



University of Zurich
Zurich Open Repository and Archive

Winterthurerstr. 190
CH-8057 Zurich
<http://www.zora.uzh.ch>

Year: 2008

A systematic review of the 5-year survival and complication rates of implant-supported single crowns

Jung, R E; Pjetursson, B E; Glauser, R; Zembic, A; Zwahlen, M; Lang, N P

Jung, R E; Pjetursson, B E; Glauser, R; Zembic, A; Zwahlen, M; Lang, N P (2008). A systematic review of the 5-year survival and complication rates of implant-supported single crowns. *Clinical Oral Implants Research*, 19(2):119-130.

Postprint available at:
<http://www.zora.uzh.ch>

Posted at the Zurich Open Repository and Archive, University of Zurich.
<http://www.zora.uzh.ch>

Originally published at:
Clinical Oral Implants Research 2008, 19(2):119-130.

A systematic review of the 5-year survival and complication rates of implant-supported single crowns

Abstract

OBJECTIVES: The objective of this systematic review was to assess the 5-year survival of implant-supported single crowns (SCs) and to describe the incidence of biological and technical complications. **METHODS:** An electronic MEDLINE search complemented by manual searching was conducted to identify prospective and retrospective cohort studies on SCs with a mean follow-up time of at least 5 years. Failure and complication rates were analyzed using random-effects Poisson's regression models to obtain summary estimates of 5-year proportions. **RESULTS:** Twenty-six studies from an initial yield of 3601 titles were finally selected and data were extracted. In a meta-analysis of these studies, survival of implants supporting SCs was 96.8% [95% confidence interval (CI): 95.9-97.6%] after 5 years. The survival rate of SCs supported by implants was 94.5% (95% CI: 92.5-95.9%) after 5 years of function. The survival rate of metal-ceramic crowns, 95.4% (95% CI: 93.6-96.7%), was significantly ($P=0.005$) higher than the survival rate, 91.2% (95% CI: 86.8-94.2%), of all-ceramic crowns. Peri-implantitis and soft tissue complications occurred adjacent to 9.7% of the SCs and 6.3% of the implants had bone loss exceeding 2 mm over the 5-year observation period. The cumulative incidence of implant fractures after 5 years was 0.14%. After 5 years, the cumulative incidence of screw or abutment loosening was 12.7% and 0.35% for screw or abutment fracture. For supra-structure-related complications, the cumulative incidence of ceramic or veneer fractures was 4.5%. **CONCLUSION:** It can be concluded that after an observation period of 5 years, high survival rates for implants and implant-supported SCs can be expected. However, biological and particularly technical complications are frequent.

A systematic review of the survival and complication rates of implant supported single crowns after an observation period of at least 5 years

Ronald E. Jung¹, Bjarni E. Pjetursson², Roland Glauser³, Anja Zembic¹, Marcel Zwahlen⁴ and Niklaus P. Lang¹

- 1) Department of Fixed and Removable Prosthodontics and Dental Material Science, University of Zurich, Switzerland
- 2) University of Berne School of Dental Medicine, Berne, Switzerland
- 3) Private Practice, Zürich, Switzerland
- 4) Division of Epidemiology and Biostatistics, Department of Social and Preventive Medicine, University of Berne, Bern, Switzerland

Running head: Systematic review of SCs.

Key words: Implant dentistry, single crowns, systematic review, survival, success, longitudinal, failures, complication rates, technical complications, biological complications, periimplantitis.

Address for correspondence: Dr. Ronald E. Jung
Department of Fixed and Removable Prosthodontics and Dental Material Science
Dental School, University of Zurich
Plattenstrasse 11
CH-8032 Zurich, Switzerland
Phone: +41 44 634 32 51
Fax: +41 44 634 43 05
e-mail: jung@zzmk.unizh.ch

Abstract

Objectives:

The objective of this systematic review was to assess the 5 year survival of implant supported single crowns (SCs) and to describe the incidence of biological and technical complications.

Methods:

An electronic Medline search complemented by manual searching was conducted to identify prospective and retrospective cohort studies on SCs with a mean follow-up time of at least 5 years. Failure and complication rates were analyzed using random-effects *Poisson* regression models to obtain summary estimates of 5-year proportions.

Results:

Twenty-six studies from an initial yield of 3601 titles were finally selected and data were extracted. In a meta-analysis of these studies survival of implants supporting SCs was 96.8% (95 percent confidence interval (C.I.): 95.9-97.6%) after 5 years. The survival rate of SCs supported by implants was 94.5% (95 CI: 92.5-95.9%) after 5 years of function. The survival rate of metal-ceramic crowns, 95.4% (95 CI: 93.6-96.7%) was significantly ($p=0.005$) higher than the survival rate, 91.2% (95 CI: 86.8-94.2%) of all-ceramic crowns.

Periimplantitis and soft tissue complications occurred in 9.7% of the SCs and 6.3% of the implants had bone loss exceeding 2 mm over the 5 years observation period. Technical complications included implant fractures, connection-related and supra-structure related complications. The cumulative incidence of implant fractures after 5 years was 0.14%. After 5 years the cumulative incidence of connection-related complications was 12.7% for screw or abutment loosening and 0.35% for screw or abutment fracture. For supra-structure related complications the cumulative incidence of ceramic or veneer fractures was 4.5%.

Conclusion:

Despite of high survival rates for implants and implant supported single crowns, biological and particularly technical complications are frequent. To describe and compare the long-term outcomes of implant supported SCs more studies with follow-up times of at least 10 years are required.

Introduction

The range of indications in implant dentistry was broadened in the past decades from fully edentulous to partially edentulous jaws. The therapy of single tooth gaps has become a frequent and important indication in current dentistry. A variety of therapeutic options are available to restore a single tooth gap. These therapies range from resin-bonded bridges, to fixed partial dentures up to the use of implant supported single crowns (Kerschbaum et al. 1996; Palmqvist & Swartz 1993; Romeo et al. 2004). Decision making in these indications should be based on clinical and radiographic assessments and on the knowledge of the long-term survival and complication rates of each of these therapeutic options.

The outcome of implant therapy has been presented in the majority of clinical studies by focusing only on implant survival without providing detailed information on the reconstructions (e.g. Buser et al. 1996; Vigolo & Givani 2000; Romeo et al. 2004). However, for decision making it is important to know the survival proportions and the determination of the incidence of biological and technical complications not only for the implants but also for the reconstructions. In addition, for a meaningful interpretation of the survival and complication rate a mean follow-up period of at least 5 years would be required (Pjetursson et al. 2004).

In order to evaluate the outcome of a treatment modality on the highest level of evidence the use of systematic reviews has been proposed to be an appropriate method (Egger et al. 2001). Hence, systematic reviews are employed in medicine and dentistry to summarize cumulative information on the optimal treatment for clinically important questions.

