A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. — Source link

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Abstract

OBJECTIVES: The objective of this systematic review was to assess the 5-year survival rates and incidences of complications associated with ceramic abutments and to compare them with those of metal abutments. METHODS: An electronic Medline search complemented by manual searching was conducted to identify randomized-controlled clinical trials, and prospective and retrospective studies providing information on ceramic and metal abutments with a mean follow-up time of at least 3 years. Patients had to have been examined clinically at the follow-up visit. Assessment of the identified studies and data abstraction was performed independently by three reviewers. Failure rates were analyzed using standard and random-effects Poisson regression models to obtain summary estimates of 5-year survival proportions. RESULTS: Twenty-nine clinical and 22 laboratory studies were selected from an initial yield of 7136 titles and data were extracted. The estimated 5-year survival rate of ceramic abutments was 99.1% [95% confidence interval (CI): 93.8-99.9%] and 97.4% (95% CI: 96-98.3%) for metal abutments. The estimated cumulative incidence of technical complications after 5 years was 6.9% (95% CI: 3.5-13.4%) for ceramic abutments and 15.9% (95% CI: 11.6-21.5%) for metal abutments. Abutment screw loosening was the most frequent technical problem, occurring at an estimated cumulative incidence after 5 years of 5.1% (95% CI: 3.3-7.7%). All-ceramic crowns supported by ceramic abutments exhibited similar annual fracture rates as metal-ceramic crowns supported by metal abutments. The cumulative incidence of biological complications after 5 years was estimated at 5.2% (95% CI: 0.4-52%) for ceramic and 7.7% (95% CI: 4.7-12.5%) for metal abutments. Esthetic complications tended to be more frequent at metal abutments. A meta-analysis of the laboratory data was impossible due to the non-standardized test methods of the studies included. CONCLUSION: The 5-year survival rates estimated from annual failure rates appeared to be similar for ceramic and metal abutments. The information included in this review did not provide evidence for differences of the technical and biological outcomes of ceramic and metal abutments. However, the information for ceramic abutments was limited in the number of studies and abutments analyzed as well as the accrued follow-up time. Standardized methods for the analysis of abutment strength are needed.

A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions – EAO Group 1

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Running head: Systematic review of ceramic implant abutments

Key words: implant abutments, ceramics, zirconia, metal, titanium, implant reconstructions, systematic review, survival, failures, complication rates, technical complications, biological complications, stability, strength.

Abstract

Objectives: The objective of this systematic review was to assess the 5-year survival rates and incidences of complications associated with ceramic abutments and to compare them to those of metal abutments.

Methods: An electronic Medline search complemented by manual searching was conducted to identify randomized controlled clinical trials, and prospective and retrospective studies giving information on ceramic and metal abutments with a mean follow-up time of at least 3 years. Patients had to have been examined clinically at the follow-up visit. Assessment of the identified studies and data abstraction was performed independently by three reviewers. Failure rates were analyzed using standard and random-effects Poisson regression models to obtain summary estimates of 5-year survival proportions.

Results: Twenty-nine clinical and 22 laboratory studies were selected from an initial yield of 7136 titles and data were extracted. The estimated 5-year survival rate of ceramic abutments was 99.1% (95%confidence interval (CI):93.8%-99.9%) and 97.4% (95%CI:96%-98.3%) for metal abutments. The estimated cumulative incidence of technical complications after 5 years was 6.9% (95% CI:3.5%-13.4%) for ceramic abutments and 15.9% (95%CI:11.6%-21.5%) for metal abutments. Abutment screw loosening was the most frequent technical problem, occurring at an estimated cumulative incidence after 5 years of 5.1% (95% CI:3.3%-7.7%). All-ceramic crowns supported by ceramic abutments exhibited similar annual fracture rates as metal-ceramic crowns supported by metal abutments. Cumulative incidence of biological complications after 5 years was estimated at 5.2% (95% CI:0.4%-52%) for ceramic and 7.7% (95%CI:4.7%-12.5%) for metal abutments. Esthetic complications tended to be more frequent at metal abutments. A meta-analysis of the laboratory data was impossible due to the non-standardized test methods of the included studies.

Conclusion: The 5-year survival rates estimated from annual failure rates seemed similar for ceramic and metal abutments. The information included in this review did not provide evidence for differences of the technical and biological outcomes of ceramic and metal abutments. However, the information for ceramic abutments was

limited in number of studies and abutments analyzed as well as accrued follow-up time. Standardized methods for the analysis of abutment strength are needed.

Introduction

Fixed implant-borne single crowns and fixed dental prostheses (FDPs) have become an accepted treatment option for the rehabilitation of partially dentate patients. Recent systematic reviews summarized excellent 5- and 10-year survival rates for both reconstruction types (Pjetursson et al. 2004, Pjetursson et al. 2007, Jung et al. 2008a).

Both implant-borne crowns and FDPs need to be either cemented or screw-retained on implant abutments. Until today, metal implant abutments made out of titanium have been considered to be the “conditio sine qua non” for the longevity of implant-borne reconstructions in all regions of the jaws. Clinical studies demonstrated excellent survival rates for fixed implant reconstructions supported by titanium abutments (Andersson et al. 1995). Furthermore, in a recent systematic review only a few complications were associated with metal abutments supporting fixed implant reconstructions (Pjetursson et al. 2007). For this type of abutment the most frequently occurring retrievable technical problem was loosening of the abutment screw (Pjetursson et al. 2007).

Nowadays, the esthetic outcome has become an additional criterion for the clinical success of an implant-borne reconstruction. One major drawback of metal abutments is their dark grey color. Several studies demonstrated a greyish discoloration of the peri-implant mucosa induced by metal abutments (Jung et al. 2007; Park et al. 2007). Hence, although very stable from a technical point of view, metal abutments have limited indications in esthetically delicate areas (Jung et al. 2007).

As an alternative, ceramic abutments made out of the high-strength ceramics alumina and zirconia were developed (Prestipino & Ingber 1993a, b; Wohlwend et al. 1996). Ceramic abutments offer several clinical advantages over metal abutments. Firstly, their esthetic benefit is well documented (Jung et al 2008b). Ceramic abutments induced significantly less mucosal discoloration than metal abutments (Jung et al.2008b). Secondly, less bacterial adhesion was found on ceramics such as zirconia than on titanium (Scarano et al. 2004). Finally, the soft tissue integration of the ceramics alumina and zirconia is similar to that of titanium (Hashimoto et al. 1988, Abrahamsson et al. 1998, Kohal et al. 2004). One shortcoming of ceramics is their mechanical behavior, as they are brittle and, therefore, less resistant towards tensile forces. Micro-structural defects within the material may cause cracks in combination with tensile forces (Belser et al. 2004). An increase in the fracture toughness of a

ceramic slows down crack propagation and consequently has a major influence on the material's long-term clinical stability (Conrad et al. 2007, Seghi et al. 1995).
High strength ceramics like alumina and zirconia exhibit very high fracture toughness, with zirconia exhibiting the highest fracture toughness of ceramics suitable for constructing abutments (Lüthy 1996). To date the reported clinical performance of alumina and zirconia implant abutments has been very promising (Andersson et al. 2001, Glauser et al. 2004, Canullo 2007). Alumina abutments supporting single-crowns exhibited a 93%-100% survival rate in anterior and premolar regions (Andersson et al. 2001). Zirconia abutments supporting anterior and premolar single crowns even survived in 100% of cases in several studies (Glauser et al. 2004, Canullo 2007). Furthermore, one recent randomized controlled clinical trial of zirconia and titanium abutments supporting single crowns in posterior regions reported a 100% survival rate for the ceramic abutments after 3 years (Zembic et al. in press). To date, facture of a zirconia abutment has not been reported in any clinical studies. Interestingly, loosening of the abutment screw was one of the few technical complications occurring at zirconia abutments (Glauser et al. 2004). This finding resembles the observations made at metal abutments. The mechanical strength of abutments made out of this ceramic seems to be adequate for clinical use as an alternative to metal abutments.

To be suitable for clinical use as an alternative to metal abutments, ceramic abutments need to exhibit similar performance after a mean follow-up of at least 5 years (Pjetursson et al. 2004).

Hence, the objectives of this review were:

1) To obtain robust estimates of the 5-year survival of ceramic abutments and to describe the incidence of biological and technical complications.

2) To compare the survival rates and complication rates of ceramic abutments with those of metal abutments (gold-standard).

3) To review factors influencing the mechanical strength of the two types of abutments.

Materials and Methods

Search strategy and study selection

First a general MEDLINE (PubMed search form) search from 1990 up to and including 2008 was conducted for English- and German-language articles in Dental Journals using the following search terms: “dental implants” and “ dental abutments”, “dental implants” and “dental abutments” and “titanium”, “dental implants” and “dental abutments” and “gold”, “dental implants” and “dental abutments” and “ceramic*”, “dental implants” and “dental abutments” and “alumina” and “dental implants” and “dental abutments” and “zirconia”. An additional search strategy included the terms “strength”, “load” and “stability” in order to specifically search for laboratory studies of ceramic and metal abutments. Furthermore, a Cochrane Library search was performed applying the same search terms.

Second, an update of the literature search of two recent reviews analyzing the outcomes of fixed implant-borne reconstructions was made using the search strategies of the previous authors (Pjetursson et al. 2004, Jung et al. 2008a). This search included studies from 2004 (Pjetursson et al. 2004) and 2006 (Jung et al. 2008a) up to August 2008, and was limited to human trials.

Finally, the electronic search was complemented by manual search of the bibliographies (included and excluded studies) of the two recent reviews (Pjetursson et al. 2004, Jung et al. 2008a). The manual search, furthermore, included all full-text articles and other related reviews selected from the electronic search. Moreover, manual searching was applied to the following journals for the years 2004-2008 inclusive: Schweizer Monatsschrift für Zahnmedizin (Acta Medicinae Dentium Helvetica) and Deutsche Zahnärztliche Zeitschrift and Implantologie.

All titles obtained were checked for relevant clinical and laboratory studies.

Part I: Clinical studies

Inclusion criteria

From this extensive search, three randomized controlled clinical trials (RCTs) comparing ceramic and metal abutments supporting fixed implant reconstructions were available. One additional RCT was found comparing titanium and gold abutments supporting fixed implant reconstructions.

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

- the studies had a mean follow-up time of 3 years or more
- the studies reported details of the characteristics of the implant abutments
- the studies reported on partially dentate patients receiving implant-supported single crowns and/or FDPs

Studies were excluded where the patients included had not been examined clinically at the follow-up visit, i.e. publications based on patient records, questionnaires or interviews.

Selection of studies

Titles and abstracts of the searches were initially screened by three independent reviewers (IS, AP & AZ) for possible inclusion in the review. The full text of all possibly relevant studies was then obtained for independent assessment by the reviewers. Any disagreement regarding inclusion was resolved by discussion.

Figure 1 describes the process of identifying the 29 full text articles on the clinical performance of the abutments selected from the initial yield of 7136 titles.

Excluded Studies

Of the altogether 259 full text articles examined, 223 were clinical studies. Of these clinical studies 194 were excluded from the final analysis (see reference list).

The main reasons for exclusion were: a mean observation period of less than 3 years, no detailed information on the type of abutment, no detailed analysis of the data and case descriptions of failures without relevant information on the entire patient cohort, multiple publications on the same patient cohorts.

Data extraction

Information on the survival proportions and of the biological and technical complications of the abutments and reconstructions was extracted from the 29 included studies. The number of events and the corresponding total exposure time of the reconstructions were calculated.

Survival was defined as the abutment/reconstruction remaining in situ for the observation period with or without modification.

The analysis of the technical complications included loosening of the implant, loosening/chipping/fracture of the veneer/reconstruction, presence of a gap at the junction between implant and abutment, loosening of the abutment and problems with screwed joints.

The analysis of the biological complications encompassed bone loss of more than 2mm, soft tissue recession and general soft tissue complications.

The analysis of the esthetical complications included soft tissue discoloration and other esthetic problems.

Data from all studies were extracted independently by three reviewers (IS, AP & AZ), using data extraction forms. Disagreement regarding data extraction was resolved by consensus.

Statistical analysis

Failure and complication rates were calculated by dividing the number of events (failures or complications) as the numerator by the total abutment exposure time as 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 abutments that could be followed for the whole observation time.

2) Exposure time up to failure of the abutments that were lost due to failure during the observation time.

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

If all three components for the calculation of the total exposure time were not available, the total exposure time was estimated by multiplying the mean follow-up time by the number of constructions under observation. For each study, event rates for the abutments and the reconstructions were calculated by dividing the total number of events by the total abutment exposure time in years. For further analysis, the total number of events was considered to be Poisson distributed for a given sum of abutment exposure years and Poisson regression with a logarithmic link-function and total exposure time per study as an offset variable were used (Kirkwood & Sterne 2003a). 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 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 2003b). Five-year cumulative failure rates were calculated by subtracting the five-year survival proportion from one. The 95% confidence intervals for the survival and cumulative failure rates were calculated by using the 95% confidence limits of the event rates. Multivariable Poisson regression was used to formally compare construction subtypes and to assess other study characteristics. All p-values are two-sided and analyses were performed using Stata®, version.

Results part I

Included studies

A total of 29 studies giving information on the clinical performance of the implant abutments was included in the analysis. The characteristics of the selected studies are shown in Table 1.

All of the studies were published within the past 13 years. Three studies were RCTs comparing ceramic and metal abutments. One further RCT was available. This study, however, only compared abutments made out of metal (titanium vs. gold). Sixteen studies were prospective and the remaining were retrospective (Table 1).

The studies were mainly conducted in an institutional environment. Sixteen studies were performed at Universities and 13 at Specialized Clinics. Nine studies were performed as multicenter studies, and four were performed in private practices (Table 1).

The studies included patients between the ages of 14 and 88 years. The number of patients who could not be followed for the complete study period (drop-outs) varied between 0% and 30.5%. Ten studies did not report on the drop-out of patients.

The studies reported on 8 commercially available implant systems: Brånemark® System (Nobel Biocare, Gothenburg, Sweden), Astra® Tech Dental Implants System (Astra Tech, Mölndal, Sweden), ITI® Dental Implants System (Straumann, Basel, Switzerland), 3i® Implants (Implant Innovations, Palm Beach Gardens, USA), Replace® Implant System (Nobel Biocare, Gothenburg, Sweden), TSA® Implants(Impladent, Barcelona, Spain), Frialit® 2 Implants (Friatek, Mannheim, Germany) and Bicon® Dental Implants (Bicon, Boston, USA) (Table 2).

Two of these implant systems (Brånemark® System, 3i® Implants) were designed with external implant-abutment connections, the remaining with internal implant-abutment connections (Table 2).

The 29 studies included a total of 5849 abutments. In the three RCTs the outcome of 82 ceramic abutments was compared with that of 72 metal abutments (Andersson et al. 2001, Andersson et al. 2003, Zembic et al. in press).

Altogether, the 29 studies reported on the follow-up of 166 ceramic and 5683 metal abutments (Table 2). The mean follow-up time of the ceramic abutments was 3.7 years, that of the metal abutments 4.8 years.

Seventeen of the studies analyzed abutments with an external implant-abutment connection and 10 studies analyzed internally connected abutments. Two studies reported on mixed externally and internally connected abutments (Table 2).

Additional information on the implant reconstructions was given in all except one study (Chapman & Grippo 1996),

In more detail, in 17 studies (59%) data on single crowns and in 8 studies (28%) data on FDPs was reported. Two of these studies analyzed single crowns and FDPs separately in two patient cohorts (Brägger et al. 2005, Romeo et al. 2004). In five studies (17%) single crowns and FDPs were mixed in one patient cohort, without detailed information on the individual type of reconstruction (Table 2).

Finally, 20 of the studies reported on crown and FDP material. Six studies reported on 221 all-ceramic crowns and nine studies on 823 metal-ceramic crowns. A total of 457 metal-ceramic FDPs was analyzed in six studies. No study analyzing the outcome of implant-borne all-ceramic FDPs was available for this review (Table 2).

Implant survival

The survival of the implants lost in function was reported in 22 studies. The estimated failure rate per 100 implant years ranged from 0 to 2.5. In meta-analysis, a failure rate of 0.74 failures occurring at function per 100 implant years (95% CI: 0.51-1.05) was obtained. This resulted in an estimated 5-year survival rate for the implants in function of 96.4% (95% CI: 94.9-97.5%).

Abutment survival

Twenty-three studies with a total of 4973 abutments provided data on abutment survival after a mean follow-up time of 4.6 years. Of these abutments 166 were ceramic and 4807 were metallic (Table 3).

Altogether 82 abutments, one ceramic and 81 metal abutments were lost. One ceramic abutment and nine metal abutments were lost due to fracture of the abutment

(Andersson et al. 2003, Chapman & Grippo 1996). The fractured ceramic abutment was made out of alumina. Fifty metal abutments were lost due to implant loss as reported in 11 studies (Bianco et al. 2000, Brägger et al. 2005, Cooper et al. 2007, Jemt et al. 2003, Kastenbaum et al. 1998, Krennmair et al. 2002, Muche et al. 2003, Romeo et al. 2003, Romeo et al. 2004, Scheller et al. 1998, Wyatt & Zarb 1998). Three metal abutments had to be replaced due to problems with their fit (gap) (Andersson et al. 1998, Kastenbaum et al. 1998). Four metal abutments had to be removed due to poor esthetics (Preiskel & Tsolka 2004). Eight further metal abutments were lost due to a change of treatment (Henry et al. 1996). For the remaining no reason for loss was reported.

