined as periodontal subjects [age-related bone loss (Ar-B) $\geqslant$55] and non-periodontal subjects (Ar-B score $<$25) 3. Periodontal treatment – unclear 4. Periodontal condition – unclear
Roos-Jansåker et al. (2006a, b)	Case series – retrospective	1. Test – 94 Control – 62 2. Age range – reported but unclear for test and control (mixed dentate and edentulous population) 3. Drop-outs – reported but unclear for test and control (mixed dentate and edentulous population) 4. Recruited from uni/hospital (Public Dental health clinic) 5. Smokers included, mixed population (number in each group – not reported)	Test – 458 Control – 185 reported in Roos-Jansåker et al. (2006b)	9–14	Not reported	1. Sweden 2. 1 centre (govt or uni) 3. Funding – academic and govt	1. Periodontitis – not classified 2. Treated periodontitis (defined by authors as patient with a history of periodontal disease) – 31–100% of teeth with bone loss $\geqslant$4 mm at mesial and/or distal aspect measured from cemento-enamel junction (CEJ) (radiographs) Non-periodontitis – 0–30% of teeth with bone loss $\geqslant$4 mm at mesial and/or distal aspect measured from CEJ (radiographs) (defined by reviewers and implied by authors) 3. Periodontal treatment – unclear 4. Periodontal condition – not specified as the data is for the mixed dentate and edentulous population

Table 1b. (Contd.)

Study	Methods	Participants: 1. Number 2. Age range 3. Drop-outs 4. Source of recruitment 5. Smoking habits	Implants (numbers)	Follow-up in years	Inclusion/exclusion criteria (e.g. general health)	Trial characteristics: 1. Location 2. Number of centre 3. Source of funding	1. Classification of periodontitis 2. Definition of treated periodontitis and non-periodontitis groups 3. Type of treatment carried out on periodontitis patients 4. Periodontal condition of dentition during study
Rosenberg et al. (2004)	Case series – retrospective longitudinal study	1. Test – 151 Control – 183 2. Age range- 54 (mean) (test – 61.1; control – 49.5) 3. Drop-outs – no (only report on available data) 4. Recruited from periodontal practice 5. Not reported	Test – 923 Control – 588	13	Exclusion – history of cardiac, pulmonary, haematologic, metabolic, infectious, genetic, or other systemic disorders that would contraindicate or compromise the placement or healing of implants	1. USA 2. 1 centre (private periodontal practice) 3. Funding – not specified	1. Periodontitis – not classified 2. Treated periodontitis defined as history of PD that resulted in tooth loss. No PD $\geqslant$3–4 mm was present at time of placement. Non-periodontitis defined as tooth loss not caused by periodontal disease and no loss of attachment (except facial/lingual recession) or no PD $\geqslant$3–4 mm was present at time of implant placement 3. Periodontal treatment – unclear 4. Periodontal condition – not reported

*Definition – Censored: implants that had not failed at the end of the observation period.
SD, standard deviation; SRP, scaling and root planing; govt, government; uni, university.

In four out of nine studies (Watson et al. 1999, Karoussis et al. 2003, Hänggi et al. 2005, Mengel & Flores-de-Jacoby 2005), the patients treated were classified as chronic periodontitis, two of which (Hänggi et al. 2005, Mengel & Flores-de-Jacoby 2005) also had patients with aggressive periodontitis. In the remaining studies, the form of periodontal disease affecting the studies was not reported (Brocard et al. 2000) or defined according to current classification (International Workshop for a Classification of Periodontal Diseases and Conditions 1999) (Hardt et al. 2002, Evian et al. 2004, Rosenberg et al. 2004, Roos-Jansåker et al. 2006a, b).

Not surprisingly, the definitions of treated periodontitis and non-periodontitis patients were variable among the studies included. Different definitions of treated periodontitis were defined in Karoussis et al. (2003), Rosenberg et al. (2004), Hänggi et al. (2005) and Mengel & Flores-de-Jacoby (2005) based on surrogate measurements or treatment regime. While Hardt et al. (2002) and Roos-Jansåker et al. (2006a, b) defined the patients according to an age-related bone loss score (ArB-score) and the percentage of remaining teeth affected by bone loss, respectively, in other studies, the definition was either unclear (Brocard et al. 2000, Evian et al. 2004) or not reported (Watson et al. 1999).

The non-periodontitis group was clearly defined in five out of nine studies (Karoussis et al. 2003, Evian et al. 2004, Rosenberg et al. 2004, Hänggi et al. 2005 and Mengel & Flores-de-Jacoby 2005). In the other four studies, the non-periodontitis group was either not clearly defined (Watson et al. 1999, Brocard et al. 2000) or the authors had their own definition (Hardt et al. 2002, Roos-Jansåker et al. 2006a, b). The type of periodontal treatment included non-surgical and periodontal surgery (Brocard et al. 2000, Karoussis et al. 2003, Evian et al. 2004, Mengel & Flores-de-Jacoby 2005) and it was unclear in the other studies.

Intervention characteristics (Tables 2a and 2b)

Implant type and surface characteristics

In the nine studies, seven implant systems were used. Four out of the nine studies used the Brånemark System®

(Nobel Biocare, Goteborg, Sweden); in two of these studies, a turned surface was used (Rosenberg et al. 2004 – specific manufacturer specification was not reported; Mengel & Flores-de-Jacoby 2005 – Mark II type screws) and in the other two studies (Hardt et al. 2002, Roos-Jansåker et al. 2006a, b), the surface characteristics and shape were not mentioned. The ITI Dental Implant System (Straumann AG, Waldenburg, Switzerland) was also used in four studies. The solid sand-blasted large-grit acid-etched (SLA) titanium screws and titanium plasma sprayed (TPS) were used in Rosenberg et al. (2004) (specific shape for the TPS implants was not reported) and Hänggi et al. (2005) (ITI Standard and Esthetic PLUS screws), but in the other two studies (Brocard et al. 2000 – hollow screws, solid screws and hollow cylinders; Karoussis et al. 2003 – hollow screws), the specific surface modifications were not reported, although in the latter studies, the surfaces were likely to be TPS or SLA surfaces. 3i (Implant Innovation Inc., West Palm Beach, FL, USA) was used in two studies, namely Rosenberg et al. (2004) and Mengel & Flores-de-Jacoby (2005). Both studies used the Osseotite implants. In the remaining studies, Calcitek omniloc hydroxyapatite (HA)-coated cylindrical implants (Calcitek Inc., Carlsbad, CA, USA) were used only by Watson et al. (1999). Paragon (Zimmer Dental, Carlsbad, CA, USA) was used by Evian et al. (2004). In this study, the implant surface characteristics were HA coatings and pure titanium; they were mainly screw type and some had a combination of screw and press-fit type. The TPS surface of the IMZ system (Biomet/Interpore International, Irvine, CA, USA) and the HA surface of the Swede-vent/Screw-vent/Corevent system (Paragon, Encino, CA, USA) were also used by Rosenberg et al. (2004).

Type of surgical procedures

There was considerable variation in the implant placement (i.e. immediate, delayed immediate or delayed): submerged or non-submerged (i.e. one-or two-stage procedures) and the use of bone/soft tissue augmentation. In all studies, the implants were delayed loaded, except Hänggi et al. (2005), where the method of loading was unclear.

Supportive periodontal therapy or maintenance

Supportive periodontal therapy for the dentition was reported for most of the studies included (except Watson et al. 1999, Hardt et al. 2002, Evian et al. 2004); however, the type of supportive periodontal therapy appeared to vary from a regular 3-monthly regime to ''at the discretion of the referring dentist''. Similarly, supportive periodontal therapy for the implants was reported for most studies (except Brocard et al. 2000, Hardt et al. 2002) but the quality was variable among the studies.

Outcomes (Tables 3a and 3b)

The outcomes reported in the studies included show variation between the studies in relation to the definition and assessment of outcomes. Consequently, the results cannot be compared and can only be regarded separately.