Recent systematic reviews have evaluated the survival of tooth and implant supported reconstructions of different design and described the incidence of biological and technical complications after an observation period of at least 5 years (Lang et al. 2004; Pjetursson et al. 2004a; Pjetursson et al. 2004b; Tan et al. 2004). It was demonstrated that after 5 years of service, the survival of fixed partial dentures (FPD) with two different designs ranged from 92.5% for cantilever FPDs to 93.8% for conventional FPDs (Lang et al. 2004; Pjetursson et al. 2004).

In order to compare the results of survival and complication rates for tooth supported FPDs to optional treatments like the use of resin-bonded bridges and implant supported single crowns it would be of great importance to perform systematic reviews based on the same level of evidence and accomplished in exactly the same way. The therapeutic effectiveness of single-tooth replacements with implant borne reconstructions has been demonstrated in several studies (e.g. Henry et al. 1996; Avivi-Arber & Zarb 1996). However, the longevity of implant-supported single-tooth crowns has not yet been reviewed systematically.

Hence, the objective of the present systematic review was to assess the 5-year survival of implant supported single crowns (SCs) and to describe the incidence of biological and technical complications.

Materials and methods

Search strategy and study selection

A MEDLINE search from 1966 up to and including July 2006 was conducted for English-, and German-language articles in Dental Journals using the following search terms (modified from Berglundh et al. 2002) and limited to human trials: “implants” and “survival”, “implants” and “survival rate”, “implants” and “survival analysis”, “implants” and “cohort studies”, “implants” and “case control studies”, “implants” and “controlled clinical trials”, “implants” and “randomized controlled clinical trials”, “implants” and “complications”, “implants” and “clinical”, “implants” and “longitudinal”, “implants” and

“prospective”, “implants” and “retrospective”. Additional search strategies included the terms “single-tooth”, “failure”, “peri-implantitis”, “fracture”, “complication”, “technical complication”, “biological complication”, “screw loosening” and “maintenance”.

Manual searches of the bibliographies of all full-text articles and related reviews, selected from the electronic search were also performed.

Furthermore, manual searching was conducted to the following journals from 1966 (or for newer Journals since the appearance of the first issue) up to and including July 2006: *American Journal of Dentistry*, *Australian Dental Journal*, *British Journal of Oral & Maxillofacial Surgery*, *Clinical Implant Dentistry & Related Research*, *Clinical Oral Implants Research*, *Deutsche Zahnärztliche Zeitschrift*, *European Journal of Oral Sciences*, *International Dental Journal*, *International Journal of Oral & Maxillofacial Implants*, *International Journal of Periodontics & Restorative Dentistry*, *International Journal of Prosthodontics*, *Journal de Parodontologie*, *Journal of Clinical Periodontology*, *Journal of Dental Research*, *Journal of Oral Implantology*, *Journal of Oral Rehabilitation*, *Journal of Periodontology*, *Journal of Prosthetic Dentistry*, *Quintessence International*, *Swedish Dental Journal*, *Schweizerische Monatsschrift Zahnmedizin*.

From this extensive search, it was obvious that there were no randomized controlled clinical trials (RCTs) available comparing implant therapy with conventional reconstructive dentistry.

Inclusion criteria

In the absence of RCTs, this systematic review was based on prospective or retrospective cohort studies. The additional inclusion criteria for study selection were:

- that the studies had a mean follow-up time of 5 years or more,

- that the publications reported in English or German and in the Dental literature,
- that the included patients had been examined clinically at the follow-up visit, i.e. publications based on patient records only, on questionnaires or interviews were excluded.
- that the studies reported details on the characteristics of the suprastructures.
- publications that combined findings for both implant-supported FPDs and single-tooth crowns allowed for extraction of the data for the group of STCs

Selection of studies

Titles and abstracts of the searches were initially screened by two independent reviewers (R.G., R.E.J. or A.Z.) for possible inclusion in the review. The full text of all studies of possible relevance was then obtained for independent assessment by the two reviewers. Any disagreement was resolved by discussion.

Figure 1 describes the process of identifying the 26 studies selected from an initial yield of 3601 titles. Data were extracted independently by two reviewers using a data extraction form. Disagreement regarding data extraction was resolved by consensus.

Excluded Studies

Of the 54 full text articles examined, 28 were excluded from the final analysis (see reference list).

The main reasons for exclusion were a mean observation period of less than 5 years, no distinction between the type of reconstructions or between

totally/partially edentulous patients and single tooth reconstructions, and no data available with respect to characteristics of the reconstruction.

Data extraction

Of the included 26 studies information on the survival proportions of the reconstructions and on biological and technical complications was retrieved. Biological complications included disturbances in the function of the implant characterized by a biological process affecting the supporting tissues. “Periimplantitis” and “soft tissue complications” were included in this category.

Technical complications denoted mechanical damage of implants, implant components and/or the suprastructures. Among these, “fractures of the implants, screws or abutments”, “fractures of the luting cement” (loss of retention), “fractures or deformations of the framework or veneers”, “loss of the screw access hole restoration” and “screw or abutment loosening” were included. From the included studies the number of events for all of these categories were abstracted and the corresponding total exposure time of the reconstruction was calculated.

Statistical analysis

By definition, failure and complication rates are calculated by dividing the number of events (failures or complications) in the numerator by the total exposure time (SC-time and/or implant-time) in the denominator.

The numerator could usually be extracted directly from the publication. The total exposure time was calculated by taking the sum of:

- 1) Exposure time of SCs/implants that could be followed for the whole observation time.
- 2) Exposure time up to a failure of the SCs/implants that were lost due to failure during the observation time

- 3) Exposure time up to the end of observation time for SCs/implants that did not complete the observation period due to reasons such as death, change of address, refusal to participate, non-response, chronic illnesses, missed appointments and work commitments.

For each study, event rates for SCs and/or implants were calculated by dividing the total number of events by the total SCs or implant exposure time in years. For further analysis, the total number of events was considered to be Poisson distributed for a given sum of implant exposure years and Poisson regression with a logarithmic link-function and total exposure time per study as an offset variable were used (Kirkwood & Sterne 2003).

Robust standard errors were calculated to obtain 95 percent confidence intervals of the summary estimates of the event rates. To assess heterogeneity of the study specific event rates, the Spearman goodness-of-fit statistics and associated p-value were calculated. If the goodness-of-fit p-value was below 0.05, indicating heterogeneity, random-effects Poisson regression (with Gamma-distributed random-effects) was used to obtain a summary estimate of the event rates. Five year and ten year survival proportions were calculated via the relationship between event rate and survival function S , $S(T) = \exp(-T * \text{event rate})$, by assuming constant event rates (Kirkwood & Sterne 2003). The 95 percent confidence intervals for the survival proportions were calculated by using the 95 percent confidence limits of the event rates.