The summary failure rate of the abutments per 100 abutment years was 0.49 (95% CI: 0.32-0.74) (Fig 2) and the estimated 5-year abutment survival rate was 97.6% (95% CI: 96.4-98.4%) (Table 3). The failure rate of ceramic abutments per 100 abutment years was 0.2% (95% CI: 0.02%-1.3%) and the 5-year survival rate for ceramic abutments was 99.1% (95% CI: 93.8%-99.9%). For the metal abutments, the corresponding summary failure rate was 0.5% (95% CI: 0.3%-0.8%) and the estimated 5-year survival was 97.4% (95% CI: 96.0%-98.3%) (Table 7).

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Technical complications of the abutments

The estimated 5-year rate for total technical complications was lower at ceramic abutments (6.9%; 95% CI: 3.5%-13.4%) than at metal abutments (15.9%; 95% CI: 11.6%-21.5%). However, since the number of observed ceramic abutments was small, this difference was not statistically significant (Fig. 3, Table 7).

Fracture of a ceramic or a metal abutment was a rare complication (Fig. 4). Its cumulative incidence after 5-years was 0.3% (95% CI: 0.1%-0.5%) with no statistically significant differences between the two types of abutments (Tables 4 and 7). However, a trend towards a higher occurrence of fractures was found at ceramic abutments.

Additionally. a tendency towards less risk of fracture was observed at abutments with internal implant-abutment connection compared to those with external connection.

Abutment screw fracture was more frequently found than fracture of the abutment itself. Overall, the incidence of this technical complication after 5 years was 0.15% (95% CI: 0.08%-0.3%). The estimated 5-year screw fracture rate was 0% (95% CI: 0%-4.4%) at ceramic abutments and 0.8% (95% CI: 0.4%-1.7%) at metal abutments. This difference was not statistically significant (Tables 4 and 7).

The most frequent technical complication was abutment screw loosening. This was reported in all except one study (Avivi-Arber et al. 1996), and was more frequently observed at metal abutments. The cumulative incidence of screw loosening after 5 years was 5.1% (95% CI: 3.3%-7.7%) (Tables 4 and 7). The estimated rate for screw loosening of ceramic abutment years ranged between 0 and 1.36, and the rate for metal abutments between 0 and 10.32. No statistically significant difference between the screw-loosening rates of ceramic and metal abutments was found (Table 7).

A comparison of the screw loosening rates found at abutments with external and internal implant-abutment connections indicated a trend towards fewer problems at internally connected abutments (Table 7).

Abutment misfit was reported in 7 studies and its cumulative incidence after 5 years of follow-up was 5.2% (95% CI: 2%-13.3%) (Table 4). The estimated 5-year rate was lower at ceramic abutments (0%; 95% CI: 0%-11.4%) than at metal abutments (6.6%; CI: 2.4%-17.6%). Again, this difference was not statistically significant (Table 7).

Technical complications of the reconstructions

The statistical comparison of the failure data of all-ceramic and metal-ceramic implant-borne reconstructions was limited to single crowns. The reasons for this were the limited comparability of the outcome of crowns and FDPs, and the lack of data on all-ceramic FDPs. Fourteen studies with a total 2002 implant-borne single-crowns provided data on their technical outcomes after a mean follow-up time of 4.8 years.

Generally, fracture is the most catastrophic technical complication leading to the loss of the reconstruction. Interestingly, this review indicated that the abutment material apparently influenced the stability of all-ceramic crowns. Seventeen all-ceramic crowns supported by metal abutments were lost due to fracture (Andersson et al.

1998, Andersson et al. 2001, Henry et al. 1996, Krennmeier e al. 2002, Scheller et al. 1998) while no all-ceramic crown supported by a ceramic abutment fractured.

Consequently the fracture rate of ceramic crowns supported by ceramic abutments was 0 (95% CI: 0-0.12) per 100 abutment years, and the estimated 5-year survival rate 100% (95% CI: 94.6-100%). For metal-ceramic crowns supported by metal abutments the fracture rate was 0.04 (95% CI: 0.016-0.11) and the estimated 5-year survival 99.8% (95% CI: 99.4%-99.9%). No significant differences in the 5-year survival rates between these two types of reconstruction were found (Table 7).

In two studies, two metal-ceramic crowns supported by metal abutments were lost due to fracture of the metallic framework (Bischof et al. 2006, Jemt et al. 2003), however this type of failure was more frequently reported for metal-ceramic FDPs.

No statistically significant differences in the rates for reconstruction loosening and chipping of the veneering ceramic were observed at single crowns supported by ceramic abutments as compared to those supported by metal abutments (Table 7).

Biological complications

The total estimated 5-year rate for biological complications was 5.2% (95% CI: 0.4%-52%) for ceramic abutments and 7.7% (95% CI: 4.7%-12.5%) for metal abutments (Fig. 5, Tables 6 and 7).

The 5-year rate for soft tissue recession around ceramic abutments was twice that around metal abutments (8.9%; 95% CI: 1.7%-40% vs. 3.8%; 95% CI: 1.5%-9.8%) (Table 7).

Interestingly, the rate for bone loss exceeding 2 mm was higher for implants supporting metal abutments (3.9%, 95% CI: 1.7%-8.7%), than those supporting ceramic abutments (0%; 95% CI: 1.7%-8.7%) (Table 7).

Fifteen studies reported on further "soft tissue complications", most frequently without detailed description of the problems. In only two studies fistulae due to ill-fitting abutments were defined as soft tissue complication (Andersson et al. 1998, Kastenbaum et al. 1998). The estimated 5-year rate for the soft complications was

2.1% (95% CI: 0.3%-11.7%) for ceramic abutments and 4.1% (95% CI: 2.1%-7.9%) for metal abutments (Table 7).

None of the differences reached statistical significance (Table 7).

Esthetic outcomes

An esthetic parameter was measured objectively in only one study (Zembic et al., in press). In this study, the soft tissue color change caused by ceramic and metal abutments was analyzed by means of a spectrophotometer. In the remaining studies the authors reported on esthetic problems without applying standardized criteria. Finally, no study reported on patient-related outcomes regarding the esthetic outcome of the implant reconstructions.

The total estimated 5-year rate for esthetic complications for ceramic and metal abutments supporting fixed reconstructions was 5.4% (95% CI: 1.6%-17.4%). Problems with the esthetic outcome were more frequently reported for metal abutments (Fig. 6).

Esthetic problems occurred with 0% (95% CI: 0%-11.3%) of the ceramic abutments and 6.6% (95% CI: 2.0%-22.4%) of the metal abutments. Again, this difference was not statistically significant (Table 7).

Part II: Laboratory studies

Inclusion criteria

The review of mechanical stability was based on studies fulfilling the following inclusion criteria:

- studies reporting on the load at which abutments failed, measured in Newtons (N)
- studies reporting on the bending moment of the abutments, measured in Newton-centimeter (Ncm)
- studies that reported details of the characteristics of the implant abutments
- studies applying static and/or dynamic test methods.

Selection of studies

Titles and abstracts of the searches were screened by three independent reviewers (IS, AP & AZ) for possible inclusion in the review. The full text of all possibly relevant studies was then obtained for independent assessment by the reviewers. Any disagreement regarding inclusion was resolved by discussion.

Figure 7 describes the process of identifying the 22 full text articles on the laboratory performance of the abutments selected from the initial yield of 7136 titles.

Excluded Studies

Thirty-six of the total of 259 full text articles examined were laboratory studies. Of these, 14 laboratory studies were excluded from the final analysis (see reference list).

The main reason for exclusion of these studies was that no information on the stability (fracture strength, bending moment) of the abutments was available.

Data extraction

Information on the fracture strength of the abutments was extracted from the 22 included studies. The mechanical stability was analyzed by assessing the mean fracture strengths (in N) and, if available, the mean bending moments (in Ncm).

The following technical parameters were included in the analysis: abutment material, type of implant-abutment connection, type/material of reconstruction, angle (°) to long axis of implant at which load was applied, static or dynamic testing.

Data from the studies were extracted independently by the reviewers (IS, AP & AZ), using data extraction forms. Disagreement regarding data extraction was resolved by consensus.

Statistical analysis

The fracture strength data were analyzed descriptively since the test methods employed and the reporting of results were poorly standardized, precluding a meta-analysis of the strength values.

Results part II

Included studies

A total of 22 studies giving information on the mechanical stability of the implant abutments was included in the analysis (Table 8).

All studies had been published within the past 15 years, and had tested the fracture strength (in N) of ceramic and/or metal abutments in a broadly comparable manner.

The studies reported on abutments for seven commercially available implant systems: Brånemark® System (Nobel Biocare, Gothenburg, Sweden), Astra® Tech Dental Implants System (Astra Tech, Mölndal, Sweden), ITI® Dental Implants System (Straumann, Basel, Switzerland), 3i® Implants (Implant Innovations, Palm Beach Gardens, USA), Replace® Implant System (Nobel Biocare, Gothenburg, Sweden), Spline® Implant System (Zimmer Dental, Carlsbad, USA), XIVE® Implant System (Dentsply Friadent, Mannheim, Germany). Table 8 gives detailed manufacturer specific information on the tested abutments.

In 10 studies the stability of ceramic abutments was compared to that of metal abutments. The ceramic abutments were either made of glass-infiltrated or densely sintered alumina, or zirconia. Titanium abutments were tested in most of the studies, and only one had additionally analyzed gold abutments (Wiskott et al. 2004).

Seven studies tested the strength of abutments with an external implant-abutment connection. In nine studies the strength of internally connected abutments was analyzed. Five additional studies compared the strength of both kinds of abutments in the same set-up.

Nine of the 22 studies exhibited ageing of the samples by means of dynamic testing simulating use, chewing simulation and thermocycling. The remaining tested the abutments with the application of static load immediately after sample fabrication (static testing) (Table 8).

All except four studies (Balfour & O'Brien 1995, Norton 2000, Wiskott et al. 2004, Wiskott et a. 2007) tested the strength of the abutments in combination with fixed reconstructions, i.e. all-ceramic or metallic single crowns (Table 8).

Unfortunately, the studies were not performed following a standardized test method. In most of the studies a similar shape of the abutment and crown were used, simulating a maxillary incisor. Yet, with these samples the load was either applied at the incisal edge of the crown or at the palatal surface at angles varying from 0° to 50° to the long axis of the implant. Two studies tested molar crowns (Steinebrunner et al. 2008, Wolf et al. 2008). In these studies the load was applied perpendicularly to the occlusal surface (0°) (Table 8).

Most of the investigations used a universal testing machine for load application In two studies (Wiskott et al. 2004, Wiskott et al. 2007), the samples were loaded at 90° in a rotating-beam fatigue device (Table 8).

All studies tested the load until failure, i.e. fracture of the abutment or abutment screw, or plastic deformation of the abutment/implant. All reported on mean fracture strength (in N) of the abutments, two studies additionally reported on mean bending moments (in Ncm) (Table 8)

Abutment and reconstruction load

Generally, the data extracted from the studies were poorly comparable as the test methods employed in almost all studies did not follow standardized protocols (e.g. ISO standardized procedures). Variations in sample shape and size, angle of load application are only a few of the factors that exhibited an influence on the strength values obtained (Table 8). Therefore, a meta-analysis of the strength data was not attempted.

Subsequently, “comparable” studies testing various abutment-crown combinations, simulating maxillary incisors, were pooled regarding abutment and reconstruction materials and type of implant-abutment connection in order to visualize factors that exhibit influence on the strength (Fig. 8 and 9). Four investigations were excluded from this comparison due to large differences in the applied test methods (Steinebrunner et al. 2008, Wolf et al. 2008, Wiskott et al. 2004, Wiskott et al. 2007).

Strength data for ceramic abutments supporting metal anterior crowns and ceramic abutments supporting all-ceramic anterior crowns were compared to metal abutments supporting metal anterior crowns and metal abutments supporting all-ceramic anterior crowns (Fig. 8 and 9).

The mean fracture load of the ceramic abutments and supported crowns after static and/or fatigue testing ranged from 170 N for glass-infiltrated alumina abutments supporting glass-ceramic crowns (Cho et al. 2002), to 737 N for zirconia abutments supporting glass-ceramic crowns (Yildirim et al. 2003) (Table 8).

The mean fracture load of metal abutments and their crowns after static and/or fatigue testing ranged from 82 N for titanium abutments supporting glass-ceramic crowns (Andersson et al. 1994), to 1570 N for titanium abutments supporting metal crowns (Erneklint et al. 2006) (Table 8).

The angle of load application and the type of implant-abutment connection exhibited an influence on the strength values (Fig. 8). Load angle and load fracture were observed to be reciprocal. Yet, Figure 9 might indicate that higher fracture load values can be achieved at internally connected abutments at the same degree of load application as at externally connected abutments.

Internal connection of abutments tends to be beneficial both in the laboratory and in the clinical studies.

Discussion parts I and II

This systematic review of the literature indicated no significant differences in the performance of ceramic and metal abutments. Ceramic abutments exhibited similar survival and complication rates as metal abutments when supporting implant-borne crowns and FDPs. Furthermore, a tendency towards fewer technical and esthetical complications was observed with ceramic abutments. Consequently, ceramic abutments can be judged a valid alternative to metal abutments.

Systematic reviews have increasingly been used to summarize the cumulative information on the optimal treatment, which is most appropriately given in RCTs (Egger et al. 2001). For the present review, three RCTs comparing ceramic and metal abutments were available. The remaining studies were prospective and retrospective cohort studies. The shortest follow-up period of all included studies was three years. A 3-year observation period is rather short and consequently no final conclusions can be drawn on the performance of ceramic compared to metal abutments. In fact, ceramics as brittle materials are prone to fracture due to fatigue over time (Rekow & Thompson 2007). For definitive conclusions on their performance long observation periods are therefore needed. Unfortunately, very few studies have been published on ceramic abutments, although the first ceramic abutments were introduced in 1993 (reports on Prestipino & Ingbeceramic abutments in this review were published between 2001 and 2009). These studies had maximum observation periods of four years. In contrast, the observation periods in the studies of metal abutments ranged from three to eight years. The mean follow up of three years, hence, was a necessary compromise.

Implant survival

The analyses performed in this systematic review estimated a 96.4% implant-in-function survival rate for implants supporting ceramic or metal abutments for a follow-up of 5 years. In previous systematic reviews of implant-borne single crowns (Jung et al. 2008a) and FDPs (Pjetursson et al. 2004) 5-year implant survival rates of 96.8%, and 95.4% respectively, were reported.

One further review of the incidence of biological and technical complications in implant dentistry (Berglundh et al. 2002) reported a 2.06%-2.50% rate of implant loss during 5 years of single crown function. The respective rate for implants lost during 5-year support of FDPs was 2.49%-3.07% (Berglundh et al. 2002). In the present review the mean estimated rate for implant failure during 5 years of loading with single crowns or FDPs was slightly higher with 3.6% (95% CI: 2.5%-5.1%). Overall, the results of the reviews are in accordance.

Abutment survival

The survival rate of ceramic abutments was 99.1% after an estimated follow-up of 5 years. The corresponding survival rate of metal abutments was 97.4%. Most encouragingly, in the present review no significant differences in the survival rates of ceramic and metal abutments were found.

Metal abutments exhibit high survival rates due to the excellent physical properties of metal (Andersson et al. 1998). Metals are ductile, which enhances their tolerance towards small defects or cracks. Ceramics, in contrast, are delicate materials due to their brittleness. Because of this brittleness they do not well withstand tensile forces or surface defects and cracks. Fracture occurs when the tensile forces exceed the limits determined by the fracture toughness (Rekow & Thompson 2007). Improvements in the field of ceramics have encompassed the development of the high strength ceramics alumina and zirconia, which exhibit increased fracture toughness. Very promising survival rates of implant abutments made out of both alumina and zirconia have been reported (Andersson et al. 2001, Glauseret al. 2004, Canullo 2007). Among all dental ceramics zirconia exhibits the highest fracture toughness (Lüthy 1996). One recent RCT of zirconia and titanium abutments showed that this ceramic can be used as an abutment material even in posterior regions of the jaws with similar success to metal (Zembic et al. in press). Besides its successful application as an abutment material, zirconia has been demonstrated to exhibit a very promising performance as a framework material for tooth-borne FDPs in areas with high loading (Raigrodsky et al. 2006; Sailer et al. 2007; Tinschert et al. 2008; Molin & Karlsson 2008).

In summary, high-strength ceramic abutments offered excellent survival rates when supporting implant-borne fixed reconstructions. Their survival resembled that of metal abutments. It has to be considered, though, that this evidence was derived from five studies reporting on 166 ceramic abutments and 18 studies reporting on 4807 metal abutments. Furthermore, the ceramic abutments had been followed-up for 3.7 years, whereas the metal abutments had been followed-up for 4.8 years.