Implant survival between treated periodontitis and non-periodontitis patients (Table 4a)

All the studies except Watson et al. (1999) showed better implant survival for the non-periodontitis group compared with the treated periodontitis group. However, a statistically significant difference was only found in Evian et al. (2004) and Roos-Jansåker et al. (2006a).

Implant survival of the studies was not pooled due to the differences in the definition and assessment of outcomes in relation to the baseline reference time point (i.e. survival from implant placement and loading) and using the patient or the implant as the unit of analysis. Implant survival rate is generally defined as the presence of retained implants over the observation period. Cumulative implant survival rate was presented in three out of the five studies (Watson et al. 1999, Karoussis et al. 2003, Roos-Jansåker et al. 2006a), and in the other two studies, Hardt et al. (2002) presented the survival rate (not cumulative) and Evian et al. (2004) presented the proportions of censored/survived implants. Watson et al. (1999) included additional criteria requiring the retained implants to be non-mobile and capable of supporting the crown and, furthermore, Evian et al. (2004) also classified survived implants to be free from irresolvable clinical complaints. The study by Roos-Jansåker et al. (2006a) used the Kaplan–Meier estimates of survival rates based on time to first event (i.e. first losts of implant as the end-point event), with 16 events out of 94 patients for the treated periodontitis group (defined as 31–100% of teeth with bone loss) and two events out of 62 patients for the non-periodontitis group (defined as 0–30% of teeth with bone loss). Implant survival was determined from implant placement for Karoussis et al. (2003), Evian et al. (2004), Roos-Jansåker et al. (2006a) and from loading for Watson et al. (1999), Hardt et al. (2002). The unit of analysis for survival was based on implants (Watson et al. 1999, Hardt et al. 2002, Karoussis et al. 2003) or patients (Evian et al. 2004, Roos-Jansåker et al. 2006a).

Implant success between treated periodontitis and non-periodontitis patients (Table 4b)

All the studies except Watson et al. (1999) showed better implant success for the non-periodontitis group compared with the treated periodontitis group. However, a statistically significant difference was only found in Karoussis et al. (2003) ($p < 0.025$), while no statistical significance was found in Mengel & Flores-de-Jacoby (2005) and for the rest of the studies, analysis was either not carried out (Watson et al. 1999, Brocard et al. 2000) or not reported (Rosenberg et al. 2004).

The studies reporting on implant success were not combinable due to the differences in the criteria for assessment of outcomes and in relation to the baseline reference time point (i.e. success from implant placement (Rosenberg et al. 2004, Mengel & Flores-de-Jacoby 2005), loading (Watson et al. 1999), 6 months of healing (Brocard et al. 2000) or 1 year of function (Karoussis et al. 2003). Furthermore, Rosenberg et al. (2004) classified failure into failure to osseointegrate (up to 1 year after placement of definitive prosthesis) and peri-implantitis-related failure. Most of the studies included reporting on implant success have taken the cumulative success rate into account, except Rosenberg et al. (2004), who presented implant success (defined as implant survival by the authors) as absolute percentages (i.e. the proportion of censored implants in the treated periodontitis and non-periodontitis groups). Implant success was determined from implant placement for Rosenberg et al. (2004) and Mengel

Table 2a. Intervention characteristics of selected cohort studies

Study	Type of implants: 1. System, design and surface topography (as reported by authors) 2. Diameter and length	Site of implant placement: 1. Maxillary (Max) or/and Mandibular (Mand) 2. Anterior (Ant) or/and Posterior (Post)	Description of bone quantity and quality	Implant placement: 1. Immediate, delayed immediate or delayed after tooth extraction 2. 1- or 2-stage 3. Loading – immediate or delayed4. Augmentation (Aug)	Type of prosthesis	Antibiotics	Experience of operator	Supportive periodontal therapy (SPT) for dentition	Supportive periodontal therapy (SPT) for implants
Karoussis et al. (2003)	1. Straumann. Hollow screws 2. Diameter/length – not reported	Not reported	Not reported	1. Not reported 2. 1-stage 3. Delayed loading 4. Aug – not reported	Single tooth, fixed bridge	Not reported	Not reported	Yes. Patients were offered SPT to be provided in the university or dental practices of referring dentists at intervals between 3 and 6 months	Yes. Cumulative implant supportive therapy (CIST) protocol (Lang et al. 2000)
Mengel & Flores-de-Jacoby (2005)	1. Branemark (MK II) – smooth machined surface. 3i (Osseotite) – smooth/rough 2. Diameter/length – not reported	1. Max and Man 2. Ant/Post – not reported	Not reported	1. Delayed 2. 2-stage 3. Delayed loading 4. Aug – no	Single tooth, Fixed bridge (some with posterior cantilever)	Not reported	Specialist	Yes (removal of supragingival deposits and removal of sub-gingival deposits for teeth with PD > 4 mm and BOP)	Yes (removal of supragingival deposits and removal of sub-gingival deposits for implants with PD > 4 mm and BOP)
Watson et al. (1999)	1. Calcitek omniloc cylindrical hydroxyapatitie coated 2. Diameter/length – not reported	1. Max and Mand 2. Ant and Post	Misch (1990)-type III/IV	1. Not reported 2. 2-stage 3. Delayed loading 4. Aug – no	Single tooth	Yes	Specialist	Not reported	Assessment but level of care was not reported

PD, probing depth; BOP, bleeding on probing.

Table 2b. Intervention characteristics of selected case series

Study	Type of implants: 1. System, design and surface topography (as reported by authors) 2. Diameter and length	Site of implant placement: 1. Maxillary (Max) or/and Mandibular (Mand) 2. Anterior (Ant) or/ and Posterior (Post)	Description of bone quantity and quality	Implant placement: 1. Immediate, delayed immediate or delayed after tooth extraction 2. 1- or 2-stage 3. Loading – immediate or delayed 4. Augmentation (Aug)	Type of prosthesis	Antibiotics	Experience of operator	Supportive periodontal therapy (SPT) for dentition	Supportive periodontal therapy (SPT) for implants
Brocard et al. (2000)	1. Straumann. Hollow screws, solid screws and hollow cylinders 2. Diameter – standard; length – <8 mm, 8 mm, 10 mm, 12 mm and >12 mm	1. Max and Man 2. Ant and Post	Not reported	1. Not reported 2. 1-stage 3. Delayed loading 4. Aug – GBR-staged or simultaneous using bioabsorbable collagen membranes with or without HA spacer	Mixed population – single tooth, fixed bridge (including distal extension/ cantilever) and complete edentulous	Not reported	Specialist	Yes. All patients were enrolled in a periodontal maintenance program with regular professional plaque control	Unclear
Evian et al. (2004)	1. Paragon, Zimmer dental. Mainly screws and small percentage was a combination of screw and press-fit Numerous press-fit had HA coatings and the remainder was pure titanium 2. Diameter ranged from 3.3 to 6 mm; length ranged from 10 to 18 mm	Not reported	Not reported	1. Immediate and delayed (length of delay was not reported) 2. 2-stage 3. Delayed loading 4. Aug – yes – free gingival graft	Single tooth	Not reported	Specialist	Unclear	Yes (however, some patients did not return for routine maintenance or annual follow-up and presented only when problems occurred)
Hänggi et al. (2005)	1. Straumann –SLA or TPS surface; standard/standard plus 2. Diameter/length – not reported	1. Max and Man 2. Ant and Post	Not reported	1. Immediate for 14 implants and unclear for the rest (placement not reported for all implants) 2. 1-stage 3. Loading – not reported 4. Aug – yes	Single tooth, fixed bridge (no posterior cantilever)	Not reported	Unclear	Yes (dental hygienist – 3–6 months interval)	Yes, complications treated by Lang 2000 protocol

Table 2b. (Contd.)