Multivariable Poisson regression was used to investigate formally whether event rates varied by crown material (metal-ceramic versus all-ceramic) or crown design (cemented versus screw retained).

All analyses were performed using Stata®, version 8.2.

Results

Included studies

A total of 26 studies of implant supported single crowns (SCs) were included in the analysis. The characteristics of the selected studies are shown in Table 1.

All of the studies were published within the past ten years. Twenty-one of the studies were prospective and the five remaining were retrospective studies (Table 1).

The studies included patients between the age of 13 and 94 years and the total number of inserted implants was 1558 (Table 2). The proportion of patients who could not be followed for the complete study period was available for 21 of the studies and ranged from 0 to 30%.

In 19 of the studies (Henry et al. 1996, Scheller et al. 1998, Andersson et al.1998, Andersson et al.1998, Polizzi et al.1999, Thilander et al. 1999, Palmer et al. 2000, Mericske-Stern et al. 2001, Gibbard & Zarb 2002, Haas et al. 2002, Andersen et al. 2002, Gotfredsen 2004, (Group B), Romeo et al. 2004, Bernard et al. 2004, Taylor et al. 2004, Brägger et al. 2005, Bornstein et al. 2005 and Wennström et al. 2005, Levin et al. 2005, (26 out of 52)) the implants were placed by using standard surgical protocol in a healed implant site (Type III or IV, Hämmerle et al. 2004). In two studies (Gotfredsen 2004 (Group A) and Vigolo & Givani 2000) an "early" implant placement (Type II) was performed and in other three studies (Bianchi & Sanfilippo 2004, Levin et al. 2005 (26 out of 52) and Wagenberg & Froum 2006) immediate implant placement (Type I) was performed. In the three remaining studies, guided bone regeneration (GBR) was performed in combination (de Boever & de Boever 2005) or prior to the implant insertion (Buser et al. 1996, Jemt & Lekholm 2005).

Several of the studies addressed some special issues, such as implants that were loaded after only 6 weeks (Bornstein et al. 2005) or implants that were loaded immediately after placement (Andersen et al. 2002). Moreover, two

studies reported on small-diameter implants, where implants with diameter of 3.0mm (Polizzi et al.1999) and 2.9mm (Vigolo & Givani 2000) were used to support single crowns. Andersson et al. (1998) compared implants placed by general practitioners to implants placed at a specialist clinic. In one study, (Taylor et al. 2004) the patients were randomized into three groups that received different implant designs; Biolok® titanium cylinder-type, Biolok® titanium screw-type or Biolok® hydroxyapatite-coated cylinder-type implant.

The studies reported on four commercially available implant systems: Astra® Tech Implants Dental System (Astra®Tech AB, Mölndal, Sweden), Brånemark® System (Nobel Biocare AB, Göteborg, Sweden), ITI® Dental Implant System (Straumann AG, Waldenburg, Switzerland) and 3i® Implants (Implant Innovations, Palm Beach Gardens, Florida, USA), Biolok® Implants (Biolok, Deerfield, Florida, USA). One out of all included studies did not report the commercial name of the implant system that has been used (Levin et al. 2005).

The studies were mainly conducted in an institutional environment, such as university or specialized implant clinics. Two of the studies were multi-center studies.

The 26 studies included a total of 1530 SCs. Fifteen of the studies reported on crown material, 75% of the crowns were metal-ceramic, 18% were all-ceramic while the remainder were of gold-acrylic design. Only 12% of the crowns were screw retained and 88% were cemented (Table 2).

Fifteen studies reported on patient cohorts in which all the patients were followed for the same observation period and the other 11 studies represented studies with variable individual observation periods ranging from 1 to 16 years (Table 2).

Implant survival

All of the 26 studies reported on the survival of the implants (Table 3). Of the originally 1558 implants placed, 54 implants were known to be lost. Thirty or

1.9% of the inserted implants were lost prior to functional loading and the remaining 24 implants were lost in function. For failures after loading, the estimated annual failure rate was 0.28 (95 percent C.I.: 0.14 – 0.59).

The study specific 5-year survival proportion varied between 90.5-100% (Table 3) and the estimated failure rate per 100 implant years ranged from 0 to 2.00 (Fig. 2). In meta-analysis, a failure rate of 0.64 failures per 100 implant years (95 percent C.I.: 0.49 – 0.84) was estimated (Fig 2), and a survival rate after 5-years for implants supporting SCs of 96.8% (95 percent C.I.: 95.9% - 97.6%) (Table 3).

SC survival

SC survival was defined as the SCs remaining in-situ with or without modification for the observation period. Thirteen studies with a total of 534 SCs provided data on the survival of the reconstructions after a mean follow-up time of 5 years (Table 4).

Thirty-three out 534 SCs were lost and the study specific 5-year survival varied between 89.6% and 100% (Table 4). Fifteen out of the 33 SCs were lost while the supporting implants were lost but in the remaining 18 cases only the reconstructions failed. The failure rate per 100 SC years ranged from 0.0 to 2.19 (Fig. 3) and, in meta-analysis, we estimated an annual failure rate of 1.14% (95 percent C.I.: 0.83 – 1.56) (Fig. 3) translating into a survival after 5 years for implant supported SCs of 94.5% (95 percent C.I.: 92.5% - 95.9%) (Table 4).

The studies were also divided according to the material utilized: A group of seven studies with a total of 236 metal-ceramic crowns and a group of two studies with a total of 162 all-ceramic crowns. The group with metal-ceramic crowns showed a significantly higher ($p=0.005$) survival rate. The stratified summary estimates of the survival proportion after 5 years were 95.4% (95 percent C.I.: 93.6% - 96.7%) for the metal-ceramic crowns and 91.2% (95 percent C.I.: 86.8% - 94.2%) for the all-ceramic crowns.

Biological complications

Peri-implant mucosal lesions were reported, in ten studies, but in various ways by the different authors. Two studies (Henry et al. 1996 and Scheller et al. 1998) used the general term "soft tissue complications", other four studies reported on "signs of inflammation" (Gibbard & Zarb 2002), "gingival inflammation" (Vigolo & Givani 2000), "gingivitis" (Andersen et al. 2002) or "bleeding" (Andersson et al. 1998). Brägger et al. (2005) reported on "peri-implantitis" defined as probing pocket depth (PPD) \geq 5mm combined with bleeding on probing (BOP) or pus secretion and Gotfredsen (2004) described cases with "soft tissue dehiscence". Other studies (Henry et al. 1996, Andersson et al. 1998, Andersen et al. 2002 and Gotfredsen 2004) reported on fistula formation.