Technical complications

No significant differences in the technical outcomes occurred at ceramic and metal abutments.

Even more, with the exception of abutment fractures, the present review showed a trend for fewer technical complications with ceramic abutments. It has to be considered, though, that the majority of the data on ceramic abutments were obtained from anterior and premolar regions where lower occlusal forces are assumed.

Fracture of the abutment seldom occurred with either type of abutment, despite the differences in fracture resistance. Its cumulative incidence only was 0.3%.

Problems with the abutment screws were most frequently reported as a technical complication. They encompassed either fracture or loosening of the abutment screw. Abutment screw fracture solely occurred at metal abutments at an estimated 5-year rate of 0.8%. It might be hypothesized, that with ceramic abutments fracture of the abutment itself would occur prior to fracture of the abutment screw (Tripodakis et al. 1995). During occlusal loading of an implant-borne reconstruction, the region around the abutment screw head is the area of the highest torque and stress concentrations. This area has been demonstrated to be the most critical region for the stability of ceramic abutments in laboratory studies (Tripodakis et al. 1995, Att et al. 2006a, Att et al. 2006b). High tensile forces occurring in this region during function were the most frequent origin of fracture of the ceramic abutments (Tripodakis et al. 1995). With metal abutments the same forces first led to deformation and then fracture of the abutment screws (Att et al. 2006b).

Abutment screw loosening, in contrast, occurred similarly with both ceramic and metal abutments, and its cumulative incidence after 5 years was 5.1%. In a recent systematic review of implant-borne single crowns abutment screw loosening was the most common technical complication (Jung et al. 2008a). In that review a 12.7% incidence was reported after 5 years (Jung et al. 2008a). However, when the authors excluded one outlying study (Henry et al. 1996) from their meta-analysis, the incidence reduced to 5.8% (Jung et al. 2008a). The reason for the high level of screw loosening in the excluded study was considered to be the use of gold screws for securing the abutments (Henry et al. 1996, Jung et al. 2008a). Another review of implant-borne FDPs reported screw loosening of 5.8% after 5 years. These findings are in accordance with the screw loosening rates found at abutments supporting both crowns and FDPs in the present review.

Several factors have been demonstrated to be crucial for the reduction of abutment screw complications. In a recent review it has been shown that anti-rotational features of the implant components and screw preloading torques were the most important prerequisites for the reduction of screw loosening rates (Theoharidou et al. 2008).

Furthermore, the type of implant-abutment connection might have an influence. In laboratory studies, the internal conical connection was demonstrated to exhibit significantly higher strength than the external hexagonal connection due to a higher resistance to bending. The occurrence of abutment screw fractures or other problems with abutment screws was also lower with internal connection (Norton 1997, Khraisat et al. 2002). In the present review of both, clinical and laboratory studies a tendency to superior performance and less screw loosening was found with abutments with internal connections. Interestingly, this observation is not supported by the data in a recent review of screw loosening (Theoharidou et al. 2008).

Finally, the present review demonstrated that the abutment material had an influence on the performance of the reconstructions. All-ceramic crowns supported by ceramic abutments exhibited the same survival rates as metal-ceramic crowns supported by metal abutments. For both types of reconstructions the survival rate after 5 years was 100%. A previous review reported a lower survival rate of implant-borne single-crowns, and furthermore that all-ceramic crowns exhibited significantly lower survival rates than metal-ceramic crowns (91.2% vs. 95.4%) (Jung et al. 2008a). However, all the failed all-ceramic crowns were supported by metal abutments. The negative influence of metal abutments on the stability of ceramic crowns has also been noticed in present review.

Biological and esthetic complications

The cumulative rate for biological complications with ceramic abutments was 5.2% and 7.7%. with metal abutments. Yet, no statistically significant difference was found between the two types of abutments. These rates are slightly lower than those in previous reviews of implant-borne reconstructions (Pjetursson et al. 2004, Pjetursson et al. 2007, Jung et al. 2008a). Soft tissue complications have been reported as 9.7% with single implant crowns 9.7% (Jung et al. 2008a) and 8.6% with FDPs (Pjetursson et al. 2004, Pjetursson et al. 2007).

Interestingly, the present review indicated a higher incidence of soft tissue recession at ceramic abutments. The cumulative rate for recession after five years was 8.9% with ceramic and 3.8% with metal abutments. The reasons for this observation are unclear. Animal studies of the biocompatibility of ceramics have demonstrated similar soft tissue integration of alumina, zirconia and titanium (Hashimoto et al. 1988, Abrahamsson et al. 1998, Kohal et al. 2004). One reason might be that ceramic abutments are more frequently used in the esthetic zone in the anterior maxilla, where the risk of recession might be higher than in the molar region with thicker soft tissue.

The present review has indicated a superior esthetic outcome with ceramic abutments. This finding is supported by a recent RCT in which ceramic abutments induced less soft tissue discoloration than metal abutments (Jung et al 2008b).

One major limitation of the included studies of the present review is that only one study analyzed the esthetic outcome of ceramic and metal abutments in a standardized way (Zembic et al. 2009). Additionally, no study reporting on patient-related outcomes was available. In the future, there is a need for widely accepted and reproducible instruments for the assessment of the esthetic outcome (Furhauser et al. 2005, Zembic et al. 2009).

Finally, the present review delivered clinical results with mainly one type of design of ceramic abutments. In all except one study (Canullo 2007), both the alumina and zirconia abutments were designed with an external implant-abutment connection. In this study zirconia abutments with a metallic internal implant-abutment connection were tested (Canullo 2007). Currently numerous new designs of ceramic abutments are available, which might result in differences in their performance. Prior to the clinical application, therefore, laboratory tests of the fracture strength of new types of abutments are crucial.

The present review of the laboratory studies has revealed that the applied test methods were poorly standardized, hampering the interpretation of the in-vitro data. As a consequence, only few clinically relevant conclusions can be drawn, and standardization of laboratory abutment strength tests with the inclusion of clinically relevant factors is definitely needed.

Conclusion

Given the available information, the estimated 5-year failure rates for ceramic and metal abutments seemed similar. The information in the studies included in this review did not provide evidence for differences in the technical and biological outcomes of ceramic and metal abutments. Furthermore, the reconstructions supported by both types of abutments exhibit similar survival rates. However, the information for ceramic abutments was limited in the number of studies and abutments analyzed as well as the accrued follow-up time. More studies with increased follow-up times for ceramic abutments are needed to permit more definite conclusions when comparing ceramic and metal abutments.

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Gehrke, P., Dhom, G., Brunner, J., Wolf, D., Degidi, M. & Piatelli, A. (2006) Zirconium implant abutments: Fracture strength and influence of cyclic loading on retaining-screw loosening. *Quintessence International* **37**: 19-26.

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Khraisat, A., Abu-Hammad, O., Dar-Odeh, N. & Al-Kayed A.M. (2004) Abutment screw loosening and bending resistance of external hexagon implant system after lateral cyclic loading. *Clinical Implant Dentistry and Related Research* **6**: 157-164.

Leutert, C., Sailer, I., Stawarczyk, B., Sailer, T. R., Hämmerle, C.H.F. (unpublished) In-vitro study of the fracture load of zirconia and titanium abutments with internal implant-abutment connections. *Manuscript in preparation*

Norton, M.R. (2000) In vitro evaluation of the strength of the conical implant-to-abutment joint in two commercially available implant systems. *Journal of Prosthetic Dentistry* **83**: 567-571.

Sailer, I., Sailer, T., Stawarczyk, B., Jung, R.E. & Hämmerle, C.H.F. (2009) In-vitro study of the influence of the type of connection on the fracture load of zirconia abutments with internal and external implant-abutment connections. *International Journal of Oral and Maxillofacial Implants* accepted for publication

Steinebrunner, L., Wolfart, S., Ludwig, K. & Kern, M. (2008) Implant-abutment interface design affects fatigue and fracture strength of implants. *Clinical Oral Implants Research* **19**: 1276-1284.

Strub, J.R. & Gerds, T. (2003) Fracture strength and failure mode of five different single-tooth implant-abutment combinations. *International Journal of Prosthodontics* **16**: 167-171.

Sundh, A. & Sjögren, G. (2008) A study of the bending resistance of implant-supported reinforced alumina and machined zirconia abutments and copies. *Dental Materials* **24**: 611-617.

Tripodakis, A.P.D., Strub, J.R., Kappert, H.F. & Witkowski, S. (1995) Strength and mode of failure of single implant all-ceramic abutment restorations under static load. *International Journal of Prosthodontics* **8**: 265-272.

Wiskott, A.H.W., Pavone, A.F., Scherrer, S.S., Renevey, R.R. & Belser, U.C. (2004) Resistance of ITI implant connectors to multivectorial fatigue load application. *International Journal of Prosthodontics* **17**: 672-679.

Wiskott, A.H.W., Jaquet, R., Scherrer, S.S. & Belser, U.C. (2007) Resistance of internal-connection implant connectors under rotational fatigue loading. *International Journal of Oral and Maxillofacial Implants* **22**: 249-257.

Wolf, D., Bindl, A., Schmidlin, P.R., Lüthy, H. & Mörmann, W.H. (2008) Strength of CAD/CAM-generated esthetic ceramic molar implant crowns. *International Journal of Oral and Maxillofacial Implants* **23**: 609-617.

Yildirim, M., Fischer, H., Marx, R. & Edelhoff, D. (2003) In vivo fracture resistance of implant-supported all-ceramic restorations. *Journal of Prosthetic Dentistry* **90**: 325-331.

List of excluded full-text articles and the reason for exclusion
I. Clinical Studies

Andersson, B., Ödmann, P., Carlsson, L. & Brånemark, P.-I. (1992) A new Brånemark single tooth abutment: handling and early clinical exeriences. *International Journal of Oral and Maxillofacial Implants* **7**: 105-111.
Exclusion criteria: mean follow-up less than 3 years, 5-year follow-up included in this review (Andersson et al. 1998, International Journal of Prosthodontics)

Andersson, B., Ödmann, P., Lindvall, A.-M. & Lithner, B. (1995) Single-tooth restorations supported by osseointegrated implants: results and experiences from a prospective study after 2 to 3 years. *International Journal of Oral and Maxillofacial Implants* **10**: 702-711.
Exclusion criteria: 5-year follow-up included in this review (Andersson et al. 1998, International Journal of Prosthodontics)

Andersson, B. (1995) Implants for single-tooth replacement. A clinical and experimental study on the Brånemark CeraOne system. *Swedish Dental Journal:* **Supplement 108**.
Exclusion criteria: thesis reporting on already included data (Andersson et al. 1998, International Journal of Prosthodontics)

Andersson, B., Ödmann, P., Lindvall, A.-M. & Brånemark, P.-I. (1998) Five-year prospective study of prosthodontic and surgical single-tooth implant treatment in general practices and at a specialist clinic. *International Journal of Prosthodontics* **11**: 351-355.
Exclusion criteria: no abutment survival data

Anitua, E., Orive, G., Aguirre, J.J. & Andia, I. (2008) Five-year clinical evaluation of short dental implants placed in posterior areas: a retrospective study. *Journal of Periodontology* **79**: 42-48.
Exclusion criteria: no abutment survival data

Attard, N. & Zarb, G.A. (2002) Implant prosthodontic management of posterior partial edentuslism: long-term follow-up of a prospective study. *Journal of the Canadian Dental Association* **68**: 118-124.
Exclusion criteria: no abutment survival data

Attard, N.J. & Zarb, G.A. (2003) Implant-prosthodontic management of partially edentulous patients missing posterior teeth: The Toronto experience. *Journal of Prosthetic Dentistry* **89**: 352-359.
Exclusion criteria: no abutment survival data

Babbush, C.A. & Shimura, M. (1993) Five-year statistical and clinical observations with the IMZ two-stage osteointegrated implant system. *International Journal of Oral and Maxillofacial Implants* **8**: 245-253.
Exclusion criteria: no abutment survival data, mixed fixed and removable reconstructions

Balshi,T.J., Ekfeldt, A., Stenberg, T. & Vrielinck, L. (1997) Three-year evaluation of Brånemark implants connected to angulated abutments. *International Journal of Oral and Maxillofacial Implants* **12**: 52-58.
Exclusion criteria: no detailed data for implant-borne single crowns and FDPs, data mixed

Bambini, F., Lo Muzio, L. & Procaccini, M. (2001) Retrospective analysis of the influence of abutment structure design on the success of implant unit. A 3-year controlled follow-up study. *Clinical Oral Implants Research* **12**: 319-324.
Exclusion criteria: no abutment survival data, and very limited information on technical complications

Bass, S.L. & Triplett, R.G. (1991) The effects of preoperative resorption and jaw anatomy on implant success. A report of 303 cases. *Clinical Oral Implants Research* **2**: 193-198.
Exclusion criteria: no abutment survival data

Becker, W. & Becker, B.E. (1995) Replacement of maxillary and mandibular molars with single endosseous implant restorations: A retrospective study. *Journal of Prosthetic Dentistry* **74**: 51-55.
Exclusion criteria: insufficient abutment information and survival data

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**: 269-277.
Exclusion criteria: no abutment survival data

Blanes, R.J., Bernard, J.P., Blanes, Z.M. & Belser, U.C. (2007) A 10-year prospective study of ITI dental implants placed in the posterior region. I: Clinical and radiographic results. *Clinical Oral Implants Research* **18**: 699-706.
Exclusion criteria: no abutment survival data

Blanes, R.J., Bernard, J.P., Blanes, Z.M. & Belser, U.C. (2007) A 10-year prospective study of ITI dental implants placed in the posterior region. II: Influence of the crown-to-implant ratio and different prosthetic treatment modalities on crestal bone loss. *Clinical Oral Implants Research* **18**: 707-714.
Exclusion criteria: no abutment survival data

Block, M.S. & Kent, J.N. (1992) Prospective review of integral implants. Clinical trials with hydroxyapatite-coated implants. *Dental Clinics of North America* **36**: 27-37.
Exclusion criteria: no abutment survival data

Brägger, U., Hämmerle, C. & Weber, H.-P. (1990) Fixed reconstructions in partially edentulous patients using two-part ITI implants (Bonefit) as abutments. Treatment planning, indications and prosthetic aspects. *Clinical Oral Implants Research* **1**: 41-49.
Exclusion criteria: no abutment survival data

Brägger, U. Aeschlimann, S., Bürgin, W., Hämmerle, C.H.F. & 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.
Exclusion criteria: multiple publication on the same patient cohort, 10-year follow-up included in this review (Brägger et al. 2005, Clinical Oral Implants Research)

Brocard, D., Barthet, P., Baysse, E., Duffort, J.F., Eller, P. Justumus, P., Marin, P., Oscaby, F., Simonet, T., Benqué, E. & Brunel, G. (2000) A multicenter report on 1022 consecutively placed ITI implants: a 7-year longitudinal study. *International Journal of Oral and Maxillofacial Implants* **15**: 691-700.
Exclusion criteria: no abutment survival data

Buchs, A.U., Hahn, J. & Vassos, D.M. (1995) Efficacy of threaded hydroxyapatite-coated implants placed in the anterior maxilla. *Implant Dentistry* **4**: 272-275.
Exclusion criteria: mean follow-up less than 3 years

Buchs, A.U., Hahn, J. & Vassos, D.M. (1995) Interim clinical study report: A threaded, hydoxylapatite-coated implant – Five-year post-restoration safety and efficacy. *Journal of Oral Implantology* **21**: 266-274.
Exclusion criteria: no abutment survival data

Buser, D., Mericske-Stern, R., Bernard, J.P., Behneke, A., 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.
Exclusion criteria: no abutment survival data

Carbone, M., Goss, E., Borione, M., Bava, L., Broccoletti, R., Carrozzo, M. & Gandolfo, S. (2007) *Minerva Stomatologica* **56**: 481-495.
Exclusion criteria: no abutment survival data

Carlson, B. & Carlsson, G.E. (1994) Prosthodontic complications in osseointegrated dental implant treatment. *International Journal of Oral and Maxillofacial Implants* **9**: 90-94.
Exclusion criteria: insufficient information on abutments and lack of survival data

Cavicchia, F. & Bravi, F. (1994) Free-standing vs tooth-connected implant-supported fixed partial restorations: A comparative restrospective clinical study of the prosthetic results. *International Journal of Oral and Maxillofacial Implants* **9**: 711-718.
Exclusion criteria: mean follow-up less than 3 years

Cordaro, L., Torsello, F., di Mirisola, V. & Rossini, T.C. (2006) Retrospective evaluation of mandibular incisor replacement with narrow neck implants. *Clinical Oral Implants Research* **17**: 730-735.
Exclusion criteria: no abutment survival data

Cordioli, G., Castagna, S. & Consolati, E. (1994) Single-tooth implant rehabilitation: A retrospective study of 67 implants. *International Journal of Prosthodontics* **7**: 525-531.
Exclusion criteria: mean follow-up less than 3 years

Cosci, F. & Cosci, B. (1997) A 7-year retrospective study of 423 immediate implants. *Compendium* **18**: 940-948.
Exclusion criteria: no abutment survival data