Study	Type of implants: 1. System, design and surface topography (as reported by authors) 2. Diameter and length	Site of implant placement: 1. Maxillary (Max) or/and Mandibular (Mand) 2. Anterior (Ant) or/ and Posterior (Post)	Description of bone quantity and quality	Implant placement: 1. Immediate, delayed immediate or delayed after tooth extraction 2. 1- or 2-stage 3. Loading – immediate or delayed 4. Augmentation (Aug)	Type of prosthesis	Antibiotics	Experience of operator	Supportive periodontal therapy (SPT) for dentition	Supportive periodontal therapy (SPT) for implants
Hardt et al. (2002)	1. Branemark 2. Diameter – majority was 3.75 mm, 10% were 4 mm and 5% were 5 mm. Length of implants – range of 6 and 20 mm. Average implant length – test – 11.8 mm (SD – 2.4); control – 12.7 mm (SD – 1.7)	1. Max only 2. Post only (canine to molar region)	Lekholm & Zarb (1985) Bone quantity – test – Grade D – 20%; Grade A or B – 20%; control – Grade D – 0%; Grade A or B – 48%. Bone quality – Both test and control the same, score 3 – 80% and score 4 – 20%	1. Not reported 2. 2-stage 3. Delayed loading 4. Aug – no	Fixed bridge	Not reported	Not reported	Not reported	Not reported
Roos-Jansåker et al. (2006a, b)	1. Branemark 2. Diameter/length – not reported	1. Max and Man 2. Ant and Post	Not reported	1. Not reported 2. 2-stage 3. Delayed loading 4. Aug – not reported	Mixed population – implant-support fixed or removable (partial and complete edentulous)	Yes	Specialist	Yes but at discretion of referring dentist (i.e. unclear as to how regular)	Yes but at discretion of referring dentist (i.e. unclear as to how regular)
Rosenberg et al. (2004)	1. Branemark (turned titanium); ITI Straumann (SLA, TPS); IMZ (TPS); 3i/ Osseotite (acid-etched); Swede-vent/ screw-vent/ corevent – Paragon (HA) 2. Diameter – $\leqslant$4 mm/$>$4 mm; length – $<$10 mm/ 10–13 mm/ $>$13 mm	1. Max and Man 2. Ant and Post	Not reported	1. Not reported 2. 1-stage and 2-stage according to the manufacturer's guidelines and recommendation 3. Delayed loading 4. Aug – not reported	Not reported	Yes	Specialist	Yes (at least every 3 months)	Yes (3 monthly assess for mobility and clinical signs of inflammation) Radiograph as needed

HA, hydroxyapatite; SLA, sandblasted, large-girt, acid-etched; TPS, titanium plasma sprayed; SD, standard deviation; GBR, guided bone regeneration.

Table 3a. Outcome characteristics of selected cohort studies

Study	Plaque (implants)	Gingival health (implants)	Peri-implant conditions	Bone loss (definition and result)	Implant survival (definition and %)	Implant success (definition and %)	Peri-implantitis (definition and %)
Karoussis et al. (2003)	Yes. mPII Mombelli et al. (1987) Test – 0.47 (SD – 0.51); Control – 0.33 (SD – 0.38)	Yes. mBII Mombelli et al. (1987) Test – 0.28 (SD – 0.44); Control – 0.16 (SD – 0.24)	Mean *PPD:* Test – 3.03 (SD – 1.58); Control – 2.52 (SD – 0.64); *PAL:* Test – – 3.59 (SD – 1.40); Control – – 3.12 (SD – 0.72); *BOP:* Test – 0.29 (SD – 0.36); Control – 040 (SD – 0.33)	*Definition:* Changes in the bone height measured between the shoulder of the implant and the first clear bone-to-implant contact, mesially and distally. Radiographic measurements at baseline (1 year after implant insertion) and follow-up (10 years) Test Mesial – 1.00 (SD – 1.38); Distal – 0.94 (SD – 0.73) Control Mesial – 0.48 (SD – 1.10); Distal – 0.50 (SD – 1.08)	*Definition:* Presence of implants (i.e. not lost) over 10 years Cumulative survival rate from implant placement to 10 years Test – 90.5% (SE – 0.064); Control – 96.5% (SE – 0.020) Survival is counted from implant placement (insertion) Survival is based on implant level	*Definition:* Success rate – no annual bone loss > 0.2 mm mesially or distally; no site with PPD > 5 mm; no site with PPD = 5 mm and BOP+; absence of mobility, persistent subjective compliant and continuous radiolucency around implant Test – 52.4%; Control – 79.1% Success is taken from clinical and radiographic evaluations at 1 year baseline and 10 year s of function Success is based on implant level	*Definition:* Incidence of PPD ⩾5 mm with BOP+ and radiographic signs of bone loss. Time period from implant installation until the occurrence of a biological complication or until the end of the evaluation period of 10 years was determined for all implants (cumulative) Test – 28.6% (SE – 0.098); Control – 5.8% (SE – 0.025) Peri-implantitis is based on implant level
Mengel & Flores-de-Jacoby (2005)	Yes Silness & Löe (1964)	Yes Löe & Silness (1963)	Yes (PD, AL)	*Definition:* Bone loss measured from the marginal bone level to the top edge of the implant and expressed in relation to the torsion section of the implant (different implant system) Bone loss after 3 years from insertion of superstructure: GAgP – total of 1.14 mm GCP – total of 0.86 mm Control – total of 0.70 mm [all successful according to Albrektsson et al. (1986)]	Not applicable (study reported implant survival, i.e. not lost or removed due to mobility, as one of the implant success criteria)	*Definition:* Authors mentioned success rate was computed with reference to Albrektsson et al. (1986) using Kaplan–Meier survival curve. Furthermore, any implant that was not lost/ removed due to mobility was deemed as success Success from implant placement to 3 years: Test: GAgP – 95.7% in maxilla; 100% in mandible GCP – 100% Control – 100% Success from implant placement to 3 years Success is based on implant level	Not reported

Table 3a. (Contd.)

Study	Plaque (implants)	Gingival health (implants)	Peri-implant conditions	Bone loss (definition and result)	Implant survival (definition and %)	Implant success (definition and %)	Peri-implantitis (definition and %)
Watson et al. (1999)	Not reported	Not reported	Not reported	Not reported	*Definition:* Retained non-mobile implant capable of supporting crown during normal function Cumulative survival from loading to 4 years: Test – 100% Control – 100% Survival is based on implant level	*Definition:* Functional, symptom free, had no obvious clinical pathology or radiographic signs of progressive cervical bone loss, which exceeded 4 mm or over a third of the implant length (Spiekermann et al. 1995) Cumulative success from loading to 4 years: Test – 100% Control – 56% (calculated by reviewer) Success is based on implant level	*Definition:* Not defined or compared between test and control

BOP, bleeding on probing; mPII, modified plaque index; mBII, modified bleeding index; PPD/PD, probing pocket depth/probing depth; PAL/AL, probing attachment level/attachment level; SD, standard deviation; SE, standard error; GAgP, generalized aggressive periodontitis; GCP, generalized chronic periodontitis.

& Flores-de-Jacoby (2005); from loading for Watson et al. (1999); from 6 months of healing for Brocard et al. (2000); and from 1-year baseline of function for Karoussis et al. (2003). Success was based on implants as the unit of analysis for all the studies.

Bone-level change between treated periodontitis and non-periodontitis patients (Table 4c)

Radiographic bone-level change was reported in five studies. All the studies showed less bone loss in the non-periodontitis group in comparison with the treated periodontitis group. However, a statistically significant difference was only reported in Hardt et al. (2002) ($p = 0.029$) and a borderline significance was reported in Hänggi et al. (2005) ($p = 0.058$). Hänggi et al. (2005) concluded that patients with aggressive periodontitis before implant placement had an ''increased'' probability of additional crestal bone loss in comparison with patients with chronic periodontitis or non-periodontitis. The rest of the studies did not find any statistically significant difference (Mengel & Flores-de-Jacoby 2005, Roos-Jansåker et al. 2006b) or the data on statistical significance were not reported (Karoussis et al. 2003).