In a *random-effects* Poisson-model analysis, the estimated cumulative rate of various peri-implant mucosal lesions after 5 years was 9.7% (95 percent C.I.: 5.1% - 17.9%) (Table 5).

Ten studies, evaluated changes in marginal bone height, evaluated on radiographs, over the observation period. In meta-analysis, the cumulative rate of implants having bone loss exciding 2 mm after 5 was 6.3% (95 percent C.I.: 3.0% - 13.0%) (Table 5).

Multivariable Poisson regression was used to investigate formally whether incidence of soft tissue complications and incidence of bone loss $>$ 2 mm varied between cemented and screw retained crowns. No significant difference ($p= 0.42$ and $p=0.84$) was detected regarding influence of crown design on these biological complications.

Esthetic

Seven studies reported on the esthetic out-come of the treatment. The esthetic appearance was evaluated either by dental professionals (Levin et al. 2005; Bernard et al. 2004; Haas et al. 2002; Gibbard & Zarb 2002; Andersson et al. 1998; Andersson et al. 1998; Henry et al. 1996) or by the patient himself

(Gibbard & Zarb 2002). In a meta-analysis, the cumulative rate of crowns having unacceptable or semi-optimal esthetic appearance was 8.7% (95 percent C.I.: 3.2% - 22.6%) (Table 5).

Technical complications

The most common technical complication, abutment or occlusal screw loosening, was reported in 13 studies and its cumulative incidence after 5 years of follow-up was 12.7% (95 percent C.I.: 5.7%- 27.0%) (Table 6). In this aspect one study (Henry et al. 1996), reporting on single crowns on Brånemark implants that were tightened with gold-screws, was a clear outlier. If this study is excluded from the analysis the cumulative incidence goes down to 5.8% (95 percent C.I.: 2.9%- 11.5%).

The second most common technical complication, fractures of the luting cement (loss of retention), was reported in 6 studies and its cumulative incidence after 5 years was 5.5% (95 percent C.I.: 2.2%- 13.5%) (Table 6).

The third most common technical complication was fracture of a veneer material (ceramic or acrylic). After 5 years, 4.5% (95 percent C.I.: 2.4% - 8.4%) of the crowns had some kind of fracture or chipping of the veneer material (Table 6). Fracture of the crown framework (coping) was reported in 7 studies, and its cumulative incidence after 5 years was 3.0% (95 percent C.I.: 1.1%- 8.3%) (Table 6). This technical complication was significantly higher ($p=0.016$) in studies reporting on all-ceramic crowns.

Fractures of components; implants, abutments and occlusal screws, were rare complications. The cumulative incidence of abutment or screw fracture was 0.35% (95 percent C.I.: 0.09% - 1.4%) and the cumulative incidence of implant fracture was only 0.14% (95 percent C.I.: 0.03% - 0.64%) after a follow-up time of 5 years.

Discussion

This systematic review is part of a series of systematic reviews addressing the survival and complication rates of different treatment options for the therapy of partially edentulous jaws (Lang et al. 2004; Pjetursson et al. 2004a; Pjetursson et al. 2004b; Tan et al. 2004). It was demonstrated that implant supported single tooth crowns show a high survival rate after 5 years but also a particularly high rate of biological and most notably technical complications.

A single tooth gap can possibly be treated by a conventional fixed partial denture (FPD), a FPD with a cantilever or an implant supported single tooth crown (SC). In order to compare these treatment modalities randomized, controlled clinical trials (RCTs) would be the most favorable study designs. However, no RCTs were available comparing these different treatment modalities. In absence of RCTs, a lower level of evidence, i.e., prospective and retrospective cohort studies were included in the present systematic review. In multiple clinical indications it is of great importance to compare and to evaluate the different treatment modalities in order to choose the appropriate treatment and to properly advise the patient. Therefore, the different above mentioned systematic reviews were performed based on the same criteria, including prospective and retrospective studies with an observation period of at least 5 years.

It can be argued that a follow-up period of 5 years is too short to obtain reliable information on survival rates and complication rates. Due to the fact that all the studies included in the present review were published within the last ten years and more than one-third within the last 2 years indicates, that the use of dental implants to support SCs is relatively new. Hence, a mean follow-up period of at least 5 years was a necessary compromise. In contrast, 10 years studies on the longevity of conventional FPDs date back to the 1980s and 1990s, and there is a paucity of studies performed in the new century (Tan et al. 2004). Consequently, caution must be exercised to the comparison of technical complications (i.e. veneer fractures) of conventional FPDs made more than 20 years ago and implant supported SCs made 5-10 years ago. The majority of the studies on conventional FPDs reported on

gold-acrylic FPDs whereas the implant supported SCs are mainly made of metal-ceramic.

Implant survival

The present systematic review revealed a survival rate of 96.8% for implants supporting single tooth crowns after an observation period of at least 5 years. This evidence derived from 26 studies including 1558 placed implants. The evaluation of 15 studies on implant supported FPD including 3549 originally placed implants estimated an implant survival rate of 95.4% (95% CI: 93.9-96.5%) after 5 years (Pjetursson et al. 2004). This indicates that implant survival after 5 years seems to be slightly higher for implants supporting SCs compared to implants supporting FPDs. In agreement with previous systematic reviews on the outcome of dental implants the present study revealed that approximately half of the implants were lost prior to functional loading (Berglundh et al. 2002; Pjetursson et al. 2004). However, it was reported that the percentage of single tooth implants lost before loading decreased when “immediate placement following tooth extraction”, “early loading” and “ridge augmentation procedures” were excluded for the analysis of single tooth implants (Berglundh et al. 2002).

Single crown survival

In the present study, the survival rate of the implant supported single tooth crowns was 94.5% after 5 years. This evidence derived from 13 studies including 534 implant supported SCs. The analysis of 1289 implant supported FPDs demonstrated a very similar survival proportion after 5 years of 95% (95% CI: 92.2-96.8%). In order to compare the different treatment modalities for a single tooth gap the outcome for the implant supported SCs must be compared to the outcomes of conventional and cantilever FPDs. The meta-analysis of a total number of 2881 conventional FPDs indicated an estimated survival of 93.8% (95% CI: 87.9%-96.9%) after 5 years and 89.1% (95% CI: 81.0%-93.8%) after 10 years (Tan et al. 2004). The estimated survival of 671 cantilever FPDs was 92.5% (95% CI: 87.3%- 95.7%) after 5 and 81.8% (95% CI: 78.2%-84.9%) after 10 years (Pjetursson et al. 2004). Comparing the

survival rates after 5 years the values for the implant supported SCs are very similar to the ones from the conventional FPDs and slightly better compared to the cantilever FPDs. For the implant supported FPDs and the cantilever FPDs the failure proportion increased over the second five-year period (Pjetursson et al. 2004a and b). Therefore, it would be of great importance to gather long-term data for the implant supported SCs.