Cummings, J. & Arbree, N.S. (1995) Prosthodontic treatment of patients receiving implants by predoctoral students: Five-year follow-up with the IMZ system. *Journal of Prosthetic Dentistry* **74**: 56-59.
Exclusion criteria: only removable reconstructions were analyzed

De Bruyn, H., Collaert, B., Lindén, U., Johansson, C. & Albrektsson, T. (1999) Clinical outcome of Screw Vent implants. A 7-year prospective follow-up study. *Clinical Oral Implants Research* **10**: 139-148.
Exclusion criteria: no abutment survival data

De Leonardis, D., Garg, A.K. & Pecora, G.E. (1999) Osseointegration of rough acid-etched titanium implants: 5-year follow-up of 100 minimatic implants. *International Journal of Oral and Maxillofacial Implants* **14**: 384-391.
Exclusion criteria: no abutment survival data

Deporter, D.A., Todescan, R., Watson, P.A., Pharoah, M., Pilliard, R.M. & Tomlinson, G. (2001) A prospective human clinical trial of Endopore dental implants in restoring the partially edentulous maxilla using fixed prostheses. *International Journal of Oral and Maxillofacial Implants* **16**: 527-536.
Exclusion criteria: no abutment survival data

Dhanrajani, P.J. & Al-Rafee, M.A. (2005) Single-tooth implant restorations: A retrospective study. *Implant Dentistry* **14**: 125-130.
Exclusion criteria: insufficient information on abutments and lack of survival data

Döring, K., Eisenmann, E. & Stiller, M. (2004) Functional and esthetic considerations for single-tooth Ankylos implant-crowns: 8 years of clinical performance. *Journal of Oral Implantology* **30**: 198-209.
Exclusion criteria: insufficient information on abutments and lack of survival data

Duncan, J.P., Nazarova, E., Vogiatzi, T. & Taylor, T.D. (2003) Prosthodontic complications in a prospective clinical trial of single-stage implants at 36 months. *International Journal of Oral and Maxillofacial Implants* **18**: 561-565.
Exclusion criteria: insufficient information on abutments and lack of survival data

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.
Exclusion criteria: insufficient information/data on abutments

Ekfeldt, A., Carlsson, G.E. & Borjesson, G. (1994) Clinical evaluation of single-tooth restorations supported by osseointegrated implants: A retrospective study. *International Journal of Oral and Maxillofacial Implants* **9**: 179-183.
Exclusion criteria: mean follow-up less than 3 years

Eliasson, A. (2008) On the role of number of fixtures, surgical technique and timing of loading. *Swedish Dental Journal Supplement 197*: 3-95.
Exclusion criteria: thesis, no clinical study

Engquist, B., Nilson, H. & Astrand, P., (1995) Single-tooth replacement by osseointegrated Brånemark implants. A retrospective study of 82 implants. *Clinical Oral Implants Research* **6**: 238-245.
Exclusion criteria: mean follow-up less than 3 years

Ericsson, I., Randow, K., Nilner, K. & Peterson, A., (2000) Early functional loading of Brånemark dental implants: 5-year clinical follow-up study. *Clinical Implant Dentistry and Related Research* **2**: 70-77.
Exclusion criteria: edentulous patients

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**: 422-426.
Exclusion criteria: no abutment survival data

Fiorellini, J.P., Martuscelli, G. & Weber, H.P., (1998) Longitudinal studies of implant systems. *Periodontology 2000* **17**: 125-131.
Exclusion criteria: no clinical study

Friberg, B., Nilson, H., Olsson, M. & Palmquist, C., (1997) Mk ii: The self-tapping Brånemark implant: 5-year results of a prospective 3-center study. *Clinical Oral Implants Research* **8**: 279-285.
Exclusion criteria: no abutment survival data, mixed fixed and removable reconstructions

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 cylinders up to 60+ months in function. *International Journal of Oral and Maxillofacial Implants* **8**: 617-621.
Exclusion criteria: removable reconstructions

Fugazzotto, P.A., Vlassis, J. & Butler, B., (2004) ITI implant use in private practice: Clinical results with 5,526 implants followed up to 72+ months in function. *International Journal of Oral and Maxillofacial Implants* **19**: 408-412.
Exclusion criteria: no abutment survival data

Fugazzotto, P.A., Wheeler, S.L. & Lindsay, J.A., (1993) Success and failure rates of cylinder implants in type IV bone. *Journal of Periodontolgy* **64**: 1085-1087.
Exclusion criteria: no abutment survival data

Garlini, G., Bianchi, C., Chierichetti, V., Sigurta, D., Maiorana, C. & Santoro, F., (2003) Retrospective clinical study of Osseotite implants: Zero- to 5-year results. *International Journal of Oral and Maxillofacial Implants* **18**: 589-593.
Exclusion criteria: mean follow-up less than 3 years, mixed fixed and removable reconstructions

Golec, T.S. & Krauser, J.T., (1992) Long-term retrospective studies on hydroxyapatite coated endosteal and subperiosteal implants. *Dental Clinics of North America* **36**: 39-65.
Exclusion criteria: review. mixed reconstructions on blade and cylindrical implants

Gomez-Roman, G., Schulte, W., d'Hoedt, B. & Axman-Krcmar, D., (1997) The Frialit-2 implant system: Five-year clinical experience in single-tooth and immediately postextraction applications. *International Journal of Oral and Maxillofacial Implants* **12**: 299-309.
Exclusion criteria: no abutment survival data

Gotfredsen, K. & Karlsson, U., (2001) A prospective 5-year study of fixed partial prostheses supported by implants with machined and TiO_2-blasted surface. *Journal of Prosthodont*ics **10**: 2-7.
Exclusion criteria: no abutment survival data

Gothberg, C., Bergendal, T. & Magnusson, T., (2003) Complications after treatment with implant-supported fixed prostheses: A retrospective study. *The International Journal of Prosthodontics* **16**: 201-207.
Exclusion criteria: 75 of 78 patients edentulous, no abutment survival data on 3 FDP

Greenfield, E.J., (2008) Implantation of artificial crown and bridge abutments. 1913. *Compendium Continuing Education in Dentistry* **29**: 232-237.
Exclusion criteria: no abutment survival data

Groisman, M., Ferreira, H.M., Frossard, W.M., de Menezes Filho, L.M. & Harari, N.D., (2001) Clinical evaluation of hydroxyapatite-coated single-tooth implants: A 5-year retrospective study. *Practical Procedures & Aesthetic Dentistry* **13**: 355-360; quiz 362.
Exclusion criteria: insufficient information on abutments and lack of survival data

Gunne, J., Åstrand, P., Ahlen, K., Borg, K. & Olsson, M., (1992) Implants in partially edentulous patients. A longitudinal study of bridges supported by both implants and natural teeth. *Clinical Oral Implants Research* **3**: 49-56.
Exclusion criteria: combined tooth-implant supported FPDs

Gunne, J., Åstrand, P., Lindh, T., Borg, K. & Olsson, M., (1999) Tooth-implant and implant supported fixed partial dentures: A 10-year report. *International Journal of Prosthodontics* **12**: 216-221.
Exclusion criteria: combined tooth-implant supported FPDs, no abutment survival data

Gunne, J., Jemt, T. & Linden, B., (1994) Implant treatment in partially edentulous patients: A report on prostheses after 3 years. *International Journal of Prosthodontics* **7**: 143-148.
Exclusion criteria: no abutment survival data

Gunne, J., Nystrom, E. & Kahnberg, K.E., (1995) Bone grafts and implants in the treatment of the severely resorbed maxillae: A 3-year follow-up of the prosthetic restoration. *International Journal of Prosthodontics* **8**: 38-45.
Exclusion criteria: edentulous patients

Haas, R., Mensdorff-Pouilly, N., Mailath, G. & Watzek, G., (1995) Brånemark single tooth implants: A preliminary report of 76 implants. *Journal of Prosthetic Dentistry* **73**: 274-279.
Exclusion criteria: mean follow-up less than 3 years

Haas, R., Mensdorff-Pouilly, N., Mailath, G. & Watzek, G., (1996) Survival of 1,920 IMZ implants followed for up to 100 months. *International Journal of Oral and Maxillofacial Implants* **11**: 581-588.
Exclusion criteria: insufficient information on abutments and lack of survival data

Haas, R., Polak, C., Furhauser, R., Mailath-Pokorny, G., Dortbudak, O. & Watzek, G., (2002) A long-term follow-up of 76 Brånemark single-tooth implants. *Clinical Oral Implants Research* **13**: 38-43.
Exclusion criteria: insufficient information on abutments and lack of survival data

Hahn, J. & Vassos, D.M., (1997) Long-term efficacy of hydroxyapatite-coated cylindrical implants. *Implant Dentistry* **6**: 111-115.
Exclusion criteria: no abutment survival data

Hedkvist, L., Mattsson, T. & Hellden, L.B., (2004) Clinical performance of a method for the fabrication of implant-supported precisely fitting titanium frameworks: A retrospective 5- to 8-year clinical follow-up study. *Clinical Implant Dentistry and Related Research* **6**: 174-180.
Exclusion criteria: no abutment survival data

Heller, A.L. & Heller, R.L., (1996) Clinical evaluations of a porous-surfaced endosseous implant system. *Journal of Oral Implantology* **22**: 240-246.
Exclusion criteria: no abutment survival data

Henriksson, K. & Jemt, T., (2003) Evaluation of custom-made procera ceramic abutments for single-implant tooth replacement: A prospective 1-year follow-up study. *International Journal of Prosthodontics* **16**: 626-630.

Exclusion criteria: mean follow-up less than 3 years

Henry, P.J., Tolman, D.E. & Bolender, C., (1993) The applicability of osseointegrated implants in the treatment of partially edentulous patients: Three-year results of a prospective multicenter study. *Quintessence International* **24**: 123-129.
Exclusion criteria: insufficient information on abutments

Heydecke, G., Sierraalta, M. & Razzoog, M.E., (2002) Evolution and use of aluminum oxide single-tooth implant abutments: A short review and presentation of two cases. *International Journal of Prosthodontics* **15**: 488-493.
Exclusion criteria: no information on observation period

Higuchi, K.W., Folmer, T. & Kultje, C., (1995) Implant survival rates in partially edentulous patients: A 3-year prospective multicenter study. *Journal of Oral and Maxillofacial Surgery* **53**: 264-268.
Exclusion criteria: insufficient information on abutments

Hosny, M., Duyck, J., van Steenberghe, D. & Naert, I., (2000) Within-subject comparison between connected and nonconnected tooth-to-implant fixed partial prostheses: Up to 14-year follow-up study. *International Journal of Prosthodontics* **13**: 340-346.
Exclusion criteria: insufficient information on abutments

Hürzeler, M.B., Kirsch, A., Ackermann, K.L. & Quinones, C.R., (1996) Reconstruction of the severely resorbed maxilla with dental implants in the augmented maxillary sinus: A 5-year clinical investigation. *International Journal of Oral and Maxillofacial Implants* **11**: 466-475.
Exclusion criteria: insufficient informations on abutments

Ingber, A. & Prestipino, V. (1991) High-strength ceramic abutment provides esthetic, functional alternative. *Dental Implantology Update* **2**: 70-72.
Exclusion criteria: description of a specific abutment

Ivanoff, C.J., Grondahl, K., Sennerby, L., Bergstrom, C. & Lekholm, U., (1999) Influence of variations in implant diameters: A 3- to 5-year retrospective clinical report. *International Journal of Oral and Maxillofacial Implants* **14**: 173-180.
Exclusion criteria: insufficient information on abutments

Jaggers, A., Simons, A.M. & Badr, S.E., (1993) Abutment selection for anterior single tooth replacement. A clinical report. *Journal of Prosthetic Dentistry* **69**: 133-135.
Exclusion criteria: case report, no information on observation period

Jebreen, S.E. & Khraisat, A., (2007) Multicenter retrospective study of ITI implant-supported posterior partial prosthesis in jordan. *Clinical Implant Dentistry & Related Research* **9**: 89-93.
Exclusion criteria: insufficient information on abutments

Jemt, T. & Lekholm, U., (1993) Oral implant treatment in posterior partially edentulous jaws: A 5-year follow-up report. *International Journal of Oral and Maxillofacial Implants* **8**: 635-640.
Exclusion criteria: insufficient information on abutments

Jemt, T. & Pettersson, P., (1993) A 3-year follow-up study on single implant treatment. *Journal of Dentistry* **21**: 203-208.
Exclusion criteria: insufficient information on abutments

Johansson, L.A. & Ekfeldt, A., (2003) Implant-supported fixed partial prostheses: A retrospective study. *International Journal of Prosthodontics* **16**: 172-176.
Exclusion criteria: insufficient information on abutments

Johnson, R.H. & Persson, G.R., (2001) A 3-year prospective study of a single-tooth implant--prosthodontic complications. *International Journal of Prosthodontics* **14**: 183-189.
Exclusion criteria: mixed one-piece abutments and "others", lack of information on abutments

Kaptein, M.L., De Putter, C., De Lange, G.L. & Blijdorp, P.A., (1999) A clinical evaluation of 76 implant-supported superstructures in the composite grafted maxilla. *Journal of Oral Rehabilitation* **26**: 619-623.
Exclusion criteria: insufficient information on abutments

Karl, M., Rosch, S., Graef, F., Taylor, T.D. & Heckmann, S.M., (2005) Static implant loading caused by as-cast metal and ceramic-veneered superstructures. *Journal of Prosthetic Dentistry* **93**: 324-330.
Exclusion criteria: insufficient information on abutments

Karoussis, I.K., Brägger, U., Salvi, G.E., Bürgin, 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.
Exclusion criteria: insufficient information on abutments

Keller, W., Brägger, U. & Mombelli, A., (1998) Peri-implant microflora of implants with cemented and screw retained suprastructures. *Clinical Oral Implants Research* **9**: 209-217.
Exclusion criteria: insufficient information on abutments, unclear observation period

Kindberg, H., Gunne, J. & Kronström, M., (2001) Tooth- and implant-supported prostheses: A retrospective clinical follow-up up to 8 years. *International Journal of Prosthodontics* **14**: 575-581.
Exclusion criteria: combined tooth-implant supported FPDs

Klineberg, I., (1993) An overview of Brånemark osseointegrated oral implants in Australia and New Zealand 1981-1992. *Australian Prosthodontic Journal* **7 Suppl**: 57-64.
Exclusion criteria: insufficient information on abutments

Knauf, M., Gerds, T., Muche, R. & Strub, J.R., (2007) Survival and success rates of 3i implants in partially edentulous patients: Results of a prospective study with up to 84-months' follow-up. *Quintessence International* **38**: 643-651.
Exclusion criteria: insufficient information on abutments

Ko, S.M., Lee, J.K., Eckert, S.E. & Choi, Y.G., (2006) Retrospective multicenter cohort study of the clinical performance of 2-stage implants in south korean populations. *International Journal of Oral and Maxillofacial Implants* **21**: 785-788.
Exclusion criteria: insufficient information on abutments

Kollar, A., Huber, S., Mericske, E. & Mericske-Stern, R., (2008) Zirconia for teeth and implants: A case series. *International Journal of Periodontics & Restorative Dentistry* **28**: 479-487.
Exclusion criteria: observation period too short

Kourtis, S.G., Sotiriadou, S., Voliotis, S. & Challas, A., (2004) Private practice results of dental implants. Part I: Survival and evaluation of risk factors--part II: Surgical and prosthetic complications. *Implant Dentistry* **13**: 373-385.
Exclusion criteria: insufficient information on abutments

Kronström, M., McGrath, L. & Chaytor, D., (2008) Implant dentistry in the undergraduate dental education program at dalhousie university. Part 1: Clinical outcomes. *International Journal of Prosthodontics* **21**: 124-128.
Exclusion criteria: insufficient information on abutments

Kucey, B.K., (1997) Implant placement in prosthodontics practice: A five-year retrospective study. *Journal of Prosthetic Dentistry* **77**: 171-176.
Exclusion criteria: unclear patients cohort, mixed reconstructions, insufficient information on abutments

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. *International Journal of Oral and Maxillofacial Implants* **18**: 826-834.
Exclusion criteria: insufficient information on abutments

Laney, W.R., Jemt, T., Harris, D., Henry, P.J., Krogh, P.H., Polizzi, G., Zarb, G.A. & Herrmann, I., (1994) Osseointegrated implants for single-tooth replacement: Progress report from a multicenter prospective study after 3 years. *International Journal of Oral and Maxillofacial Implants* **9**: 49-54.
Exclusion criteria: insufficient information on abutments

Lazzara, R., Siddiqui, A.A., Binon, P., Feldman, S.A., Weiner, R., Phillips, R. & Gonshor, A., (1996) Retrospective multicenter analysis of 3i endosseous dental implants placed over a five-year period. *Clinical Oral Implants Research* **7**: 73-83.
Exclusion criteria: mixed reconstructions, insufficient information on abutments

Ledermann, P.D., Hassell, T.M. & Hefti, A.F., (1993) Osseointegrated dental implants as alternative therapy to bridge construction or orthodontics in young patients: Seven years of clinical experience. *Pediatric Dentistry* **15**: 327-333.
Exclusion criteria: insufficient information on abutments