There are several differences in relation to the outcome measurements for bone-level change rendering the results incomparable between studies. Variation between the studies includes the differences in radiographic reference points because of dissimilar implant systems; the differences in the baseline time point (e.g. radiographic baseline measurement at insertion of superstructure in Hänggi et al. 2005, whereas in Karoussis et al. 2003, it was measured at 1 year after surgical implant placement) and observation period (ranged from 3 to 14 years) as well as differences in the presentation of results [Roos-Jansåker et al. (2006b) measured the number of implant threads not supported by bone and counted the number of outcome events defined as <3 threads and $\geqslant 3$ threads]. Furthermore, three out of five studies provided information about standardization of the radiographs taken (Hardt et al. 2002, Karoussis et al. 2003, Hänggi et al. 2005).

Peri-implantitis (Table 4d)

All three studies (Karoussis et al. 2003, Rosenberg et al. 2004, Roos-Jansåker

Table 3b. Outcome characteristics of selected case series

Study	Plaque (implants)	Gingival health (implants)	Peri-implant conditions	Bone loss (definition and result)	Implant survival (definition and %)	Implant success (definition and %)	Peri-implantitis (definition and %)
Brocard et al. (2000)	Not reported	Not reported	Not reported	Not reported	Yes – but unclear for test and control (mixed dentate and edentulous population)	*Definition:* Albrektsson et al. (1986) and adapted by Buser et al. (1997) Cumulative success rate – Test – 74.7%; Control – 88.8% (Control – healthy – mixed group of partially dentate and complete edentulous; unclear whether periodontally healthy, not just systemically healthy) Success measured from 6 months of healing Success is based on implant level	Not reported
Evian et al. (2004)	Not reported	Not reported	Not reported	Not reported	*Definition:* Survivals if they continued to support a load-bearing restoration and were free from irresolvable clinical complaints (e.g. peri-implant radiolucency, chronic pain, implant mobility and progressive bone loss) Implants with advanced bone loss, acute infection, pain or irresolvable discomfort were removed. If the implants were removed, they were listed as failures Test – 79.22% Control – 91.67% Survival is measured from implant placement Survival is based on patient	Not reported	Not reported

Table 3b. (Contd.)

Study	Plaque (implants)	Gingival health (implants)	Peri-implant conditions	Bone loss (definition and result)	Implant survival (definition and %)	Implant success (definition and %)	Peri-implantitis (definition and %)
					level (1 implant per patient)		
Hänggi et al. (2005)	Yes (dental hygiene	classification) – Good – 17 pts; Adequate – 42 pts; Poor – 9 pts	Not reported	Not reported	*Definition:* Crestal bone levels measured from the microgap/interface to the first bone-to-implant contact. Radiographs taken shortly after implant placement and compared with those taken at various subsequent post-placement times (up to 3 years) to evaluate crestal bone level changes (mesial/distal aspect) The level of periodontitis (i.e. aggressive periodontitis) before implant placement had a marginal effect for additional crestal bone loss ($p = 0.058$ at 1-year follow-up)	Not reported	Not reported
Not reported Hardt et al. (2002)	Not reported	Not reported	Not reported	*Definition:* Distance between the implant platform (implant–abutment junction) and the bone-to-implant contact at the mesial and distal aspect of each implant recorded to the nearest 0.1 mm. Bone loss from abutment connection to 5 years (radiographic examination) Test – 2.2 mm (SD – 0.8); Control – 1.7 mm (SD – 0.8)	*Definition:* Presence of implants (i.e. not lost) over 5 years Test – 92%; Control – 96.7% Survival is counted from bridge installation to 5 years Survival is based on implant level	Not reported	Not reported

Table 3b. (Contd.)

Study	Plaque (implants)	Gingival health (implants)	Peri-implant conditions	Bone loss (definition and result)	Implant survival (definition and %)	Implant success (definition and %)	Peri-implantitis (definition and %)
Roos-Jansåker et al. (2006a, b)	Yes – FMPS – but unclear for test and control (mixed dentate and edentulous population)	Yes – FMBS – but unclear for test and control (mixed dentate and edentulous population)	Not reported	*Definition:* Bone level – <3 threads and $\geqslant 3$ threads not supported by bone (measured at the mesial and distal aspects of the implants on radiographs obtained 1 year after placement of suprastructure and at final examination) Test – 128/458 Control – 26/185 (number of outcome events over the total implants in that category) Not significant between test and control in the multivariate analysis (reported in Roos-Jansaker et al. 2006b)	*Definition:* Kaplan–Meier estimates of survival rates. Time to first event (first lost of implant) in maxilla or mandible was considered as the end-point event Survival from implant placement to 14 years Test (31–100% bone loss) – 16 events out of 94 patients Control (0–30% bone loss) – 2 events out of 62 patients Survival is based on patient level	Not reported	*Definition:* Bone level $\geqslant 3$ threads when comparing the radiographs taken at the final examination with the radiograph taken 1 year after placement of the suprastructure, combined with BOP and/or pus Test – 42/458 Control – 4/185 Multivariate analysis showed OR = 4.7 (1.0–22) with $p = 0.05$ (borderline significant) Peri-implantitis is based on implant level. (reported in Roos-Jansåker et al. 2006b)
Rosenberg et al. (2004)	Not reported	Not reported	Not reported	Not reported	Study reported implant success as implant survival	*Definition:* Albrektsson et al. (1986) Test – 90.7% Control – 93.7% (not cumulative) Failure further classified into 1. Failure to osseointegrate (up to 1year after placement of definitive prosthesis) – test – 74% Control – 95% 2. Peri-implantitis-related failure Success (''Survival'') from implant placement to 13 years Success (''Survival'') is based on implant level	*Definition:* Peri-implantitis defined as failure that occurs after 1 year of loading (period after prosthesis had been in place for 1 year until more than 5 years) Test – 25.6% Control – 5.4% Peri-implantitis is based on implant level

FMBS, full mouth bleeding score; FMPS, full mouth plaque score; OR, odds ratio.

Table 4a. Implant survival (as defined by authors of included studies) in treated periodontitis patients compared with non-periodontitis patients

Study	Follow-up in years	Survival of treated periodontitis	Survival of non-periodontitis	Statistical tests
Evian et al. (2004)	>10	79.22%	91.67%	Cox proportional hazards regression (periodontal status made a significant contribution, Wald's χ^2, $p = 0.0122$ for periodontal status *versus* $p > 0.5$ for time of placement) Log-rank test was statistically significant for periodontal status ($p = 0.0213$) Analysed at the level of the patient. This shows that implant survival is compromised by a history of periodontitis
Hardt et al. (2002)	5	92%	96.7%	Not reported
Karoussis et al. (2003)	10	90.5% (SE – 0.064)	96.5% (SE – 0.020)	Kaplan–Meier estimate of survival rate. Differences between groups were tested by log-rank test and Wilcoxon's test (not statistically significant) Analysed at the level of the implant
Roos-Jansåker et al. (2006a)	9–14	16 events out of 94 patients	2 events out of 62 patients	Kaplan–Meier curves – time to event for implant loss. Log-rank test (and Cox's regression analyses) showed a significant effect ($p = 0.01$) Analysed at the level of the patient. This shows that there is more implant loss in patients who presented with more periodontal bone loss of the remaining teeth at implant placement
Watson et al. (1999)	4	100%	100%	No statistical analysis between treated and non-periodontitis groups

SE, standard error.

Table 4b. Implant success (as defined by authors of included studies) in treated periodontitis patients compared with non-periodontitis patients

Study	Follow-up in years	Success of treated periodontitis	Success of non-periodontitis	Statistical tests
Brocard et al. (2000)	7	74.4%	88.8%	Treated periodontitis was compared with the total number of implants No analysis between treated and non-periodontitis groups
Karoussis et al. (2003)	10	52.4%	79.1%	Fisher's exact test for success: $p < 0.025$. Statistically significant Analysed at the level of the implant. This shows that implants placed in previously periodontally compromised patients demonstrated lower success rates than implants placed in patients who lost their teeth due to reasons other than periodontitis
Mengel & Flores-de-Jacoby (2005)	3	95.7% (GAgP – maxilla) 100% (GAgP – mandible; GCP)	100%	Success rate was computed with reference to Albrektsson et al. (1986) using Kaplan–Meier survival curve. Comparison between groups – MANOVA test (not statistically significant) Analysed at the level of the implant
Rosenberg et al. (2004)	13	90.7%	93.7%	Not reported
Watson et al. (1999)	4	100%	56%	No statistical analysis between treated and non-periodontitis groups

GAgP, generalized aggressive periodontitis; GCP, generalized chronic periodontitis.

et al. 2006b) reported lower occurrences of peri-implantitis in the non-periodontitis patients in comparison with treated periodontitis patients. However, a statistically significant difference was reported in Karoussis et al. (2003) ($p = 0.002$) and Roos-Jansåker et al. (2006b) ($p = 0.05$; OR = 4.7). The incidence of peri-implantitis was presented in Karoussis et al. (2003), while Rosenberg et al. (2004) and Roos-Jansåker et al. (2006b) presented the proportions of implants affected by peri-implantitis.