The present study additionally evaluated the influence of the crown material on the survival rate. It was demonstrated that metal-ceramic crowns (95.4%) showed a statistically significant higher survival rate compared to all-ceramic crowns (91.2%). These values for all-ceramic implant crowns were similar to the values of a recent systematic review evaluating all-ceramic crowns on tooth abutments (Wassermann et al. 2006). In 12 included studies, a total number of 1724 In-Ceram Alumina crowns were observed over a minimum period of 1.3 months up to a maximum period of 100 months. Survival rates ranged from 86.5% to 100%. They reported a cumulative survival rate according to the Kaplan-Meier method for In-Ceram Alumina crowns of 92% after 5 years.

Biological complications

The most frequent biologic complications for implant supported SCs are peri-implant mucosal lesions (9.7% after 5 years). This value is similar to the pooled cumulative survival rate of biological complications after 5 years (8.6% [95% CI: 5.1-14.1%]) for patients treated with implant supported FPDs (Pjetursson et al. 2004).

In the present study, it was demonstrated that the crown design (screw retained vs. cemented) did not have an influence on these biological complications. This finding is in agreement with a clinical study evaluating the peri-implant microflora of implants with cemented and screw retained suprastructures (Keller et al. 1998). It was concluded that impact of the dental microflora on the microbial colonization of the implants appears to be more important than the mode of fixation of the suprastructure.

Comparing implant supported SCs with tooth supported FPDs the latter showed more biologic complications. It was reported that about 10% of the tooth abutment lost vitality after 10 years and about 9.1-9.5% revealed caries on the tooth abutments (Pjetursson et al. 2004; Tan et al. 2004). Regarding the therapeutic consequences of these biologic complications the treatment of non-vital teeth and caries is generally more technique sensitive and more time consuming than the local treatment of the majority of the described peri-implant mucosal lesions.

Esthetic

Although, the esthetic outcome has become a main focus of interest in partially edentulous patients only 7 out of 26 of the included studies evaluated the esthetic appearance of implant supported SCs. The cumulative rate of crowns having unacceptable or semi-optimal esthetic appearance was 8.7%. This value is difficult to interpret because of a lack of standardized esthetic criteria and the fact that either dental professionals or the patients have evaluated the esthetic outcome. Hence, there is a need for widely accepted and reproducible esthetic scores not only for the evaluation of teeth but also for the peri-implant soft tissues (Fürhauser et al. 2005).

Technical complications

The distribution of the technical complications regarding implant supported FPDs versus SCs were found to be different. For implant supported SCs the incidence of abutment or screw loosening (12.7% after 5 years) was about two-times higher compared to implant supported FPDs revealing 5.8% abutment or screw loosening after 5 years (Pjetursson et al. 2004). However, it must be emphasized that one study using an old gold-screw design was mainly responsible for the high number of screw loosening (Henry et al. 1996). Excluding this study from the analysis the cumulative incidence decreases to 5.8%. Hence, this value is very similar to the incidence reported for implant supported FPDs. Regarding the incidence of veneer fractures implant supported FPDs demonstrated after 5 years approximately 3-times more complications (13.2%) compared to SCs (4.5%) (Pjetursson et al. 2004).

This difference might be explained by the high number of veneer fractures of FPDs with a gold framework and acrylic veneers compared to the SCs mainly made of metal-ceramics.

Comparing tooth supported FPDs with implant supported SCs the incidence of technical complications are generally smaller for conventional FPDs (9.6%) than for SCs (22.7%) (Tan et al. 2004). The therapeutic consequences of these complications have not yet been systematically evaluated. However, it might be speculated that a loss of retention is in the majority of the situations more difficult to treat for a tooth supported FPD than for an implant supported SC.

Conclusion

Despite of high survival rates for implants and implant supported single crowns, biological and particularly technical complications are frequent. This, in turn, means that substantial amounts of chair time have to be accepted by the clinician following the incorporation of implant supported SCs. More studies with follow-up times of 10 and more years are needed to describe the long-term outcomes of implant supported SCs.

References

- Andersen, E., Haanaes, H.R. & Knutsen, B.M. (2002) Immediate loading of single-tooth ITI implants in the anterior maxilla: a prospective 5-year pilot study. *Clinical Oral Implants Research* **13**: 281-7.
- Andersson, B., Odman, P., Lindvall, A.M. & Branemark, P.I. (1998) Cemented single crowns on osseointegrated implants after 5 years: results from a prospective study on CeraOne. *The International Journal of Prosthodontics* **11**: 212-8.
- Andersson, B., Odman, P., Lindvall, A.M. & Branemark, P.I. (1998) Five-year prospective study of prosthodontic and surgical single-tooth implant treatment in general practices and at a specialist clinic. *The International Journal of Prosthodontics* **11**: 351-5.
- Avivi-Arber, L. & Zarb, G.A. (1996) Clinical effectiveness of implant-supported single-tooth replacement. The Toronto study. *International Journal of Oral & Maxillofacial Implants* **11**: 311-321.
- 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**: 197-212.
- Bernard, J.P., Schatz, J.P., Christou, P., Belser, U. & Kiliaridis, S. (2004) Long-term vertical changes of the anterior maxillary teeth adjacent to single implants in young and mature adults. A retrospective study. *Journal of Clinical Periodontology* **31**: 1024-8.
- Bianchi, A.E. & Sanfilippo, F. (2004) Single-tooth replacement by immediate implant and connective tissue graft: a 1-9-year clinical evaluation. *Clinical Oral Implants Research* **15**: 269-77.
- Bornstein, M.M., Schmid, B., Belser, U.C., Lussi, A. & Buser, D. (2005) Early loading of non-submerged titanium implants with a sandblasted and acid-etched surface. 5-year results of a prospective study in partially edentulous patients. *Clinical Oral Implants Research* **16**: 631-8.
- Brägger, U., Karoussis, I., Persson, R., Pjetursson, B., Salvi, G. & Lang, N. (2005) Technical and biological complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study. *Clinical Oral Implants Research* **16**: 326-34.
- Buser, D., Dula, K., Lang, N.P. & Nyman, S. (1996) Long-term stability of osseointegrated implants in bone regenerated with the membrane technique. 5-year results of a prospective study with 12 implants. *Clinical Oral Implants Research* **7**: 175-83.
- Cochran, D. (1996) Implant therapy I. *Annals of Periodontology* **1**: 707-91.