Lekholm, U., Gröndahl, K. & Jemt, T., (2006) Outcome of oral implant treatment in partially edentulous jaws followed 20 years in clinical function. *Clinical Implant Dentistry and Related Research* **8**: 178-186.
Exclusion criteria: insufficient information on abutments

Lekholm, U., Gunne, J., Henry, P., Higuchi, K., Linden, U., Bergstrom, C. & van Steenberghe, D., (1999) Survival of the Brånemark implant in partially edentulous jaws: A 10-year prospective multicenter study. *International Journal of Oral and Maxillofacial Implants* **14**: 639-645.
Exclusion criteria: insufficient information on abutments

Levine, R.A., Clem, D., Beagle, J., Ganeles J., Johnson, P., Solnit, G. & Keller, G.W. (2002) Multicenter retrospective analysis of the solid-screw ITI implant for posterior single-tooth replacements. *International Journal of Oral and Maxillofacial Implants* **17**: 550-556.
Exclusion criteria: mean follow-up less than 3 years

Levine, R.A., Ganeles, J., Jaffin, R.A., Clem, D.S., 3rd, Beagle, J.R. & Keller, G.W., (2007) Multicenter retrospective analysis of wide-neck dental implants for single molar replacement. *International Journal of Oral and Maxillofacial Implants* **22**: 736-742.
Exclusion criteria: insufficient information on abutments

Lewis, S.G., Llamas, D. & Avera, S., (1992) The UCLA abutment: A four-year review. *Journal of Prosthetic Dentistry* **67**: 509-515.
Exclusion criteria: report on technical complications, but no data on survival

Lindh, T., Gunne, J., Tillberg, A. & Molin, M., (1998) A meta-analysis of implants in partial edentulism. *Clinical Oral Implants Research* **9**: 80-90.
Exclusion criteria: insufficient information on abutments

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

Lorenzoni, M., Pertl, C., Polansky, R.A., Jakse, N. & Wegscheider, W.A., (2002) Evaluation of implants placed with barrier membranes. A restrospective follow-up study up to five years. *Clinical Oral Implants Research* **13**: 274-280.
Exclusion criteria: insufficient information on abutments

Mahn, D.H. & Polack, M.A., (2008) Replacement of maxillary central incisors with implants. *Dentistry Today* **27**: 160, 162, 164.
Exclusion criteria: no information on observation period

Makkonen, T.A., Holmberg, S., Niemi, L., Olsson, C., Tammisalo, T. & Peltola, J., (1997) A 5-year prospective clinical study of Astra Tech dental implants supporting fixed bridges or overdentures in the edentulous mandible. *Clinical Oral Implants Research* **8**: 469-475.
Exclusion criteria: mixed fixed and removable reconstructions

Mangano, C. & Bartolucci, E.G., (2001) Single tooth replacement by morse taper connection implants: A retrospective study of 80 implants. *International Journal of Oral and Maxillofacial Implants* **16**: 675-680.
Exclusion criteria: insufficient information on abutments

McDermott, N.E., Chuang, S.K., Woo, V.V. & Dodson, T.B., (2003) Complications of dental implants: Identification, frequency, and associated risk factors. *International Journal of Oral and Maxillofacial Implants* **18**: 848-855.
Exclusion criteria: insufficient information on abutments

McMillan, A.S., Allen, P.F. & Bin Ismail, I., (1998) A retrospective multicenter evaluation of single tooth implant experience at three centers in the United Kingdom. *Journal of Prosthetic Dentistry* **79**: 410-414.
Exclusion criteria: mean follow-up less than 3 years, no detailed report on abutments/reconstructions

Mengel, R., Schröder, T. & Flores-de-Jacoby, L., (2001) Osseointegrated implants in patients treated for generalized chronic periodontitis and generalized aggressive periodontitis: 3- and 5-year results of a prospective long-term study. *Journal of Periodontology* **72**: 977-989.
Exclusion criteria: mixed fixed and removable reconstructions

Mericske-Stern, R., Grütter, L., Rösch, R. & Mericske E. (2001) Clinical evaluation and prosthetic complications of single tooth replacements by non-submerged implants. *Clinical Oral Implants Research* **12**: 309-318.
Exclusion criteria: mean follow-up less than 3 years

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.
Exclusion criteria: insufficient information on abutments

Muftu, A. & Chapman, R.J., (1998) Replacing posterior teeth with freestanding implants: Four-year prosthodontic results of a prospective study. *Journal of the American Dental Association* **129**: 1097-1102.
Exclusion criteria: insufficient information on abutments

Naert, I.E., Duyck, J.A., Hosny, M.M. & van Steenberghe, D. (2001) Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients. Part I: An up to 15-years clinical evaluation. *Clinical Oral Implants Research* **12**: 237-244.
Exclusion criteria: insufficient information/data on abutments

Naert, I., Koutsikakis, G., Duyck, J., Quirynen, M., Jacobs, R. & van Steenberghe, D. (2000) Biologic outcome of single-implant restorations as tooth replacements: A long-term follow-up study. *Clinical Implant Dentistry and Related Research* **2**: 209-218.
Exclusion criteria: insufficient information/data on abutments

Naert, I., Koutsikakis, G., Duyck, J., Quirynen, M., Jacobs, R. & van Steenberghe, D. (2002) Biologic outcome of implant-supported restorations in the treatment of partial edentulism. Part 1: A longitudinal clinical evaluation. *Clinical Oral Implants Research* **13**: 381-389.
Exclusion criteria: insufficient information/data on abutments

Naert, I., Koutsikakis, G., Quirynen, M., Duyck, J., van Steenberghe, D. & Jacobs, R. (2002) Biologic outcome of implant-supported restorations in the treatment of partial edentulism. Part 2: A longitudinal radiographic study. *Clinical Oral Implants Research* **13**: 390-395.
Exclusion criteria: insufficient information/data on abutments

Naert, I., Quirynen, M., van Steenberghe, D. & Darius, P. (1992) A six-year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism. *Journal of Prosthetic Dentistry* **67**: 236-245.
Exclusion criteria: mean follow-up less than 3 years

Naert, I., Quirynen, M., van Steenberghe, D. & Darius, P. (1992) A study of 589 consecutive implants supporting complete fixed prostheses. Part ii: Prosthetic aspects. *Journal of Prosthetic Dentistry* **68**: 949-956.
Exclusion criteria: insufficient information/data on abutments

Nedir, R., Bischof, M., Szmukler-Moncler, S., Belser, U.C. & Samson, J. (2006) Prosthetic complications with dental implants: From an up-to-8-year experience in private practice. *International Journal of Oral and Maxillofacial Implants* **21**: 919-928.
Exclusion criteria: insufficient information/data on abutments

Nevins, M. & Langer, B. (1993) The successful application of osseointegrated implants to the posterior jaw: A long-term retrospective study. *International Journal of Oral and Maxillofacial Implants* **8**: 428-432.
Exclusion criteria: insufficient information/data on abutments

Nickenig, H.J., Schäfer, C. & Spiekermann, H. (2006) Survival and complication rates of combined tooth-implant-supported fixed partial dentures. *Clinical Oral Implants Research* **17**: 506-511.
Exclusion criteria: combined tooth-implant supported FPDs

Nickenig, H.J., Spiekermann, H., Wichmann, M., Andreas, S.K. & Eitner, S. (2008) Survival and complication rates of combined tooth-implant-supported fixed and removable partial dentures. *International Journal of Prosthodontics* **21**: 131-137.
Exclusion criteria: combined tooth-implant supported FPDs

Noack, N., Willer, J. & Hoffmann, J. (1999) Long-term results after placement of dental implants: Longitudinal study of 1,964 implants over 16 years. *International Journal of Oral and Maxillofacial Implants* **14**: 748-755.
Exclusion criteria: insufficient information/data on abutments

Norton, M.R. (1997) The Astra Tech single-tooth implant system: a report on 27 consecutively placed and restored implants. *International Journal of Periodontics and Restorative Dentistry* **17**: 575-583.
Exclusion criteria: for a magnitude of abutments mean follow-up less than 3 years, no detailed information on abutments with more than 3 years of follow-up

Norton, M.R. (2006) Multiple single-tooth implant restorations in the posterior jaws: Maintenance of marginal bone levels with reference to the implant-abutment microgap. *International Journal Oral and Maxillofacial Implants* **21**: 777-784.
Exclusion criteria: insufficient information/data on abutments

Olsson, M., Gunne, J., Åstrand, P. & Borg, K. (1995) Bridges supported by free-standing implants versus bridges supported by tooth and implant. A five-year prospective study. *Clinical Oral Implants Research* **6**: 114-121.
Exclusion criteria: insufficient information/data on abutments

Ormianer, Z. & Palti, A. (2006) Long-term clinical evaluation of tapered multi-threaded implants: Results and influences of potential risk factors. *Journal of Oral Implantology* **32**: 300-307.
Exclusion criteria: insufficient information/data on abutments

Ormianer, Z. & Schiroli, G. (2006) Maxillary single-tooth replacement utilizing a novel ceramic restorative system: Results to 30 months. *Journal of Oral Implantology* **32**: 190-199.
Exclusion criteria: mean follow-up less than 3 years

Örtorp, A. & Jemt, T. (1999) Clinical experiences of implant-supported prostheses with laser-welded titanium frameworks in the partially edentulous jaw: A 5-year follow-up study. *Clinical Implant Dentistry and Related Research* **1**: 84-91.
Exclusion criteria: lack of abutment survival and complication data

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

Oxby, G., Bengtsson, J., Busch, S., Hedkvist, L., Lindqvist, J. & Moberg, P. (2004) An alternative method for the fabrication of customised abutments for single tooth replacements. A clinical follow-up after 18 months. *Swedish Dental Journal* **28**: 21-27.
Exclusion criteria: description of a customised abutment fabrication method

Özkan, Y., Özcan, M., Akoglu, B., Ucankale, M. & Kulak-Özkan, Y. (2007) Three-year treatment outcomes with three brands of implants placed in the posterior maxilla

and mandible of partially edentulous patients. *Journal of Prosthetic Dentistry* **97**: 78-84.
Exclusion criteria: insufficient information/data on abutments

Palmer, R.M., Howe, L.C. & Palmer, P.J. (2005) A prospective 3-year study of fixed bridges linking Astra Tech ST implants to natural teeth. *Clinical Oral Implants Research* **16**: 302-307.
Exclusion criteria: combined tooth-implant supported FPDs

Palmer, R., Palmer, P. & Howe, L. (1999) Complications and maintenance. *British Dental Journal* **187**: 653-658.
Exclusion criteria: descriptive article

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**: 179-182.
Exclusion criteria: insufficient information/data on abutments

Parein, A.M., Eckert, S.E., Wollan, P.C. & Keller, E.E., (1997) Implant reconstruction in the posterior mandible: A long-term retrospective study. *Journal of Prosthetic Dentistry* **78**: 34-42.
Exclusion criteria: insufficient information/data on abutments

Polack, M.A. & Mahn, D.H. (2008) The use of a customized prefabricated zirconia abutment and zirconia crown in the restoration of an immediately provisionalized implant in the esthetic zone. The *Compendium of Continuing Education in Dentistry* **29**: 358-362.
Exclusion criteria: report of a single case

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

Prestipino, V. & Ingber, A. (1993) Esthetic high strength implant abutments. Part I. *Journal of Esthetic Dentristy* **5**: 29-36.
Exclusion criteria: description of a specific abutment

Prestipino, V. & Ingber, A. (1993) Esthetic high strenght implant abutments. Part II. *Journal of Esthetic Dentristy* **8**: 255-262.
Exclusion criteria: description of a specific abutment

Priest, G. (1999) Single-tooth implants and their role in preserving remaining teeth: A 10-year survival study. *International Journal of Oral and Maxillofacial Implants* **14**: 181-188.
Exclusion criteria: mean follow-up less than 3 years

Pylant, T., Triplett, R.G., Key, M.C. & Brunsvold, M.A. (1992) A retrospective evaluation of endosseous titanium implants in the partially edentulous patient. *International Journal of Oral and Maxillofacial Implants* **7**: 195-202.

Exclusion criteria: mean follow-up less than 3 years

Quirynen, M., Naert, I., van Steenberghe, D., Dekeyser, C. & Callens, A. (1992) Periodontal aspects of osseointegrated fixtures supporting a partial bridge. An up to 6-years retrospective study. *Journal of Clinical Periodontology* **19**: 118-126.
Exclusion criteria: mean follow-up less than 3 years

Rasmusson, L., Roos, J. & Bystedt, H. (2005) A 10-year follow-up study of titanium dioxide-blasted implants. *Clinical Implant Dentistry and Related Research* **7**: 36-42.
Exclusion criteria: insufficient information/data on abutments

Renouard, F., Arnoux, J.P. & Sarment, D.P. (1999) Five-mm-diameter implants without a smooth surface collar: Report on 98 consecutive placements. *International Journal of Oral and Maxillofacial Implants* **14**: 101-107.
Exclusion criteria: mean follow-up less than 3 years

Rodriguez, A.M., Orenstein, I.H., Morris, H.F. & Ochi, S. (2000) Survival of various implant-supported prosthesis designs following 36 months of clinical function. *Annals of Periodontology* **5**: 101-108.
Exclusion criteria: insufficient information/data on abutments

Romeo, E., Lops, D., Amorfini, L., Chiapasco, M., Ghisolfi, M. & Vogel, G. (2006) Clinical and radiographic evaluation of small-diameter (3.3 mm) implants followed for 1-7 years: A longitudinal study. *Clinical Oral Implants Research* **17**: 139-148.
Exclusion criteria: insufficient information/data on abutments

Saadoun, A.P. & Le Gall, M.G. (1996) An 8-year compilation of clinical results obtained with Steri-Oss endosseous implants. *Compendium* **17**: 669-684.
Exclusion criteria: no abutment survival data

Sadoun, M. & Perelmuter, S. (1997) Alumina-zirconia machinable abutments for implant-supported single-tooth anterior crowns. *Practical Periodontics and Aesthetic Dentistry* **9**: 1047-1053; quiz 1054.
Exclusion criteria: description of a specific abutment, no follow-up

Schaffner, H.M., Behneke, N., Müller, F. & Scheller, H. (2004) Klinische Untersuchungen zur Versorgung mit ProceraAllCeram-Kronen auf natürlichen Zähnen und Implantaten. *Deutsche Zahnärztliche Zeitschrift* **59:** 17-22.
Exclusion criteria: mean follow-up less than 3 years

Schnitman, P.A., Wöhrle, P.S., Rubenstein, J.E., DaSilva, J.D. & Wang, N.H. (1997) Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. *International Journal of Oral and Maxillofacial Implants* **12**: 495-503.
Exclusion criteria: insufficient information/data on abutments

Scholander, S. (1999) A retrospective evaluation of 259 single-tooth replacements by the use of Brånemark implants. *International Journal of Prosthodontics* **12**: 483-491.
Exclusion criteria: insufficient information/data on abutments

Schmitt, A. & Zarb, G.A. (1993) The longitudinal clinical effectiveness of osseointegrated dental implants for single-tooth replacement. *International Journal of Prosthodontics* **6**: 197-202.
Exclusion criteria: insufficient information/data on abutments

Schwartz-Arad, D., Samet, N. & Samet, N. (1999) Single tooth replacement of missing molars: A retrospective study of 78 implants. *Journal of Periodontology* **70**: 449-454.
Exclusion criteria: mean follow-up less than 3 years

Sethi, A., Kaus, T. & Sochor, P. (2000) The use of angulated abutments in implant dentistry: Five-year clinical results of an ongoing prospective study. *International Journal of Oral and Maxillofacial Implants* **15**: 801-810.
Exclusion criteria: insufficient information/data on abutments

Sethi, A., Kaus, T., Sochor, P., Axmann-Krcmar, D. & Chanavaz, M. (2002) Evolution of the concept of angulated abutments in implant dentistry: 14-year clinical data. *Implant Dentistry* **11**: 41-51.
Exclusion criteria: insufficient outcome data on abutments

Singer, A. & Serfaty, V. (1996) Cement-retained implant-supported fixed partial dentures: A 6-month to 3-year follow-up. *International Journal of Oral and Maxillofacial Implants* **11**: 645-649.
Exclusion criteria: mean follow-up less than 3 years

Small, P.N., Tarnow, D.P. & Cho, S.C. (2001) Gingival recession around wide-diameter versus standard-diameter implants: A 3- to 5-year longitudinal prospective study. *Practical Procedures & Aesthetic Dentistry* **13**: 143-146.
Exclusion criteria: insufficient information/data on abutments

Smedberg, J.I., Johansson, P., Ekenback, D. & Wannfors, D. (2001) Implants and sinus-inlay graft in a 1-stage procedure in severely atrophied maxillae: Prosthodontic aspects in a 3-year follow-up study. *International Journal of Oral and Maxillofacial Implants* **16**: 668-674.
Exclusion criteria: insufficient information/data on abutments

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 Investigations* **4**: 13-20.
Exclusion criteria: insufficient information/data on abutments

Steenberghe van, D., Klinge, B., Lindén, 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.
Exclusion criteria: no abutment survival data