The three studies were not comparable due to differences in the definition of peri-implantitis and outcome measurement.

Methodological quality of the studies included

Following discussions, there was good agreement among reviewers concerning the study quality issues as summarized in Tables 5a and 5b. All the studies were rated as having a high risk of bias except one cohort study (Mengel & Flores-de-Jacoby 2005) and two case series (Hardt et al. 2002, Evian et al. 2004) that were classified as medium risk.

Cohort or subgroup of cohort studies

Although completeness of follow-up was found in all three cohort studies, the rest of the quality assessment criteria were not fulfilled in the studies. Mengel & Flores-de-Jacoby (2005)'s study was

classified as having a medium risk because they fulfilled most of the quality assessments that could affect outcomes (measurement of bone-level change was accounted for by masking of assessor). However, the reporting of the baseline bone quality and prosthetic needs was inadequate to allow classification of the study as low risk. Nevertheless, classification of baseline bone quality allows a subjective indication of the bone quality as determined by the assessor to limit the risk of bias because objectively determining the bone morphological quality before implant placement is more difficult. The other two studies (Watson et al. 1999, Karoussis et al. 2003) were considered as having a high risk of bias because of inadequate reporting of the baseline bone quality and prosthetic needs and masking of assessor. Furthermore, the inclusion criteria were unclear for Karoussis et al. (2003) and the reasons for drop-outs were not clear for all the patients in Watson et al. (1999).

Case series or subgroup of case series

Two out of six studies were considered to be medium risk (Hardt et al. 2002, Evian et al. 2004). In Hardt et al. (2002), all the quality criteria were fulfilled except for consecutive entering of patients, which is less important in this particular study because the treated and non-periodontitis patients were defined in relation to the age-related bone loss score, while in Evian et al. (2004), all the quality criteria were fulfilled except for reporting of baseline characteristics and masking of assessor for survival of implants indicating the presence or absence of the implants. Although Brocard et al. (2000) appeared to fulfil most of the criteria as Evian et al. (2004), it was considered to be at a high risk of bias because there were considerable differences in the baseline characteristics of bone quality and prosthetic needs as the non-periodontitis group had a combination of partially dentate and completely edentulous patients. The other three case series (Rosenberg et al. 2004, Hänggi et al. 2005, Roos-Jansåker et al. 2006a, b) were deemed as having a high risk of bias because most of the quality criteria were either not carried out or not explicitly reported.

Confounding factors

Adjustment of confounding factors (e.g. multivariate analysis) in the outcome analysis was only carried out by Roos-Jansåker et al. (2006a, b). However, some studies carried out univariate/bi-variate analysis on smokers who were included in the patient population (Brocard et al. 2000, Karoussis et al. 2003, Hänggi et al. 2005). Other studies did not report on the presence or absence of smokers in the population (Hardt et al. 2002, Evian et al. 2004, Rosenberg et al. 2004). Watson et al. (1999) did not carry out an analysis for smoking (20 or more a day) as the authors reported that the patient sample was too small and heavy smokers were excluded from the study. Patients with other confounders (i.e. systemic diseases, medications and radio-therapy or chemo-therapy) were mostly excluded from the study populations. In the case of Karoussis et al. (2003), smoking status was not presented in their inclusion criteria.

Discussion

Key findings

Of the five studies presenting data on implant survival, four reported higher implant survival for non-periodontitis patients in comparison with treated periodontitis patients (Table 4a). Two case series studies (Evian et al. 2004 and Roos-Jansåker et al. 2006a) with a large patient sample and a long observation period found a statistically significant difference in survival, which was associated with the patient's periodontal status.

Table 4c. Bone level change around implants (as defined by authors of included studies) in treated periodontitis patients compared with non-periodontitis patients

Study	Follow-up in years	Bone loss of treated periodontitis	Bone loss of non-periodontitis	Statistical tests
Hänggi et al. (2005)	3	Not reported	Not reported	Mixed-model analysis of variance (ANOVA). $p = 0.058$ for level of periodontitis before implant placement (''marginal effect'') This shows that at the 1 year follow-up, patients diagnosed with aggressive periodontitis before implant placement may have a limited tendency for additional crestal bone loss in comparison with patients with chronic periodontitis or periodontally healthy
Hardt et al. (2002)	5	2.2 ± 0.8 mm (SD)	1.7 ± 0.8 mm (SD)	Multiple regression analysis. Coefficient – 0.69, $p = 0.029$. Statistically significant. This shows that longitudinal bone loss (follow-up of 5 years) around implants is correlated to previous experience of loss of periodontal bone support
Karoussis et al. (2003)	10	Mesial – 1.0 ± 1.38 mm (SD); Distal – 0.94 ± 0.73 mm (SD)	Mesial – 0.48 ± 1.10 mm (SD); Distal – 0.50 ± 1.08 mm (SD)	Kruskal–Wallis test (statistical significance was not reported)
Mengel & Flores-de-Jacoby (2005)	3	GAgP – 1.14 mm; GCP – 0.86 mm	0.70 mm	Comparison between groups – MANOVA test (not statistically significant)
Roos-Jansåker et al. (2006b)	9–14	128/458 of implants affected by bone loss	26/185 of implants affected by bone loss	Logistic regression with random effects (multivariate analysis – not significant)

GAgP, generalized aggressive periodontitis; GCP, generalized chronic periodontitis.

Table 4d. Peri-implantitis around implants (as defined by authors of included studies) in treated periodontitis patients compared with non-periodontitis patients

Study	Follow-up in years	Peri-implantitis in treated periodontitis	Peri-implantitis in non-periodontitis	Statistical tests
Karoussis et al. (2003)	10	28.6% (SE – 0.098)	5.8% (SE – 0.025)	Wilcoxon's test, $p = 0.0001$; Log-rank test, $p = 0.0002$ Statistically significant Analysed at the level of the implant. This shows that the incidence of peri-implantitis was higher in implants placed in patients with a history of chronic periodontitis than for implants placed in patients without
Roos-Jansåker et al. (2006b)	9–14	16% (42/258 of implants)	22% (4/185 of implants)	Logistic regression with random effects (multivariate analysis – OR = 4.7; $p = 0.05$, borderline statistically significant) Analysed at the level of the implant. This shows that occurrence of peri-implantitis was related to a previous history of periodontitis
Rosenberg et al. (2004)	13	25.6%	5.4%	Statistical test was not reported

SE, standard error; OR, odds ratio.