De Boever, A.L. & De Boever, J.A. (2005) Guided bone regeneration around non-submerged implants in narrow alveolar ridges: a prospective long-term clinical study. *Clinical Oral Implants Research* **16**: 549-56.

Egger, M., Smith, G.D. & Sterne, J.A. (2001) Uses and abuses of meta-analysis. *Clinical Medicine* **1**: 478-84.

Elkhoury, J.S., McGlumphy, E.A., Tatakis, D.N. & Beck, F.M. (2005) Clinical parameters associated with success and failure of single-tooth titanium plasma-sprayed cylindrical implants under stricter criteria: a 5-year retrospective study. *International Journal of Oral & Maxillofacial Implants* **20**: 687-94.

Esposito, M., Hirsch, J.M., Lekholm, U. & Thomsen, P. (1998) Biological factors contributing to failures of osseointegrated oral implants (II). Etiopathogenesis. *European Journal of Oral Sciences* **106**: 721-64.

Fiorellini, J.P., Martuscelli, G. & Weber, H.P. (1998) Longitudinal studies of implant systems. *Periodontology 2000* **17**: 125-31.

Furhauser, R., Florescu, D., Benesch, T., Haas, R., Mailath, G. & Watzek, G. (2005) Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. *Clinical Oral Implants Research* **16**: 639-44.

Gibbard, L.L. & Zarb, G. (2002) A 5-year prospective study of implant-supported single-tooth replacements. *Journal of the Canadian Dental Association* **68**: 110-6.

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

Haas, R., Polak, C., Furhauser, R., Mailath-Pokorny, G., Dortbudak, O. & Watzek, G. (2002) A long-term follow-up of 76 Branemark single-tooth implants. *Clinical Oral Implants Research* **13**: 38-43.

Hämmerle, C.H., Chen, S.T. & Wilson, T.G. Jr. (2004) Consensus statements and recommended clinical procedures regarding the placement of implants in extraction sockets. *International Journal of Oral & Maxillofacial Implants* **19**: 26-8.

Henry, P.J. (2000) Tooth loss and implant replacement. *Australian Dental Journal* **45**: 150-72.

Henry, P.J., Laney, W.R., Jemt, T., Harris, D., Krogh, P.H., Polizzi, G., Zarb, G.A. & Herrmann, I. (1996) Osseointegrated implants for single-tooth replacement: a prospective 5-year multicenter study. *International Journal of Oral & Maxillofacial Implants* **11**: 450-5.

- Jemt, T. & Lekholm, U. (2005) Single implants and buccal bone grafts in the anterior maxilla: measurements of buccal crestal contours in a 6-year prospective clinical study. *Clinical Implant Dentistry and Related Research* **7**: 127-35.
- Keller, W., Brägger, U. & Mombelli, A. (1998) Peri-implant microflora of implants with cemented and screw retained suprastructures. *Clinical Oral Implants Research* **9**: 209-17.
- Kerschbaum, T., Haastert, B. & Marinello, C.P. (1996) Risk of debonding in three-unit resin-bonded fixed partial dentures. *The Journal of Prosthetic Dentistry* **75**: 248-53.
- Kirkwood, B.R. & Sterne, J.A.C. (2003a) Poisson regression. In: *Essential Medical Statistics*: 249-262. Oxford: Blackwell Science Ltd.
- Kirkwood, B.R. & Sterne, J.A.C. (2003b) Survival analysis: displaying and comparing survival patterns. In: *Essential Medical Statistics*: 272-286.
- Lang, N.P., Berglundh, T., Heitz-Mayfield, L.J., Pjetursson, B.E., Salvi, G.E. & Sanz, M. (2004) Consensus statements and recommended clinical procedures regarding implant survival and complications. *International Journal of Oral & Maxillofacial Implants* **19**: 150-4.
- Levin, L., Pathael, S., Dolev, E. & Schwartz-Arad, D. (2005) Aesthetic versus surgical success of single dental implants: 1- to 9-year follow-up. *Practical Procedures & Aesthetic Dentistry* **17**: 533-8
- Mericske-Stern, R., Grutter, L., Rosch, R. & Mericske, E. (2001) Clinical evaluation and prosthetic complications of single tooth replacements by non-submerged implants. *Clinical Oral Implants Research* **12**: 309-18.
- Palmer, R.M., Palmer, P.J. & Smith, B.J. (2000) A 5-year prospective study of Astra single tooth implants. *Clinical Oral Implants Research* **11**: 179-82.
- Palmqvist, S. & Swartz, B. (1993) Artificial crowns and fixed partial dentures 18 to 23 years after placement. *The International Journal of Prosthodontics* **6**: 279-85.
- Pjetursson, B.E., Tan, K., Lang, N.P., Bragger, U., Egger, M. & Zwahlen, M. (2004) A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clinical Oral Implants Research* **15**: 625-42.
- Pjetursson, B.E., Tan, K., Lang, N.P., Bragger, U., Egger, M. & Zwahlen, M. (2004) A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clinical Oral Implants Research* **15**: 667-76.

Polizzi, G., Fabbro, S., Furri, M., Herrmann, I. & Squarzoni, S. (1999) Clinical application of narrow Branemark System implants for single-tooth restorations. *International Journal of Oral & Maxillofacial Implants* **14**: 496-503.

Priest, G.F. (1996) Failure rates of restorations for single-tooth replacement. *The International Journal of Prosthodontics* **9**: 38-45.

Romeo, E., Lops, D., Margutti, E., Ghisolfi, M., Chiapasco, M. & Vogel, G. (2004) Long-term survival and success of oral implants in the treatment of full and partial arches: a 7-year prospective study with the ITI dental implant system. *International Journal of Oral & Maxillofacial Implants* **19**: 247-59.

Scheller, H., Urgell, J.P., Kultje, C., Klineberg, I., Goldberg, P.V., Stevenson-Moore, P., Alonso, J.M., Schaller, M., Corria, R.M., Engquist, B., Toreskog, S., Kastenbaum, F. & Smith, C.R. (1998) A 5-year multicenter study on implant-supported single crown restorations. *International Journal of Oral & Maxillofacial Implants* **13**: 212-8.

Tan, K., Pjetursson, B.E., Lang, N.P. & Chan, E.S. (2004) A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clinical Oral Implants Research* **15**: 654-66.

Taylor, R.C., McGlumphy, E.A., Tatakis, D.N. & Beck, F.M. (2004) Radiographic and clinical evaluation of single-tooth BioloK implants: a 5-year study. *International Journal of Oral & Maxillofacial Implants* **19**: 849-54.