Steenberghe van, D., Lekholm, U., Bolender, C., Folmer, T., Henry, P., Herrmann, I., Higuchi, K., Laney, W., Linden, U. & Åstrand, P. (1990) Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: A prospective

multicenter study on 558 fixtures. *International Journal of Oral and Maxillofacial Implants* **5**: 272-281.
Exclusion criteria: insufficient information/data on abutments

Steveling, H., Roos, J. & Rasmusson, L. (2001) Maxillary implants loaded at 3 months after insertion: Results with Astra Tech implants after up to 5 years. *Clinical Implant Dentistry and Related Research* **3**: 120-124.
Exclusion criteria: insufficient information/data on abutments

Stultz, E.R., Lofland, R., Sendax, V.I. & Hornbuckle, C. **(1993)** A multicenter 5-year retrospective survival analysis of 6200 Integral implants. *Compendium of Continuing Education in Dentistry* **14**: 478, 480, 482 passim.
Exclusion criteria: no abutment survival data

Strietzel, F.P. & Reichart, P.A. (2007) Oral rehabilitation using Camlog screw-cylinder implants with a particle-blasted and acid-etched microstructured surface. Results from a prospective study with special consideration of short implants. *Clinical Oral Implants Research* **18**: 591-600.
Exclusion criteria: insufficient information/data on abutments

Tangerud, T., Gronningsaeter, A.G. & Taylor, A. (2002) Fixed partial dentures supported by natural teeth and Brånemark system implants: A 3-year report. *International Journal of Oral and Maxillofacial Implants* **17**: 212-219.
Exclusion criteria: combined tooth-implant supported FPDs

Tawil, G., Aboujaoude, N. & Younan, R. (2006) Influence of prosthetic parameters on the survival and complication rates of short implants. *International Journal of Oral and Maxillofacial Implants* **21**: 275-282.
Exclusion criteria: insufficient information/data on abutments

Tawil, G. & Younan, R. (2003) Clinical evaluation of short, machined-surface implants followed for 12 to 92 months. *International Journal of Oral and Maxillofacial Implants* **18**: 894-901.
Exclusion criteria: insufficient information/data on abutments

Thierer, T., Davliakos, J.P., Keith, J.D., Jr., Sanders, J.J., Tarnow, D.P. & Rivers, J.A. (2008) Five-year prospective clinical evaluation of highly crystalline HA MP-1-coated dental implants. *Journal of Oral Implantology* **34**: 39-46.
Exclusion criteria: insufficient informations/data on abutments

Tinschert, J., Tokmakidis, K., Latzke, P., Natt, G., Spiekermann, H. (2007) Zirkonoxid in der Implantologie- Grundlagen und aktuelle Aspekte. *Implantologie* **15**: 371-381.
Exclusion criteria: descriptive article, no data

Tolman, D.E. & Laney, W.R. (1992) Tissue-integrated prosthesis complications. *International Journal of Oral and Maxillofacial Implants* **7**: 477-484.
Exclusion criteria: fully edentulous patients supporting overdentures

Turkyilmaz, I. (2006) A 3-year prospective clinical and radiologic analysis of early loaded maxillary dental implants supporting single-tooth crowns. *International Journal of Prosthodontics* **19**: 389-390.
Exclusion criteria: insufficient information/data on abutments

Turkyilmaz, I., Avci, M., Kuran, S. & Ozbek, E.N. (2007) A 4-year prospective clinical and radiological study of maxillary dental implants supporting single-tooth crowns using early and delayed loading protocols. *Clinical Implant Dentistry and Related Research* **9**: 222-227.
Exclusion criteria: insufficient information/data on abutments

Vafiadis, D. (2008) Predictable Implant Abutment Selection. *Practical Procedures & Aesthetic Dentistry* ***20**: 224.*
Exclusion criteria: editorial commentary

Vigolo, P., Givani, A., Majzoub, Z. & Cordioli, G. (2004) Cemented versus screw-retained implant-supported single-tooth crowns: A 4-year prospective clinical study. *International Journal of Oral and Maxillofacial Implants* **19**: 260-265.
Exclusion criteria: insufficient information/data on abutments

Walther, W., Klemke, J., Wörle, M. & Heners, M. (1996) Implant-supported single-tooth replacements: Risk of implant and prosthesis failure. *Journal of Oral Implantology* **22**: 236-239.
Exclusion criteria: blade implants, insufficient data

Walton, J.N. & MacEntee, M.I. (1994) Problems with prostheses on implants: A retrospective study. *Journal of Prosthetic Dentistry* **71**: 283-288.
Exclusion criteria: insufficient information/data on abutments

Watkin, A. & Kerstein, R.B.(2008) Improving darkened anterior peri-implant tissue color with zirconia custom implant abutments. *The Compendium of Continuing Education in Dentistry* **29**: 238-240, 242.
Exclusion criteria: report of 2 cases, no follow-up

Watson, C.J., Tinsley, D., Ogden, A.R., Russell, J.L., Mulay, S. & Davison, E.M. (1999) A 3 to 4 year study of single tooth hydroxylapatite coated endosseous dental implants. *British Dental Journal* **187**: 90-94.
Exclusion criteria: insufficient information/data on abutments

Watson, C.J., Tinsley, D. & Sharma, S. (2000) Implant complications and failures: The single-tooth restoration. *Dental Update* **27**: 35-38, 40, 42.
Exclusion criteria: no follow-up

Weber, H.P., Crohin, C.C. & Fiorellini, J.P. (2000) A 5-year prospective clinical and radiographic study of non-submerged dental implants. *Clinical Oral Implants Research* **11**: 144-153.
Exclusion criteria: insufficient information/data on abutments

Weber, H.P., Kim, D.M., Ng, M.W., Hwang, J.W. & Fiorellini, J.P. (2006) Peri-implant soft-tissue health surrounding cement- and screw-retained implant

restorations: A multi-center, 3-year prospective study. *Clinical Oral Implants Research* **17**: 375-379.
Exclusion criteria: insufficient information/data on abutments

Wedgwood, D., Jennings, K.J., Critchlow, H.A., Watkinson, A.C., Shepherd, J.P., Frame, J.W., Laird, W.R. & Quayle, A.A. (1992) Experience with ITI osseointegrated implants at five centres in the uk. The *British Journal of Oral & Maxillofacial Surgery* **30**: 377-381.
Exclusion criteria: insufficient information/data on abutments

Weibrich, G., Buch, R.S., Wegener, J. & Wagner, W. (2001) Five-year prospective follow-up report of the Astra Tech standard dental implant in clinical treatment. *International Journal of Oral and Maxillofacial Implants* **16**: 557-562.
Exclusion criteria: mean follow-up less than 3 years

Wennerberg, A. & Jemt, T (1999) Complications in partially edentulous implant patients: A 5-year retrospective follow-up study of 133 patients supplied with unilateral maxillary prostheses. *Clinical Implant Dentistry and Related Research* **1**: 49-55.
Exclusion criteria: insufficient information on abutments and lack of survival data

Wennerberg, A., Sennerby, L., Kultje, C. & Lekholm, U. (2003) Some soft tissue characteristics at implant abutments with different surface topography. A study in humans. *Journal of Clinical Periodontology* **30**: 88-94.
Exclusion criteria: mean follow-up less than 3 years

Wheeler, S.L. (1996) Eight-year clinical retrospective study of titanium plasma-sprayed and hydroxyapatite-coated cylinder implants. *International Journal of Oral and Maxillofacial Implants* **11**: 340-350.
Exclusion criteria: insufficient information/data on abutments

Yildirim, M., Edelhoff, D., Hanisch, O. & Spiekermann, H. (2000) Ceramic abutments--a new era in achieving optimal esthetics in implant dentistry. *International Journal of Periodontics and Restorative Dentistry* **20**: 81-91.
Exclusion criteria: descriptive article, no follow-up

Yoshida, K., Takamatsu, Y., Adachi, Y., Kishi, M., Sekine, H. & Shigematsu, T. (1996) Functioning survival rate of fixtures and superstructures of osseointegrated implants: Ten years of progress in Tokyo Dental College Hospital (second report). *The Bulletin of Tokyo Dental College* **37**: 55-62.
Exclusion criteria: insufficient information/data on abutments

Zarb, G.A. & Schmitt, A. (1989) The longitudinal clinical effectiveness of osseointegrated dental implants: The Toronto study. Part II: The prosthetic results. *The Journal of Prosthetic Dentistry* **64**: 53-61.
Exclusion criteria: edentulous patients supporting fixed prostheses

Zarb, G.A. & Schmitt, A. (1989) The longitudinal clinical effectiveness of osseointegrated dental implants: The Toronto study. Part III: Problems and complications encountered. *The Journal of Prosthetic Dentistry* **64**: 185-194.
Exclusion criteria: edentulous patients supporting fixed and removable prostheses

Zarb, G.A. & Schmitt, A. (1993) The longitudinal clinical effectiveness of osseointegrated dental implants in anterior partially edentulous patients. *Int J Prosthodont* **6**: 180-188.
Exclusion criteria: insufficient information/data on abutments

Zarb, G.A. & Schmitt, A. (1993) The longitudinal clinical effectiveness of osseointegrated dental implants in posterior partially edentulous patients. *International Journal of Prosthodontics* **6**: 189-196.
Exclusion criteria: insufficient information/data on abutments

Zarb, J.P. & Zarb, G.A. (2002) Implant prosthodontic management of anterior partial edentulism: Long-term follow-up of a prospective study. *Journal of the Canadian Dental Association* **68**: 92-96.
Exclusion criteria: insufficient information/data on abutments

Zarone, F., Sorrentino, R., Vaccaro, F., Russo, S. & De Simone, G. (2005) Retrospective clinical evaluation of 86 Procera AllCeram anterior single crowns on natural an implant-supported abutments. *Clinical Implant Dentistry and Related Research* **7** (Supplement 1): S95-S103.
Exclusion criteria: insufficient information on abutments and lack of survival data

Zinsli, B., Sägesser, T., Mericske, E. & Mericske-Stern, R. (2004) Clinical evaluation of small-diameter ITI implants: A prospective study. *International Journal of Oral and Maxillofacial Implants* **19**: 92-99.
Exclusion criteria: mixed removable and fixed reconstructions, no detailed data for fixed reconstructions

II. Laboratory Studies

Basten, C. H.-J., Nicholls, J.I., Daly, C.H. & Taggart, R. (1996) Load fatigue performance of two implant-abutment combinations. *International Journal of Oral and Maxillofacial Implants* **11**: 522-528.
Exclusion criteria: no data on stability of abutments

Brodbeck, U. (2003) The ZiReal post: A new ceramic implant abutment. *Journal of Esthetic and Restorative Dentistry* **15**: 10-24.
Exclusion criteria: no data on stability of abutments

Canullo, L., Morgia, P. & Marinotti, F. (2007) Preliminary laboratory evaluation of biocomponent customized zirconia abutments. *International Journal of Prosthodontics* **20**: 486-488.
Exclusion criteria: insufficient data on stability of abutments

Khraisat, A., Stegaroiu, R., Nomura, S. & Miyakawa, O. (2002) Fatigue resistance of two implant/abutment joint designs. *Journal of Prosthetic Dentistry* **88**: 604-610.
Exclusion criteria: no data on stability of abutments

Khraisat, A. (2005) Stability of implant-abutment interface with a hexagon-mediated butt joint: Failure mode and bending resistance. *Clinical Implant Dentistry and Related Research* **7**: 221-228.
Exclusion criteria: same setting but different load application like in already the included study (Khraisat et al. 2004, Clinical Implant Dentistry and Related Research)

Perriard, J., Wiskott, W.A., Mellal, A., Scherrer, S.S., Botsis, J. & Belser, U.C. (2002) Fatigue resistance of ITI implant-abutment connectors – a comparison of the standard cone with a novel internally keyed design. *Clinical Oral Implants Research* **13**: 542-549.
Exclusion criteria: no data on stability of abutments

Papavasiliou, G., Tripodakis, A.P.D., Kamposiora, P., Strub, J.R. & Bayne, S.C. (1996) Finite element analysis of ceramic abutment-restoration combinations for osseointgrated implants. *International Journal of Prosthodontics* **9**: 254-260.
Exclusion criteria: no data on stability of abutments

Quaresma, S.E.T., Cury, P.R., Sendyk, W.R. & Sandyk, C. (2008) A finite element analysis of two different dental implants: stress distribution in the prosthesis, abutment, implant, and supporting bone. *Journal of Oral Implantology* **34**: 1-6.
Exclusion criteria: no data on stability of abutments

Quek, H.C., Tan, K.B. & Nicholls, J.I. (2008) Load fatigue performance of four implant-abutment interface designs: Effect of torque level and implant system. *International Journal of Oral and Maxillofacial Implants* **23**: 253-262.
Exclusion criteria: no data on stability of abutments

Rossen van, I.P., Braak, L.H., de Putter, C. & de Groot, K. (1990) Stress-absorbing elements in dental implants. *Journal of Prosthetic Dentistry* **64**: 198-205.
Exclusion criteria: no data on stability of abutments

Tan, K.B. & Nicholls, J.I. (2001) Implant-abutment screw joint preload of 7 hex-top abutment systems. *International Journal of Oral and Maxillofacial Implants* **16**: 367-377.
Exclusion criteria: no data on stability of abutments

Vigolo, P., Fonzi, F., Majzoub, Z. & Cordioli, G. (2005) An in vitro evaluation of ZiReal abutments with hexagonal connection: In original state and following abutment preparation. *International Journal of Oral and Maxillofacial Implants* **20**: 108-114.
Exclusion criteria: no data on stability of abutments

Vult von Steyern, P., Kokubo, Y. & Nilner, K. (2005) Use of abutment-teeth vs. dental implants to support all-ceramic fixed partial dentures. An in-vitro study on fracture strength. *Swedish Dental Journal* **29**: 53-60.
Exclusion criteria: no data on stability of abutments, only analysis of FPD stability

Yüzügüllü, B. & Avci, M. (2008) The implant-abutment interface of alumina and zirconia abutments. *Clinical Implant Dentistry and Related Research* **10**: 113-121.
Exclusion criteria: no data on stability of abutments