Table 5a. Results of quality assessment of selected cohort studies

Study	Similarity of baseline characteristics – bone quality and prosthetic needs	Masking of assessor	Completeness of follow-up	Similarity of drop-outs and reasons for drop-outs	Inclusion criteria explicit	Risk of bias
Karoussis et al. (2003)	Unclear	Unclear	Yes	No drop-out	Unclear	High
Mengel & Flores-de-Jacoby (2005)	Unclear	Yes for radiographic examination; no for clinical examination	Yes	No drop-out	Yes	Medium
Watson et al. (1999)	Unclear	No	Yes	Unclear	Yes	High

Table 5b. Results of quality assessment of selected case series

Study	Patients consecutively entered	Inclusion criteria explicit	Similarity of baseline characteristics – bone quality and prosthetic needs	Masking of assessor	Similarity of drop-outs and reasons for drop-outs	Risk of bias
Brocard et al. (2000)	Yes	Yes	Unclear (non-periodontitis group had partially dentate and complete edentulous patients)	No	Unclear	High
Evian et al. (2004)	Yes	Yes	Unclear	No (based on implant survival)	Not reported	Medium
Hänggi et al. (2005)	Unclear	Unclear	Unclear	No	Not reported	High
Hardt et al. (2002)	No	Yes	Yes	Yes	Not reported	Medium
Roos-Jansåker et al. (2006a, b)	Unclear	No	No	No	Unclear	High
Rosenberg et al. (2004)	No	Yes	Unclear	Unclear	Not reported	High

Similarly, in the five studies with data on implant success (Table 4b), more favourable results were reported in four studies (Brocard et al. 2000, Karoussis et al. 2003, Rosenberg et al. 2004, Mengel & Flores-de-Jacoby 2005) for patients without periodontitis in comparison with treated periodontitis patients. One cohort study (Karoussis et al. 2003) showed statistically significant lower success rates in implants placed in previously periodontally compromised patients.

Longitudinal radiographic bone loss around implants was also associated with a history of periodontitis as shown in all five included studies (Table 4c). Statistically greater bone loss was only found in Hardt et al. (2002). However, the periodontal treatment carried out in Hardt et al. (2002) was not reported and therefore the risk of ongoing periodontitis affecting the bone level around implants cannot be dismissed.

The occurrence of peri-implantitis was reported in three out of nine studies; in two of these studies, statistically more complications around treated periodontitis occurred in comparison with non-periodontitis (Karoussis et al. 2003, Roos-Jansåker et al. 2006b). In both studies, there was a higher frequency of peri-implantitis and a lower survival rate

(Roos-Jansåker et al. 2006a, b) or a lower success rate (Karoussis et al. 2003) between the treated periodontitis patients in comparison with non-periodontitis patients. The possible correlation between peri-implantitis and implant survival or success, and the influence of implant surfaces on the incidence of peri-implantitis could not be evaluated because of insufficient data. The lack of data on peri-implantitis may suggest that the incidence or reporting of peri-implantitis is rare and may be more commonly observed when a longer observation period of at least 10 years has been carried out.

Strength of evidence

The variability in the study designs, the definition of patient population and outcome measurements (including analytic techniques) makes it difficult to draw definitive conclusions. Furthermore, a number of these factors may have an impact on the clinical outcomes. Firstly, the main aspects of the study design that were incomplete were reporting of baseline characteristics (i.e. similarity of the bone volume and prosthetic needs) and masking of assessors. The former is important because unless the groups were balanced for relevant baseline characteristics, the differences in the outcomes cannot be attributed confidently to periodontitis. Masking of the assessors is difficult but important to protect against measurement bias for subjective outcomes such as probing depth, although it is less important for objective outcomes such as implant survival (Moher et al. 1999). Furthermore, only two out of six case series (Brocard et al. 2000, Evian et al. 2004) mentioned the inclusion of consecutive cases. This was recommended by Wennström & Palmer (1999) in the absence of a proper control (i.e. predefined non-periodontitis group) to reduce the risk of selection or attrition bias and the possible overestimation of favourable results.

Secondly, both the classification and the definition of treated periodontitis and non-periodontitis patients were variable among the studies included, particularly the effectiveness of periodontal treatment and whether the non-periodontitis patients were without evidence of periodontitis. The implication of this is that inadequate control of periodontitis might act as a confounding factor on the outcomes. Moreover, there was substantial heterogeneity in the quality and frequency of supportive periodontal therapy for both the implants and the surrounding dentition, which might also influence the outcomes. The data might suggest that meticulous supportive therapy is as important for implants as for teeth when comparing the Karoussis et al. (2003) study where the supportive therapy followed a specific protocol compared with patients in the Roos-Jansåker et al. (2006a, b) study, where there was no structured supportive therapy. However, there was no direct evidence to support the importance of supportive therapy for implants as for periodontally treated teeth and thus the impact of this cannot be elucidated further.

Further aspects that could affect the evaluation of clinical outcomes were methodological factors. These included the implant survival (and success) data that should be presented as a cumulative rate to take into account the time at risk for each implant to have ''survived''/censored at the various observation times after placement. Most studies did take cumulative rate into account except Hardt et al. (2002), Evian et al. (2004) and Rosenberg et al. (2004). Both Evian et al. (2004) and Rosenberg et al. (2004) reported on absolute percentages for implant survival and success, respectively (i.e. the proportion of censored implants in the treated periodontitis and the non-periodontitis groups). Although the absolute values have been used in other implant literature (Albrektsson et al. 1986), this does not allow an evaluation of implant performance for a given time. Absolute values also tend to overestimate survival, because long-term failures are diluted by the early survival of recently placed implants (Eckert & Wollan 1998). Implant survival and success analysis should consider using analysis such as Kaplan & Meier (1958). Equally, peri-implantitis should be presented as incidence rates as shown in Karoussis et al. (2003), to take into account the time-to-event for the patient/implant concerned.

Most studies except Evian et al. (2004) and Roos-Jansåker et al. (2006a) on implant survival/success were analysed at the level of the implant rather than the patient. This has the risk of showing a more favourable result in comparison with patient/subject-based analysis because the prevalence calculated from implant-based data becomes diluted from the large number of implants included in the subject sample (Fransson et al. 2005). When a patient has two or more implants used for statistical analysis, each implant is not independent and this would have an effect on the survival confidence interval when performing survival analysis such as Kaplan–Meier (Chuang et al. 2001). Chuang et al. (2002) showed that the overall consequence is that by assuming independence of the clustered observations, the 95% confidence intervals for survival estimates were narrower than the dependence method estimates. In other words, the estimation of implant survival by assuming independence of clustered observations would risk spurious statistically significant findings.

Other methodological factors include presentation of the data for implant outcomes calculated from different baselines (e.g. implant placement, implant loading) as shown in Tables 3a and 3b. This makes comparison of data difficult when dissimilar baselines were used. Hence, data should be presented from both insertion and post-loading to account for all implants. If they were taken from post-loading, there is a risk of more favourable rates of outcomes (Morris & Ochi 2000).

Finally, smoking is a risk factor for peri-implant bone loss, and an elevated rate of implant failure has been associated with heavy smoking (Bain & Moy 1993, Wilson & Nunn 1999). However, some of the selected studies did not provide information regarding the smoking status of the patient population (Hardt et al. 2002, Evian et al. 2004, Rosenberg et al. 2004) and hence adjustment for this covariate in an analysis such as multi-variate analysis might not have taken place. Hence, the negative effect of smoking on implant outcomes cannot be excluded when interpreting the results.

Potential biases in the review process

We have attempted to limit the effect of publication bias by not setting language restrictions and by searching for unpublished studies, although no unpublished studies were found. Other aspects of quality assurance were independent and duplicate screening of study eligibility and the a priori establishment of the study protocol.

Comparison with other systematic reviews

A systematic review on this topic was reported by Van der Weijden et al.

(2005), who concluded that the outcome of implant therapy in periodontitis patients may be different compared with individuals without such a history as evidenced by loss of supporting bone and implant loss. Differences between this systematic review and the previous study are in terms of searching and screening of the articles and the inclusion criteria. More specifically, in Van der Weijden et al. (2005), searching of the articles was based on articles published in English from a single electronic database (MEDLINE) and explicitly included terms for periodontitis or periodontal diseases. The specific nature of their search strategy risked not retrieving studies where patients with periodontitis were included but were not the focus of the study. Furthermore, screening of the articles was carried out independently but the level of agreement was not reported. Although Van der Weijden et al. (2005) appraised the quality of the studies included, assessment of components of the study methodology shown to affect study outcomes was not reported. These differences between the two systematic reviews may have resulted in the identification of six other comparative studies in our review, providing further evidence of the difference between the two groups. Another systematic review by Schou et al. (2006) reviewed the outcome of implant therapy in patients with previous tooth loss due to periodontitis, a comparison between our review and Schou et al. (2006) could not be made due to the differences in our focused question. In our study, meta-analysis especially for the implant outcomes was not carried out due to marked heterogeneity as evident in many aspects of the study characteristics.