Thilander, B., Odman, J. & Jemt, T. (1999) Single implants in the upper incisor region and their relationship to the adjacent teeth. An 8-year follow-up study. *Clinical Oral Implants Research* **10**: 346-55.

Van Steenberghe, D., Naert, I., Jacobs, R. & Quirynen, M. (1999) Influence of inflammatory reactions vs. occlusal loading on peri-implant marginal bone level. *Advances in Dental Research* **13**: 130-5.

Vigolo, P. & Givani, A. (2000) Clinical evaluation of single-tooth mini-implant restorations: a five-year retrospective study. *Journal of Prosthetic Dentistry* **84**: 50-4.

Wagenberg, B. & Froum, S.J. (2006) A retrospective study of 1925 consecutively placed immediate implants from 1988 to 2004. *International Journal of Oral & Maxillofacial Implants* **21**: 71-80.

Wassermann, A., Kaiser, M. & Strub, J.R. (2006) Clinical long-term results of VITA In-Ceram Classic crowns and fixed partial dentures: A systematic literature review. *The International Journal of Prosthodontics* **19**: 355-63.

Wennström, J.L., Ekestubbe, A., Grondahl, K., Karlsson, S. & Lindhe, J. (2005) Implant-supported single-tooth restorations: a 5-year prospective study. *Journal of Clinical Periodontology* **32**: 567-74.

List of excluded full-text articles and the reason for exclusion

Attard, N.J. & Zarb, G.A. (2003) Implant prosthodontic management of partially edentulous patients missing posterior teeth: the Toronto experience. *The Journal of Prosthetic Dentistry* **89**: 352-9.

Exclusion criteria: no single tooth implants.

Block, M.S., Gardiner, D., Kent, J.N., Misiak, D.J., Finger, I.M. & Guerra, L. (1996) Hydroxyapatite-coated cylindrical implants in the posterior mandible: 10-year observations. *International Journal of Oral and Maxillofacial Implants* **11**: 626-33.

Exclusion criteria: multiple publications on the same patient cohorts.

Block, M.S. & Kent, J.N. (1994) Long-term follow-up on hydroxylapatite-coated cylindrical dental implants: a comparison between developmental and recent periods. *Journal of Oral and Maxillofacial Surgery* **52**: 937-43.

Exclusion criteria: no detailed information on single tooth implants.

Buser, D., Ingimarsson, S., Dula, K., Lussi, A., Hirt, H.P. & Belser, U.C. (2002) Long-term stability of osseointegrated implants in augmented bone: a 5-year prospective study in partially edentulous patients. *International Journal of Periodontics and Restorative Dentistry* **22**: 109-17.

Exclusion criteria: no detailed information on single tooth implants.

Ekfeldt, A., Carlsson, G.E. & Borjesson, G. (1994) Clinical evaluation of single-tooth restorations supported by osseointegrated implants: a retrospective study. *The International Journal of Oral and Maxillofacial Implants* **9**: 179-83.

Exclusion criteria: mean follow-up time less than 5 years.

Ericsson, I., Randow, K., Nilner, K. & Petersson, A. (1997) Some clinical and radiographical features of submerged and non-submerged titanium implants. A 5-year follow-up study. *Clinical Oral Implants Research* **8**: 422-6.

Exclusion criteria: no single tooth implants.

Fugazzotto, P.A., Gulbransen, H.J., Wheeler, S.L. & Lindsay, J.A. (1993) The Use of IMZ Osseointegrated Implants in Partially and Completely Edentulous Patients: Success and Failure Rates of 2,023 Implant Cylinder up to 60+ Months in Function. *International Journal of Oral and Maxillofacial Implants* **8**: 617-621.

Exclusion criteria: mean follow-up time less than 5 years.

Guttenberg, S.A. (1993) Longitudinal report on hydroxyapatite-coated implants and advanced surgical techniques in a private practice. *Compendium Supplement* **15**:S549-53.

Exclusion criteria: no detailed information on single tooth implants.

Haas, R., Mensdorff-Pouilly, N., Mailath, G. & Bernhart, T. (1998) Five-year results of maxillary Intramobile Zylinder implants. *British Journal of Oral & Maxillofacial Surgery* **36**: 123-128.

Exclusion criteria: no detailed information on single tooth implants.

Haas, R., Mensdorff-Pouilly, N., Mailath, G. & Watzek, G. (1995) Brånemark single tooth implants: a preliminary report of 76 implants. *The Journal of Prosthetic Dentistry* **73**: 274-9.

Exclusion criteria: mean follow-up time less than 5 years.

Jemt, T., Lekholm, U. & Adell, R. (1990) Osseointegrierte Implantate in der Behandlung von Patienten mit Lückengebiss- Eine Vorstudie über 876 nacheinander gesetzte Implantate. *Die Quintessenz* **12**: 1935-1946.

Exclusion criteria: no detailed information on single tooth implants.

Jones, J.D., Lupori, J., Van Sickels, J.E. & Gardner, W. (1999) A 5-year comparison of hydroxyapatite-coated titanium plasma-sprayed and titanium plasma-sprayed cylinder dental implants. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **87**: 649-52.

Exclusion criteria: no detailed information on single tooth implants.

Krennmair, G., Piehslinger, E. & Wagner, H. (2003) Status of teeth adjacent to single-tooth implants. *The International Journal of Prosthodontics* **16**: 524-8.

Exclusion criteria: mean follow-up time less than 5 years.

Lambrecht, J.T., Filippi, A., Kunzel, A.R. & Schiel, H.J. (2003) Long-term evaluation of submerged and nonsubmerged ITI solid-screw titanium implants: a 10-year life table analysis of 468 implants. *The International Journal of Oral & Maxillofacial Implants* **18**: 826-34.

Exclusion criteria: no detailed information on single tooth implants.

Malevez, C., Hermans, M. & Daelemans, P. (1996) Marginal bone levels at Branemark system implants used for single tooth restoration. The influence of implant design and anatomical region. *Clinical Oral Implants Research* **7**: 162-9.

Exclusion criteria: mean follow-up time less than 5 years.

Manz, M.C. (2000) Factors Associated With Radiographic Vertical Bone Loss Around Implants Placed in a Clinical Study. *Annals of Periodontology* **5**: 137-151.

Exclusion criteria: no detailed information on single tooth implants.

McDermott, N.E., Chuang, S.K., Woo, V.V. & Dodson, T.B. (2003) Complications of dental implants: identification, frequency, and associated risk factors. *The International Journal of Oral & Maxillofacial Implants* **18**: 848-55.

Exclusion criteria: no single tooth implants.

Nedir, R., Bischof, M., Briaux, J.M., Beyer, S., Szmukler-Moncler, S. & Bernard, J.P. (2004) A 7-year life table analysis from a prospective study on ITI implants with special emphasis on the use of short implants. Results from a private practice. *Clinical Oral Implants Research* **15**: 150-7.