Figures, Tables and Legends – CLINICAL STUDIES

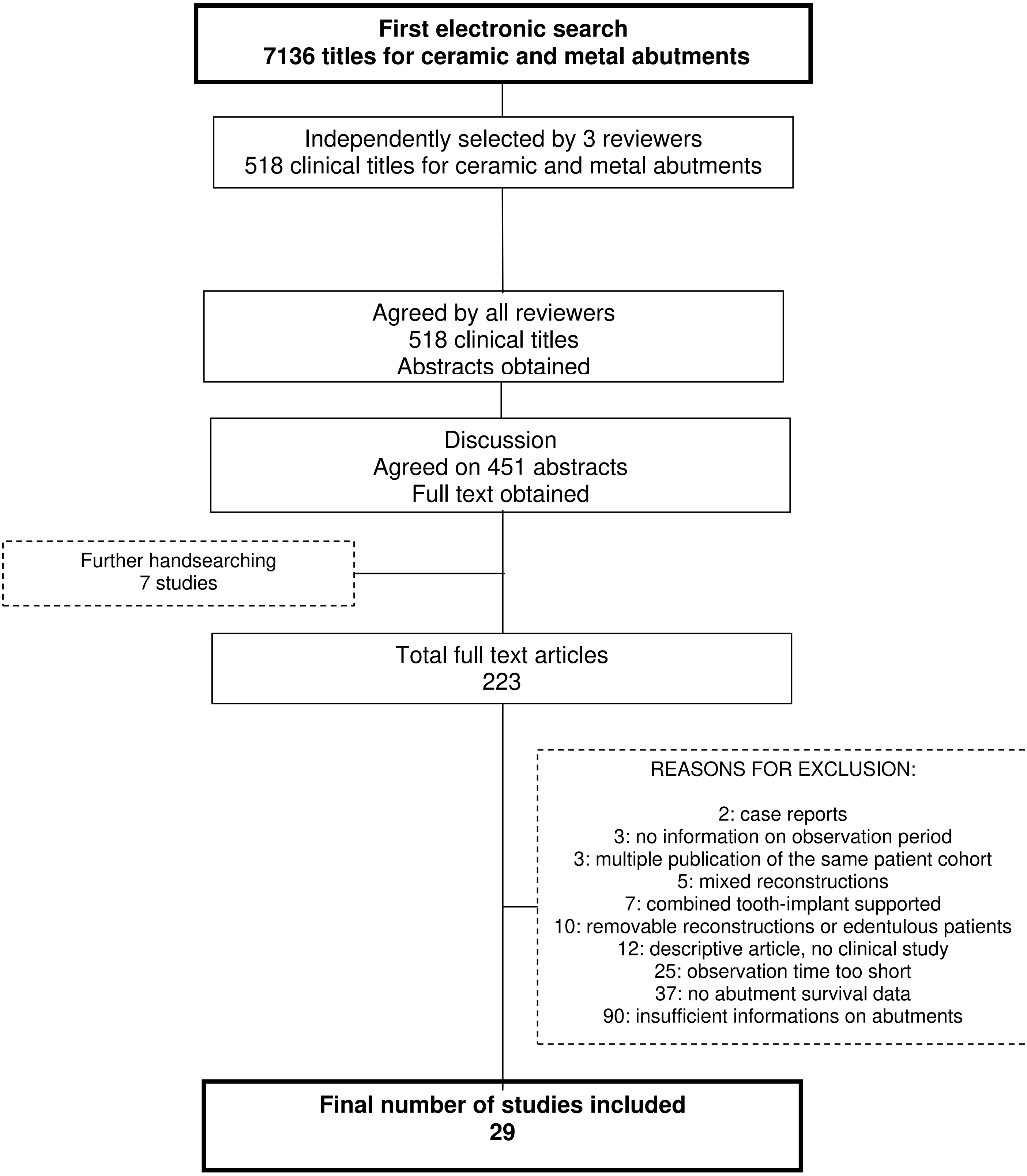

Fig. 1 - Search strategy of the clinical studies

Study	Year of publication	Study design	Total no. of included patients	Mean age	Age range	Setting	Mean follow-up	Droup-out (in %)
Zembic et al.	2009	RCT	22	41.3	23-59	University	3	9.1%
Cooper et al.	2007	Prospective	48	30.6	n.r.	Two universities	3	18.8%
Canullo	2007	Prospective	25	n.r.	25-70	Private Practice	3.3	n.r.
Kreissl et al.	2006	Retrospective	76	45	18-76	University	5	n.r.
Bischof et al.	2006	Prospective	212	n.r.	n.r.	Private practice	5	n.r.
Vigolo et al.	2006	RCT	20	n.r.	n.r.	University	4	0%
de Boever et al.	2006	Prospective	105	59.1	25-86	University	5.2	0%
Brägger et al.	2005	Prospective	127	49.3	19-78	University	10	n.r.
Romeo et al.	2004	Prospective	250	n.r.	20-67	University	3.9	n.r.
Preiskel & Tsolka	2004	Retrospective	44	64.2	n.r.	Specialized Clinic	7.1	0%
Glauser et al.	2004	Prospective	27	44	26-75	University	4.1	n.r.
Muche et al.	2003	Retrospective	76	45	n.r.	University	3	n.r.
Andersson et al.	2003	RCT	32	53	15-71	Multicenter Specialized Clinic Private Practice	5	15.6%
Romeo et al.	2003	Prospective	38	51	21-71	University, Specialized Clinic	4	0%
Jemt et al.	2003	Prospective	42	53	25-74	Multicenter Specialized Clinic	5	7.1%
Krennmair et al.	2002	Retrospective	112	31.3	n.r.	Private Practice University	3	n.r.
Andersson et al.	2001	RCT	15	n.r.	17-49	Specialized Clinic	3	0%
Behneke et al.	2000	Prospective	55	44	17-81	University	3.2	14.5%
Bianco et al.	2000	Retrospective	214	n.r.	16-70	Mutlicenter Private Practice	8	4.2%
Wannfors & Smedberg	1999	Prospective	69	26	17-72	Specialized Clinic	3	4.3%
Levine et al.	1999	Retrospective	129	n.r.	n.r.	Multicenter	3.3	14.7%
Wyatt & Zarb	1998	Retrospective	77	45.1	15-72	University	5.4	n.r.
Behr et al.	1998	Retrospective	66	n.r.	18-88	University	3.5	n.r.
Kastenbaum et al.	1998	Prospective	50	n.r.	n.r.	Mulitcenter University	3	18%
Scheller et al.	1998	Prospective	82	35	14-73	Mulitcenter	3.7	30.5%
Andersson et al.	1998	Prospective	57	32	n.r.	Specialized Clinic	5	8.8%
Avivi-Arber et al.	1996	Prospective	41	33	15-64	University	4	12.2%
Chapman and Grippo	1996	Retrospective	n.r.	n.r.	n.r.	Multicenter Private Practice	4.9	n.r.
Henry et al.	1996	Prospective	92	n.r.	n.r.	Multicenter	5	8.7%

Table 1 - Characteristics of the included clinical studies; n.r. stands for "not reported".

Study	Year of publication	Implant system	Total no. of abutm.	Abutment material	Abutment connection	Total no. of recon-struction	Type of recon-struction	Recon-struction material	Cemented	Screw retained
Zembic et al.	2009	Brånemark	19	zirconia	external hexagon	18	SC	all-ceramic	17	2
Zembic et al.	2009	Brånemark	12	titanium	external hexgagon	10	SC	metal-ceramic	12	0
Cooper et al.	2007	Astra	54	titanium	internal	43	SC	metal-ceramic all-ceramic	54	0
Canullo	2007	TSA	30	zirconia with titanium connection	internal	n.r.	SC	all-ceramic	30	0
Kreissl et al.	2006	3i	205	metal	external hexagon	112	SC, FDP	metal-ceramic	n.r.	n.r.
Bischof et al.	2006	ITI	263	metal	internal	237	SC, FPD	n.r.	226	n.r.
Vigolo et al.	2006	3i	20	titanium	external hexagon	20	SC	metal-ceramic	20	n.r.
Vigolo et al.	2006	3i	20	gold	external hexagon	20	SC	metal-ceramic	20	n.r.
de Boever et al.	2006	ITI	283	titanium	internal	ca. 150	SC, FPD	n.r.	127	45
Brägger et al.	2005	ITI	69	metal	internal	69	SC	n.r.	67	2
Brägger et al.	2005	n.r.	69	metal	internal	33	FDP	n.r.	25	8
Romeo et al.	2004	ITI	123	titanium	internal	121	SC	metal-ceramic	n.r.	n.r.
Romeo et al.	2004	ITI	336	titanium	internal	137	FDP	n.r.	n.r.	n.r.
Preiskel & Tsolka	2004	Replace	286	titanium	external and internal hexagon	78	FPD	n.r.	161	124
Glauser et al.	2004	Brånemark	54	zirconia	external hexagon	n.r.	SC	all-ceramic	54	0
Muche et al.	2003	3i	205	metal	external hexagon	46	SC	metal-ceramic	5	200
Andersson et al.	2003	Brånemark	53	densely sintered alumina	external hexagon	19	FDP	n.r.	53	n.r.
Andersson et al.	2003	n.r.	50	titanium	external hexagon	17	FDP	n.r.	50	n.r.
Romeo et al.	2003	ITI, Brånemark	100	metal	external hexagon, internal	49	FDP	metal-ceramic	n.r.	n.r.
Jemt et al.	2003	Bränemark	117	titanium	external hexagon	42	FDP	gold alloy titanium	n.r.	n.r.
Jemt et al.	2003	n.r.	53	titanium	external hexagon	21	FDP	titanium framework	n.r.	n.r.
Krennmair et al.	2002	Frialit 2	146	metal	internal	n.r.	SC	metal-ceramic all-ceramic	93	53
Andersson et al.	2001	Brånemark	10	densely sintered alumina	external hexagon	10	SC	all-ceramic	10	n.r.
Andersson et al.	2001	n.r.	10	titanium	external hexagon	10	SC	all-ceramic	10	n.r.
Behneke et al.	2000	ITI	114	metal	internal	n.r.	SC, FPD	metal-ceramic	13	55
Bianco et al.	2000	Brånemark	252	titanium	external hexagon	229	SC	metal metal-ceramic all-ceramic	203	31
Wannfors & Smedberg	1999	Brånemark	44	gold	external hexagon	42	SC	gold-resin metal-ceramic	n.r.	44
Wannfors & Smedberg	1999	Brånemark	36	titanium	external hexagon	34	SC	metal-ceramic all-ceramic	36	n.r.
Levine et al.	1999	ITI	174	titanium	internal	157	SC	n.r.	n.r.	n.r.
Wyatt & Zarb	1998	Brånemark	230	titanium	external hexagon	97	FPD	metal-acrylic metal-ceramic	0	97
Behr et al.	1998	ITI	138	titanium	internal	25	SC, FPD	metal-ceramic	n.r.	n.r.
Kastenbaum et al.	1998	Brånemark	200	titanium	external hexagon	n.r.	FDP,FCD	n.r.	n.r.	n.r.
Scheller et al.	1998	Brånemark	99	titanium	external hexagon	65	SC	all-ceramic metal ceramic	97	0
Andersson et al.	1998	Brånemark	65	titanium	external hexagon	n.r.	SC	all-ceramic, metal-ceramic	65	n.r.
Avivi-Arber et al.	1996	Brånemark	49	titanium	external hexagon	42	SC	metal-ceramic metal-acrylic all-ceramic	n.r.	n.r.
Chapman and Grippo	1996	Bicon	1757	titanium	internal	n.r.	n.r.	n.r.	n.r.	n.r.
Henry et al.	1996	Bränemark	104	titanium	external hexagon	96	SC	n.r.	n.r.	n.r.

Table 2 - Material and type of connection and retention. n.r. stands for "not reported".

Study	Year of publi-cation	Total no. of abutments	Mean follow-up time	Total FPDs exposure time	Number of failures	Estimated failure rate (per 100 ab. years)
Metal abutment						
Zembic et al.	2009	12	3	30	0	0
Cooper et al.	2007	54	3	129	3	2.33
Bischof et al.	2006	263	5	1245	1	0.08
Vigolo et al.	2006	20	4	80	0	0
Vigolo et al.	2006	20	4	80	0	0
de Boever et al.	2006	283	5.2	1474	3	0.20
Brägger et al.	2005	69	10	690	1	0.14
Brägger et al.	2005	69	10	690	5	0.72
Romeo et al.	2004	336	3.9	1307	12	0.92
Romeo et al.	2004	123	3.9	468	5	1.07
Preiskel & Tsolka	2004	286	7.2	2038	4	0.20
Muche et al.	2003	205	3	615	3	0.49
Andersson et al.	2003	50	5	170	0	0
Romeo et al.	2003	100	4	400	3	0.75
Jemt et al.	2003	117	5	215	3	1.40
Jemt et al.	2003	53	5	500	0	0
Krennmair et al.	2002	146	3	438	2	0.46
Andersson et al.	2001	10	3	30	0	0
Behneke et al.	2000	114	3.2	305	0	0
Bianco et al.	2000	252	8	1832	5	0.28
Kastenbaum et al.	1998	200	3	600	1	0.17
Scheller et al.	1998	99	3.7	243	4	1.64
Andersson et al.	1998	65	5	275	2	0.73
Chapman and Grippo	1996	1757	4.9	8539	9	0.11
Henry et al.	1996	104	5	480	8	1.67
Ceramic abutment						
Zembic et al.	2009	19	3	54	0	0
Canullo	2007	30	3.3	99	0	0
Glauser et al.	2004	54	4,1	148	0	0
Andersson et al.	2003	53	5	225	1	0.44
Andersson et al.	2001	10	3	30	0	0
Total		**4973**	**4.6**	**23429**		
Summary estimate (95 % CI) *						**0.49 (0.32-0.74)**
5-year failure rate (95 % CI) *						**2.4% (1.6%-3.6%)**

Table 3 - Abutments lost due to any reason.

* Based on random-effects Poisson regression.

Study	Year of publication	Total no. of abutments	Total abutment exposure time	**Estimated rate of abutment fractures** (per 100 ab. years)	**Estimated rate of abutment screw fractures** (per 100 ab. years)	**Estimated rate of misfit causing biological problems** (per 100 ab. years)	**Estimated rate of screw loosening** (per 100 ab years)
Metal abutment							
Zembic et al.	2009	12	30	0	0	0	0
Cooper et al.	2007	54	129	0	0	na.	0
Kreissl et al.	2006	205	1025	0	0.39	na.	1.37
Bischof et al.	2006	263	1245	0	0	na.	0.08
Vigolo et al.	2006	20	80	0	0	na.	0
Vigolo et al.	2006	20	80	0	0	na.	0
de Boever et al.	2006	283	1474	0	0	na.	1.56
Brägger et al.	2005	69	690	0	0	na.	0.14
Brägger et al.	2005	69	690	0	0	na.	0.29
Romeo et al.	2004	336	1307	na.	0.08	na.	0.23
Romeo et al.	2004	123	468	na.	0	na.	0
Preiskel & Tsolka	2004	286	2038	na.	0.05	na.	0.69
Muche et al.	2003	205	615	0	0.16	na.	1.30
Andersson et al.	2003	50	170	0	0	na.	0
Romeo et al.	2003	100	400	0	0	na.	0.25
Jemt et al.	2003	117	215	0	0.93	na.	0.47
Jemt et al.	2003	53	500	0	0	na.	0.40
Krennmair et al.	2002	146	438	0	0	na.	1.14
Andersson et al.	2001	10	30	0	0	na.	0
Behneke et al.	2000	114	305	0	0	na.	3.94
Bianco et al.	2000	252	1832	na.	na.	0.49	1.20
Wannfors & Smedberg	1999	44	126	na.	na.	1.59	10.32
Wannfors & Smedberg	1999	36	102	na.	na.	4.90	0.98
Levine et al.	1999	174	518	0	0	na.	0.77
Wyatt & Zarb	1998	230	1166	na.	0.86	na.	0.86
Behr et al.	1998	138	483	na.	0.21	na.	0.21
Kastenbaum et al.	1998	200	600	0	0.17	na.	0.33
Scheller et al.	1998	99	243	na.	na.	na.	1.65
Andersson et al.	1998	65	275	na.	na.	0.36	0.36
Avivi-Arber et al.	1996	49	168	na.	1.19	na.	na.
Chapman and Grippo	1996	1757	8539	0.11	0.21	na.	0.35
Henry et al.	1996	104	480	0	na.	na.	5.83
Ceramic abutment							
Zembic et al.	2009	19	54	0	0	0	0
Canullo	2007	30	99	0	0	0	0
Glauser et al.	2004	54	148	0	na.	na.	1.36
Andersson et al.	2003	53	225	0.44	0	na.	0
Andersson et al.	2001	10	30	0	0	na.	0
Total		**5849**	**27017**				
Summary estimate (95 % CI)				**0.05* (0.03-0.10)**	**0.15** (0.08-0.31)**	**1.06** (0.40-2.84)**	**1.04** (0.67-1.61)**
5-year failure rate (95 % CI)				**0.3%* (0.1%-0.5%)**	**0.8%** (0.4%-1.6%)**	**5.2%** (2%-13.3%)**	**5.1%** (3.3%-7.7%)**

Table 4 – Incidence of technical complications on abutment level

* Based on standard Poisson regression.

** Based on random-effects Poisson regression.; n.a. stands for "not available"

Study	Year of publi-cation	Total no. of abutments	Total abutment exposure time	Estimated rate of loosening of reconstruction (per 100 ab. years)	Estimated rate of ceramic chipping (per 100 ab. years)	Estimated rate of technical complication (per 100 ab. years)
Matal abutment						
Zembic et al.	2009	12	30	0	3.33	3.33
Cooper et al.	2007	54	129	1.55	2.33	3.88
Kreissl et al.	2006	205	1025	na.	0.59	2.44
Bischof et al.	2006	263	1245	0.08	0.88	1.12
Vigolo et al.	2006	20	80	0	0	0
Vigolo et al.	2006	20	80	0	0	0
de Boever et al.	2006	283	1474	1.36	0.68	3.59
Brägger et al.	2005	69	690	0.14	0.29	0.87
Brägger et al.	2005	69	690	1.44	0.43	1.88
Romeo et al.	2004	336	1307	0.38	0.31	1.07
Romeo et al.	2004	123	468	0.85	0.43	1.28
Preiskel & Tsolka	2004	286	2038	0	0.05	0.79
Muche et al.	2003	205	615	na.	0.33	1.79
Andersson et al.	2003	50	170	0	0.59	0.59
Romeo et al.	2003	100	400	0	na.	0.50
Jemt et al.	2003	117	215	1.86	1.86	5.12
Jemt et al.	2003	53	500	0.40	1.20	2.20
Krennmair et al.	2002	146	438	2.74	0.23	4.79
Andersson et al.	2001	10	30	0	0	3.33
Behneke et al.	2000	114	305	na.	2.30	6.24
Bianco et al.	2000	252	1832	0.71	0.16	2.57
Wannfors & Smedberg	1999	44	126	10.32	0.79	23.02
Wannfors & Smedberg	1999	36	102	na.	0.98	6.86
Levine et al.	1999	174	518	3.47	na.	4.25
Wyatt & Zarb	1998	230	1166	1.63	1.97	5.32
Behr et al.	1998	138	483	0.21	0.62	1.24
Scheller et al.	1998	99	243	1.23	na.	5.76
Andersson et al.	1998	65	275	na.	na.	1.45
Avivi-Arber et al.	1996	49	168	0.60	2.98	4.76
Chapman and Grippo	1996	1757	8539	na.	na.	0.46
Henry et al.	1996	104	480	2.71	na.	9.58
Ceramic abutment						
Zembic et al.	2009	19	54	0	0	0
Canullo	2007	30	99	0	1.01	1.01
Glauser et al.	2004	54	148	na.	2.03	3.39
Andersson et al.	2003	53	225	0.44	0	0.89
Andersson et al.	2001	10	30	0	0	0
Total		**5649**	**26417**			
Summary estimate (95 % CI)				**1.17* (0.70-1.95)**	**0.81* (0.55-1.18)**	**3.20* (2.33-4.40)**
5-year complication rate (95 % CI)				**5.7%* (3.4%-9.3%)**	**4.0%* (2.7%-5.7%)**	**14.8%* (11%-19.7%)**