Conclusions

There is some evidence that patients who have been treated for periodontitis may experience more implant loss and complications around implants including higher bone loss and peri-implantitis than non-periodontitis patients. The strength of evidence is stronger for implant survival than implant success, although methodological issues limit the potential to draw robust conclusions. This evidence relates particularly to patients with chronic periodontitis and may also apply to patients with a history of aggressive periodontitis.

Recommendations for research

1. We recommend further emphasis on methodological quality including standardization of reporting, analysis of outcomes and protection from bias. Studies should have standardized assessment, masking of assessors (for subjective outcomes) or independent outcome assessors to minimize measurement bias and have a follow-up of at least 10 years (Karoussis et al. 2003 and Roos-Jansåker et al. 2006a, b). Investigations for the two groups of patients should adjust for confounding risk factors (e.g. smoking habits) using analysis such as multivariate analysis. Data analysis must also take into account dependence among clustered outcomes observations within patients, e.g. multilevel modelling (Gilthorpe et al. 2002) and the outcome measures should be presented as cumulative survival or success rates and incidence of peri-implantitis.
2. Standardization of the case definitions of treated periodontitis and non-periodontitis is needed to allow meaningful clinical use of such terms. We propose treated periodontitis to be defined as patients who, before implant placement, are in a supportive periodontal therapy programme with all sites showing probing depth of $\leqslant 5$ mm without BOP. If possible, subjects should have no evidence of progressive radiographic bone loss following completion of periodontal therapy. Conversely, non-periodontitis is defined as patients without a history, clinical or radiographic evidence of periodontitis.
3. A formal consensus on universally accepted implant success criteria should be established to allow standardized monitoring and comparisons between implant studies. Ideally, a systematic review to investigate the appropriate implant success criteria in evaluating the clinical performance of the implant under observation would be necessary to establish a standardized guideline. We suggest that the following outcome criteria should be considered:

- Absence of mobility, persistent subjective complaints (pain, foreign-body sensation and/or dysaesthesia), recurrent peri-implant infection with suppuration or a continuous radiolucency around the implant (Buser et al. 1990).
- No PPD >5 mm (Mombelli & Lang 1994, Bragger et al. 2001) or no PPD $\geqslant 5$ mm and BOP (Mombelli & Lang 1994). However, absolute PPD alone cannot be used as an indicator of a pathological condition, because additional factors such as tissue thickness and different abutment lengths may influence the PPD assessments around implants.
- After the first year of loading, the annual radiographic vertical bone loss should not exceed 0.2 mm (mesially or distally) (Albrektsson et al. 1986, Albrektsson & Isidor 1994).

4. Similarly, a formal consensus on universally accepted criteria for peri-implantitis should be established to allow standardized monitoring and comparisons between implant studies. We suggest that the criteria to be considered should include a combination of the definitions proposed by Albrektsson & Isidor (1994), Karoussis et al. (2003) and Roos-Jansåker et al. (2006b). This would be an incidence of PPD $\geqslant 5$ mm with BOP/suppuration and radiographic bone loss of $\geqslant 2.5$ mm or bone loss extending $\geqslant 3$ threads for a follow-up of at least 10 years as suggested from the data taken from the three studies.
5. Identify factors that affect the prognosis of implant outcomes in patients treated for periodontitis. This should include designing a well-controlled prospective clinical study in determining the influence of the quality and frequency of supportive periodontal therapy (for the dentition and implants) as well as the influence of genetic factors such as interleukin-1 polymorphism in the prognosis of implant outcomes in patients treated for periodontitis.

Recommendations for clinical practice

1. There is limited evidence that patients treated for periodontitis might experience more implant loss and complications around implants including higher bone loss and peri-implantitis than non-periodontitis patients. Consequently, appropriate

consent should be obtained before implant therapy.

2. Although there is no direct evidence to suggest the importance of supportive therapy for implants as for periodontally treated teeth, nevertheless, periodontal therapy has been suggested to precede implant therapy in partially dentate patients (van Steenberghe et al. 1993), while systematic and continuous monitoring of the periodontal and peri-implant tissue conditions is suggested to prevent recurrence of periodontal disease and allow early diagnosis and treatment of peri-implant diseases.

References of included studies and supporting references

Albrektsson, T. & Isidor, F. (1994) Consensus report of session IV. In: Lang, N. P. & Karring, T. (eds). *Proceedings of the 1st European Workshop on Periodontology*, pp. 365–369. London: Quintessence Publishing Co. Ltd.

Albrektsson, T., Zarb, G., Worthington, P. & Eriksson, A. R. (1986) The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *International Journal of Oral and Maxillofacial Implants* **1**, 11–25.

Apse, P., Ellen, R. P., Overall, C. M. & Zarb, G. A. (1989) Microbiota and crevicular fluid collagenase activity in the osseointegrated dental implant sulcus: a comparison of sites in edentulous and partially edentulous patients. *Journal of Periodontal Research* **24**, 96–105.

Armitage, G. C. (1999) Development of a classification system for periodontal diseases and conditions. *Annals of Periodontology* **4**, 1–6.

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

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.

Brägger, U. (1994) Maintenance, monitoring, therapy of failures. In: Lang, N. P. & Karring, T. (eds). *Proceedings of the 1st European Workshop on Periodontology*, pp. 345–364. London: Quintessence Publishing Co. Ltd.

Bragger, U., Aeschlimann, S., Burgin, W., Hammerle, C. H. & Lang, N. P. (2001) Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function. *Clinical Oral Implants Research* **12**, 26–34.

Brocard, D., Barthet, P., Baysse, E., Duffort, J. F., Eller, P., Justumus, P., Marin, P., Oscaby, F., Simonet, T., Benque, E. & Brunel, G. (2000) A multicenter report on 1,022 consecutively placed ITI implants: a 7-year longitudinal study. *International Journal of Oral and Maxillofacial Implants* **15**, 691–700.

Buser, D., Mericske-Stern, R., Bernard, J. P., Behneke, A., Behneke, N., Hirt, H. P., Belser, U. C. & Lang, N. P. (1997) Long-term evaluation of non-submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants. *Clinical Oral Implants Research* **8**, 161–172.

Buser, D., Weber, H. P. & Lang, N. P. (1990) Tissue integration of non-submerged implants. 1-year results of a prospective study with 100 ITI hollow-cylinder and hollow-screw implants. *Clinical Oral Implants Research* **1**, 33–40.

Chuang, S. K., Tian, L., Wei, L. J. & Dodson, T. B. (2001) Kaplan–Meier analysis of dental implant survival: a strategy for estimating survival with clustered observations. *Journal of Dental Research* **80**, 2016–2020.

Chuang, S. K., Tian, L., Wei, L. J. & Dodson, T. B. (2002) Predicting dental implant survival by use of the marginal approach of the semi-parametric survival methods for clustered observations. *Journal of Dental Research* **81**, 851–855.

Eckert, S. E. & Wollan, P. C. (1998) Retrospective review of 1170 endosseous implants placed in partially edentulous jaws. *Journal of Prosthetic Dentistry* **79**, 415–421.

Ellegaard, B., Baelum, V. & Karring, T. (1997) Implant therapy in periodontally compromised patients. *Clinical Oral Implants Research* **8**, 180–188.

Esposito, M., Coulthard, P., Thomsen, P. & Worthington, H. V. (2005a) Interventions for replacing missing teeth: different types of dental implants. *Cochrane Database of Systematic Reviews* **CD003815**.

Esposito, M., Gabriella Grusovin, M., Coulthard, P., Thomsen, P. & Worthington, H. V. (2005b) A 5-year follow-up comparative analysis of the efficacy of various osseointegrated dental implant systems: a systematic review of randomized controlled clinical trials. *International Journal of Oral and Maxillofacial Implants* **20**, 557–568.