Exclusion criteria: no detailed information on single tooth implants.

Nevins, M., Mellonig, J.T., Clem, D.S. 3rd, Reiser, G.M. & Buser, D.A. (1998) Implants in regenerated bone: long-term survival. *International Journal of Periodontics and Restorative Dentistry* **18**: 34-45.

Exclusion criteria: mean follow-up time less than 5 years.

Noack, N., Willer, J. & Hoffmann, J. (1999) Long-term results after placement of dental implants: longitudinal study of 1,964 implants over 16 years. *The International Journal of Oral & Maxillofacial Implants* **14**: 748-55.

Exclusion criteria: no detailed information on single tooth implants.

Priest, G. (1999) Single-Tooth Implants and Their Role in Preserving Remaining Teeth: A 10-year Survival Study. *The International Journal of Oral and Maxillofacial Implants* **14**: 181-188.

Exclusion criteria: mean follow-up time less than 5 years.

Saadoun, A.P. & LeGall, M.L. (1992) Clinical results and guidelines on Steri-Oss endosseous implants. *International Journal of Periodontics and Restorative Dentistry*. **12**: 486-95.

Exclusion criteria: no detailed information on single tooth implants.

Scholander, S. (1999) A retrospective Evaluation of 259 Single-Tooth Replacements by the Use of Branemark Implants. *The International Journal of Prosthodontics* **12**: 483-491.

Exclusion criteria: mean follow-up time less than 5 years.

Snauwaert, K., Duyck, J., van Steenberghe, D., Quirynen, M. & Naert, I. (2000) Time dependent failure rate and marginal bone loss of implant supported prostheses: a 15-year follow-up study. *Clinical Oral Investigation* **4**: 13-20.

Exclusion criteria: mean follow-up time less than 5 years.

Stultz, E.R., Lofland, R., Sendax, V.I. & Hornbuckle, C. () A Multicenter 5-Year Retrospective Survival Analysis of 6,200 Integral[®] Implants. *Compendium of Continuing Education Dentistry* **14**: 478-486.

Exclusion criteria: no detailed information on single tooth implants.

ten Bruggenkate, C.M., Asikainen, P., Foitzik, C., Krekeler, G. & Sutter, F. (1998) Short (6-mm) nonsubmerged dental implants: results of a Multicenter clinical trial of 1 to 7 years. *International Journal of Oral and Maxillofacial Implants* **13**: 791-8.

Exclusion criteria: no detailed information on single tooth implants.

Vogel, R.E., Davliakos, J.P. (2002) Spline[™] Implant Prospective Multicenter Study: Interim Report on Prosthetic Screw Stability in Partially Edentulous Patients. *Journal of esthetic and restorative dentistry* **14**: 225-237.

Exclusion criteria: mean follow-up time less than 5 years.

Zitzmann, N.U., Schäfer, P. & Marinello, C.P. (2001) Long-term results of implants treated with guided bone regeneration: a 5-year prospective study. *International Journal of Oral and Maxillofacial Implants* **16**: 355-66.

Exclusion criteria: mean follow-up time less than 5 years.

Study	Year of publication	Total no. of implants	Estimated rate of implant fracture (per 100 implant years)	Total no. of crowns	Estimated rate of abutment or screw fracture (per 100 crown years)	Estimated rate of loose abutments or screws (per 100 crown years)	Estimated rate of loss of retention (per 100 crown years)	Estimated rate of ceramic chipping (per 100 crown years)	Estimated rate of framework fracture (per 100 crown years)
Wagenberg & Froum	2006	401	0	383	n.r.	n.r.	n.r.	n.r.	n.r.
Bornstein et al.	2005	39	0	39	n.r.	n.r.	n.r.	n.r.	n.r.
Elkhoury et al.	2005	39	0	39	n.r.	n.r.	n.r.	n.r.	n.r.
De Boever & de Boever	2005	10	0	10	n.r.	n.r.	n.r.	n.r.	n.r.
Wennström et al.	2005	45	0	44	0	1.44	n.r.	n.r.	0
Jemt & Lekholm	2005	10	0	10	n.r.	n.r.	n.r.	n.r.	n.r.
Brägger et al.	2005	69	n.r.	69	0	0.48	0	0.48	0
Taylor et al.	2004	39	0	38	n.r.	n.r.	n.r.	n.r.	n.r.
Bernard et al.	2004	32	0	32	n.r.	n.r.	n.r.	n.r.	n.r.
Romeo et al.	2004	123	0	121	0	0	0.56	0.28	n.r.
Bianchi & Sanfilippo	2004	94	0	94	n.r.	n.r.	n.r.	n.r.	n.r.
Gotfredsen	2004	20	0	20	n.r.	2.04	2.04	2.04	0
Andressen E. et al.	2002	8	0	8	0	7.50	n.r.	n.r.	n.r.
Haas et al.	2002	76	0.26	77	n.r.	3.14	n.r.	n.r.	n.r.
Gibbard & Zarb	2002	49	0	48	n.r.	1.39	n.r.	n.r.	n.r.
Palmer et al.	2000	15	0	15	0	0	1.52	n.r.	1.52
Vigolo & Givani	2000	52	0	52	0	0.41	2.86	n.r.	n.r.
Thilander et al.	1999	15	0	15	n.r.	n.r.	n.r.	n.r.	n.r.
Polizzi et al.	1999	30	0.63	30	0.65	0	n.r.	0	n.r.
Andersson et al.	1998	38	0	38	n.r.	n.r.	n.r.	n.r.	0.56
Andersson et al.	1998	65	0	65	0	0.34	n.r.	0.34	0.68
Scheller et al.	1998	99	n.r.	97	n.r.	0.97	0.73	1.70	1.70
Henry et al.	1996	107	0	106	0.21	18.03	n.r.	1.89	n.r.
Buser et al.	1996	5	0	5	n.r.	n.r.	n.r.	n.r.	n.r.
Summary estimate event rates (95 % CI)		0.03* (0.006-0.13)		0.07* (0.018-0.28)		2.72** (1.17-6.30)	1.13** (0.44-2.91)	0.92** (0.48-1.75)	0.61** (0.22-1.73)
Cumulative 5 year complication rates (95 % CI)		0.14%* (0.03%-0.64%)		0.35%* (0.09%-1.4%)		12.7%** (5.7%-27.0%)	5.5%** (2.2%-13.5%)	4.5%** (2.4%-8.4%)	3.0%** (1.1%-8.3%)

Table 6. – Technical complications

* Based on standard Poisson regression, ** Based on random-effects Poisson regression.