Evian, C. I., Emling, R., Rosenberg, E. S., Waasdorp, J. A., Halpern, W., Shah, S. & Garcia, M. (2004) Retrospective analysis of implant survival and the influence of periodontal disease and immediate placement on long-term results. *International Journal of Oral and Maxillofacial Implants* **19**, 393–398.

Fransson, C., Lekholm, U., Jemt, T. & Berglundh, T. (2005) Prevalence of subjects with progressive bone loss at implants. *Clinical Oral Implants Research* **16**, 440–446.

Gilthorpe, M. S., Mayhew, M. T. & Bulman, J. S. (2002) Multilevel survival analysis of amalgam restorations amongst RAF personnel. *Community Dental Health* **19**, 3–11.

Hänggi, M. P., Hänggi, D. C., Schoolfield, J. D., Meyer, J., Cochran, D. L. & Hermann, J. S. (2005) Crestal bone changes around titanium implants. Part I: A retrospective radiographic evaluation in humans comparing two non-submerged implant designs with different machined collar lengths. *Journal of Periodontology* **76**, 791–802.

Hardt, C. R., Grondahl, K., Lekholm, U. & Wennström, J. L. (2002) Outcome of implant therapy in relation to experienced loss of periodontal bone support: a retrospective 5-year study. *Clinical Oral Implants Research* **13**, 488–494.

Isidor, F. (1996) Loss of osseointegration caused by occlusal load of oral implants. A clinical and radiographic study in Monkeys. *Clinical Oral Implants Research* **7**, 143–152.

Isidor, F. (1997) Histological evaluation of peri-implant bone at implants subjected to occlusal load or plaque accumulation. *Clinical Oral Implants Research* **8**, 1–9.

Kaplan, E. L. & Meier, P. (1958) Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association* **53**, 467–481.

Karoussis, I. K., Bragger, U., Salvi, G. E., Burgin, W. & Lang, N. P. (2004) 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 Implants Research* **15**, 8–17.

Karoussis, I. K., Salvi, G. E., Heitz-Mayfield, L. J., Bragger, U., Hammerle, 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 Implants Research* **14**, 329–339.

Khan, K. S., ter Riet, G., Popay, J., Nixon, J. & Kleijen, J. (2001) *Stage II: Conducting the review. Phase 5: Study quality assessment*, pp. 1–20. Centre for Reviews and Dissemination, University of York.

Lang, N. P. (1988) *Checklisten der Zahnmedizin*. Stuttgart: Georg Thieme Verlang.

Lang, N. P., Wilson, T. G. & Corbet, E. F. (2000) Biological complications with dental implants: their prevention, diagnosis and treatment. *Clinical Oral Implants Research* **11** (Suppl. 1), 146–155.

Lekholm, U. & Zarb, G. A. (1985) Patient selection and preparation. In: Branemark, P. I., Zarb, G. A. & Albrektsson, T. (eds). *Tissue-Integrated Prostheses. Osseointegration in Clinical Dentistry*, pp. 199–210. Chicago: Quintessence.

Leonhardt, A., Adolfsson, B., Lekholm, U., Wikstrom, M. & Dahlen, G. (1993) A longitudinal microbiological study on osseointegrated titanium implants in partially edentulous patients. *Clinical Oral Implants Research* **4**, 113–120.

Löe, H. & Silness, J. (1963) Periodontal disease in pregnancy. I. Prevalence and severity. *Acta Odontologica Scandinavica* **21**, 533–551.

Mengel, R. & Flores-de-Jacoby, L. (2005) Implants in patients treated for generalized

aggressive and chronic periodontitis: a 3-year prospective longitudinal study. *Journal of Periodontology* **76**, 534–543.

Misch, C. E. (1990) Density of bone: effect on treatment plans, surgical approach, healing, and progressive loading. *International Journal of Oral Implantology* **6**, 23–31.

Moher, D., Cook, D. J., Jadad, A. R., Tugwell, P., Moher, M., Jones, A., Pham, B. & Klassen, T. (1999) Assessing the quality of reports of randomised trials: implications for the conduct of meta-analyses. *Health Technology Assessment* **3**, i–98.

Mombelli, A. & Lang, N. P. (1994) Clinical parameters for the evaluation of dental implants. *Periodontology 2000* **4**, 81–86.

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

Mombelli, A., Marxer, M., Gaberthuel, T., Grunder, U. & Lang, N. P. (1995) The microbiota of osseointegrated implants in patients with a history of periodontal disease. *Journal of Clinical Periodontology* **22**, 124–130.

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.

Morris, H. F. & Ochi, S. (2000) Influence of two different approaches to reporting implant survival outcomes for five different prosthodontic applications. *Annals of Periodontology* **5**, 90–100.

Nevins, M. & Langer, B. (1995) The successful use of osseointegrated implants for the treatment of the recalcitrant periodontal patient. *Journal of Periodontology* **66**, 150–157.

Papaioannou, W., Quirynen, M. & van Steenberghe, D. (1996) The influence of periodontitis on the subgingival flora around implants in partially edentulous patients. *Clinical Oral Implants Research* **7**, 405–409.

Quirynen, M., Vogels, R., Peeters, W., van Steenberghe, D., Naert, I. & Haffajee, A. (2006) Dynamics of initial subgingival colonization of 'pristine' peri-implant pockets. *Clinical Oral Implant Research* **17**, 25–37.

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

Rosenberg, E. S., Cho, S. C., Elian, N., Jalbout, Z. N., Froum, S. & Evian, C. I. (2004) A comparison of characteristics of implant failure and survival in periodontally compromised and periodontally healthy patients: a clinical report. *International Journal of Oral and Maxillofacial Implants* **19**, 873–879.

Schou, S., Holmstrup, P., Worthington, H. V. & Esposito, M. (2006) Outcome of implant therapy in patients with previous tooth loss due to periodontitis. *Clinical Oral Implant Research* **17** (Suppl. 2), 104–123.

Silness, J. & Löe, H. (1964) Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontologica Scandinavica* **22**, 121–135.

Spiekermann, H., Jansen, V. K. & Richter, E. J. (1995) A 10-year follow-up study of IMZ and TPS implants in the edentulous mandible using bar-retained overdentures. *International Journal of Oral and Maxillofacial Implants* **10**, 231–243.

Van der Weijden, G. A., van Bemmel, K. M. & Renvert, S. (2005) Implant therapy in partially edentulous, periodontally compromised patients: a review. *Journal of Clinical Periodontology* **32**, 506–511.

van Steenberghe, D., Klinge, B., Linden, U., Quirynen, M., Herrmann, I. & Garpland, C. (1993) Periodontal indices around natural and titanium abutments: a longitudinal multicenter study. *Journal of Periodontology* **64**, 538–541.

Watson, C. J., Tinsley, D. & Sharma, S. (1999) Implant complications and failures: the single-tooth restoration. *Dental Update* **27**, 35–38.

Wennstrom, J. & Palmer, R. (1999) Consensus report: clinical trials. In: Lang, N. P. & Karring, T. (eds). *Proceedings of the 3rd European workshop on Periodontology*, pp. 255–259. London: Quintessence Publishing Co. Ltd.

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

Address:
Professor Nikolaos Donos
Unit of Periodontology
UCL Eastman Dental Institute
256 Gray's Inn Road
London WC1X 8LD
UK
E-mail: n.donos@eastman.ucl.ac.uk

Clinical Relevance

Scientific rationale for the study: Some evidence exists that susceptibility to periodontitis confers an increased risk of biological complications around implants but the consistency and quality of the evidence are unclear. This systematic review was carried out to determine the implant outcomes in partially dentate patients treated for periodontitis compared with patients who were periodontally healthy.

Principal findings: There is limited evidence that patients treated for periodontitis may experience more implant loss and implants complications than non-periodontitis patients.

Practical implications: In clinical practice, patients treated for periodontitis who require implant therapy would need to give consent of understanding the possible effects of periodontitis on implant therapy.

Supplementary Material

The following material is available for this article online:

Table S1. Excluded studies and main reason for exclusion.

This material is available as part of the online article from: http://www.blackwell-synergy.com/doi/abs/10.1111/j.1600-051X.2008.01207.x (This link will take you to the article abstract).

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