Table 5 – Incidence of technical complications on reconstruction level

* Based on random-effects Poisson regression.

n.a. stands for "not available”

Study	Year of publication	Total no. of abutments	Total abutment exposure time	**Estimated rate of soft tissue complication** (per 100 ab. years)	**Estimated rate of soft tissue recession** (per 100 ab. years)	**Estimated rate of bone loss more then 2mm** (per 100 ab. years)	**Estimated rate of esthetic complication** (per 100 ab years)	**Estimated rate of biological complication** (per 100 ab. years)
Metal abutments								
Zembic et al.	2009	12	30	0	0	0	0	0
Cooper et al.	2007	54	129	0	0	na.	na.	0
Bischof et al.	2006	263	1245	na.	na.	0.40	na.	0.40
Vigolo et al.	2006	20	80	0	0	0	na.	0
Vigolo et al.	2006	20	80	0	0	0	na.	0
Brägger et al.	2005	69	690	na.	na.	1.88	na.	1.88
Brägger et al.	2005	69	690	na.	na.	1.16	na.	1.16
Preiskel & Tsolka	2004	286	2038	na.	na.	na.	0.05	na.
Andersson et al.	2003	50	170	0	1.76	0	0	1.76
Romeo et al.	2003	100	400	na.	na.	0	na.	na.
Jemt et al.	2003	117	215	0.47	na.	0	na.	0.47
Jemt et al.	2003	53	500	0.40	na.	0	na.	0.40
Krennmair et al.	2002	146	438	0.23	0.91	0	0.91	1.14
Andersson et al.	2001	10	30	0	0	0	0	0
Behneke et al.	2000	114	305	0.99	na.	4.60	na.	5.58
Bianco et al.	2000	252	1832	0.11	0.11	0.32	0.27	0.55
Wannfors & Smedberg	1999	44	126	na.	na.	0	9.52	0
Wannfors & Smedberg	1999	36	102	na.	na.	0	1.96	0
Wyatt & Zarb	1998	230	1166	2.23	na.	na.	na.	2.23
Scheller et al.	1998	99	243	2.06	na.	1.65	na.	3.70
Andersson et al.	1998	65	275	0.36	na.	4.00	0	4.36
Avivi-Arber et al.	1996	49	168	4.16	2.99	na.	na.	7.14
Chapman and Grippo	1996	1757	8539	na.	na.	na.	na.	na.
Henry et al.	1996	104	480	na.	na.	0.21	na.	0.21
Ceramic abutments								
Zembic et al.	2009	19	54	0	0	0	0	0
Canullo	2007	30	99	0	na.	na.	na.	0
Glauser et al.	2004	54	148	0	na.	0	na.	0
Andersson et al.	2003	53	225	1.33	3.56	0	0	4.89
Andersson et al.	2001	10	30	0	0	0	0	0
Total		**4185**	**20527**					
Summary estimate (95 % CI)				**0.76* (0.41-1.41)**	**0.99* (0.42-2.33)**	**0.68* (0.29-1.56)**	**1.12* (0.33-3.83)**	**1.54* (0.93-2.56)**
5-year complication rate (95 % CI)				**3.7%* (2.0%-6.8%)**	**4.8%* (2.1%-11%)**	**3.3%* (1.5%-7.5%)**	**5.4%* (1.6%-17.4%)**	**7.4%* (4.5%-12%)**

Table 6 – Incidence of biological and esthetic complications on abutment level

* Based on random-effects Poisson regression.

n.a. stands for "not available"

Type of comparison	Total number of abutments	Estimated annual failure or complication rate *	5 year summary estimate (95% CI)*	Total number of abutments	Estimated annual failure or complication rate *	5 year summary estimate (95% CI)*	p-value**
	Metal abutment			Ceramic abutment			
Fracture of the reconstructions***	449	**0.04** (0.02-0.11)	**0.2%** (0.1%-0.6%)	134	**0** (0-1.12)	**0%** (0%-5.4%)	p > 0.5
Abutment loss	4807	**0.52** (0.33-0.81)	**2.6%** (1.7%-4.0%)	166	**0.18** (0.025-1.28)	**0.9%** (0.1%-6.2%)	p = 0.309
Abutment fractures	4025	**0.014** (0.002-0.10)	**0.07%** (0.01%-0.5%)	166	**0.18** (0.03-1.28)	**0.9%** (0.1%-6.2%)	p = 0.166
Abutment screw fracture	5083	**0.16** (0.08-0.34)	**0.8%** (0.4%-1.7%)	112	**0** (0-0.90)	**0%** (0%-4.4%)	p > 0.5
Screw loosening	5634	**1.12** (0.71-1.77)	**5.5%** (3.5%-8.5%)	166	**0.35** (0.05-2.47)	**1.7%** (0.25%-11.6%)	p = 0.217
Misfit causing problems	409	**1.36** (0.48-3.86)	**6.6%** (2.4%-17.6%)	49	**0** (0-2.4)	**0%** (0%-11.4%)	p > 0.5
Loosening of the reconstruction	3101	**1.28** (0.75-2.19)	**6.2%** (3.7%-10.4%)	112	**0.25** (0.03-1.74)	**1.2%** (0.2%-8.3%)	p = 0.150
Ceramic chipping	3184	**0.82** (0.55-1.22)	**4.0%** (2.7%-5.9%)	166	**0.73** (0.20-2.73)	**3.6%** (1.0%-12.7%)	p = 0.872
Total technical complications	5483	**3.45** (2.47-4.84)	**15.9%** (11.6%-21.5%)	166	**1.44** (0.72-2.88)	**6.9%** (3.5%-13.4%)	p = 0.093
Soft tissue complications	1291	**0.84** (0.43-1.66)	**4.1%** (2.1%-7.9%)	166	**0.42** (0.07-2.48)	**2.1%** (0.3%-11.7%)	p = 0.439
Soft tissue recession	899	**0.78** (0.29-2.06)	**3.8%** (1.5%-9.8%)	82	**1.86** (0.34-10.24)	**8.9%** (1.7%-40.0%)	p = 0.391
Bone loss more than 2 mm	1643	**0.79** (0.34-1.81)	**3.9%** (1.7%-8.7%)	136	**0** (0-0.81)	**0%** (0%-4.0%)	p > 0.5
Total biological compliactions	1876	**1.60** (0.96-2.67)	**7.7%** (4.7%-12.5%)	166	**1.07** (0.08-14.69)	**5.2%** (0.4%-52.0%)	p = 0.771
Esthetic complication	901	**1.44** (0.41-5.07)	**6.6%** (2.0%-22.4%)	82	**0** (0-1.19)	**0%** (0%-11.3%)	p > 0.5

Table 7. – Annual failure/complication rates and a 5-year summary estimates of metal- and ceramic abutments.

* Based on random-effects Poisson regression

** Based on multivariable random-effect Poisson regression.

*** Metal ceramic crowns on metal abutments vs. ceramic crowns on ceramic abutments.

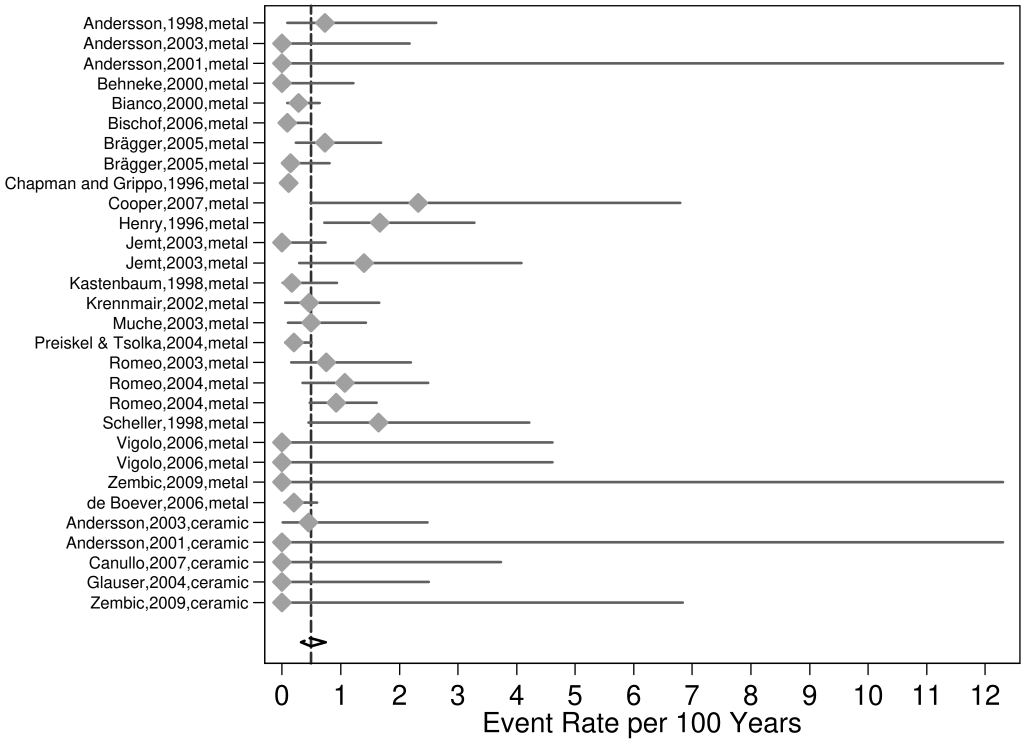

Fig. 2 – Overall annual failure rates (per 100 years) for implant abutments

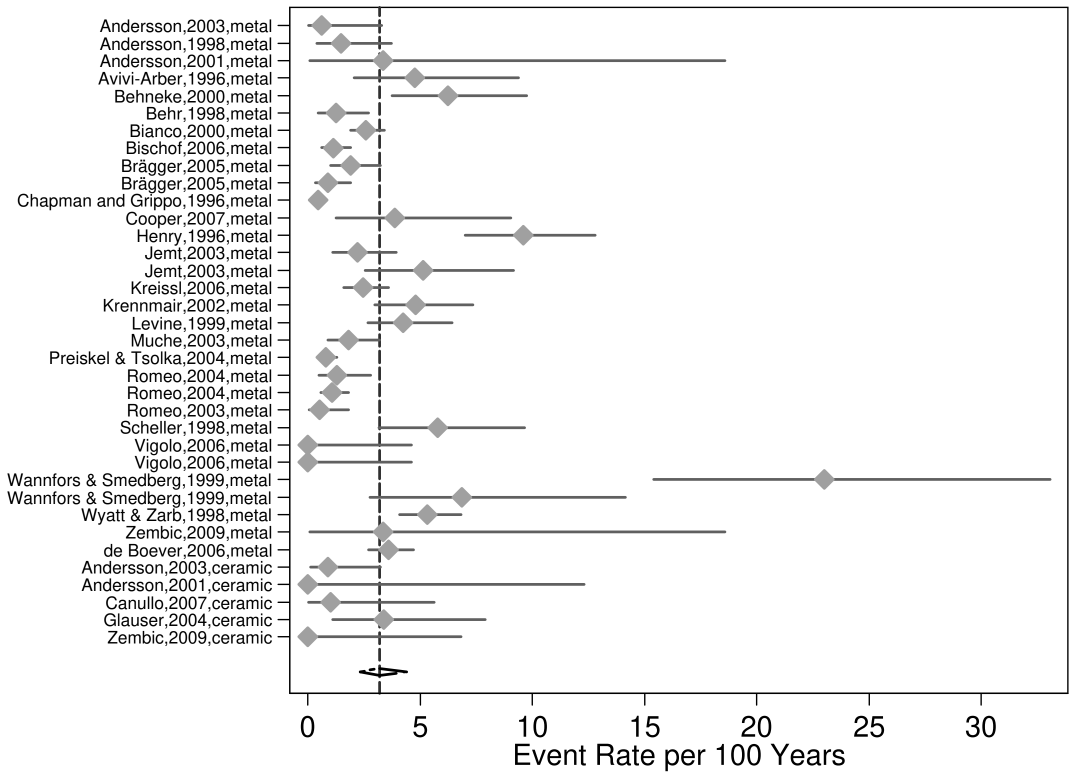

Fig. 3 - Annual rates for technical complications at ceramic and metal abutments (per 100 years)

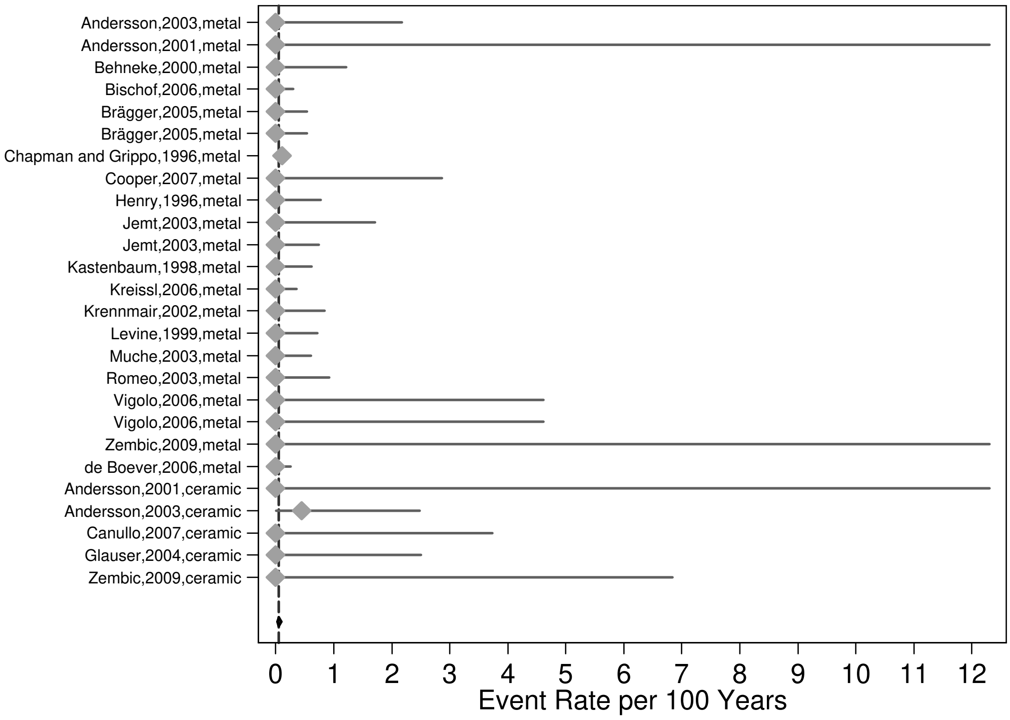

Fig. 4 - Annual rates for fracture of ceramic and metal abutments (per 100 years)

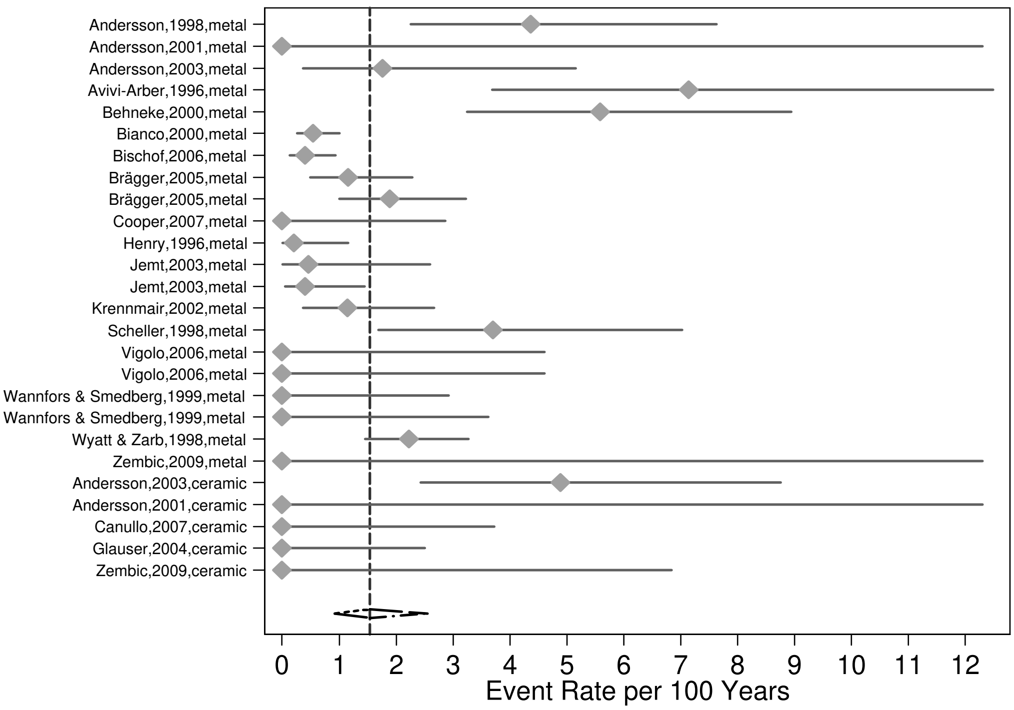

Fig. 5 - Annual rates for biological complications at ceramic and metal abutments (per 100 years)

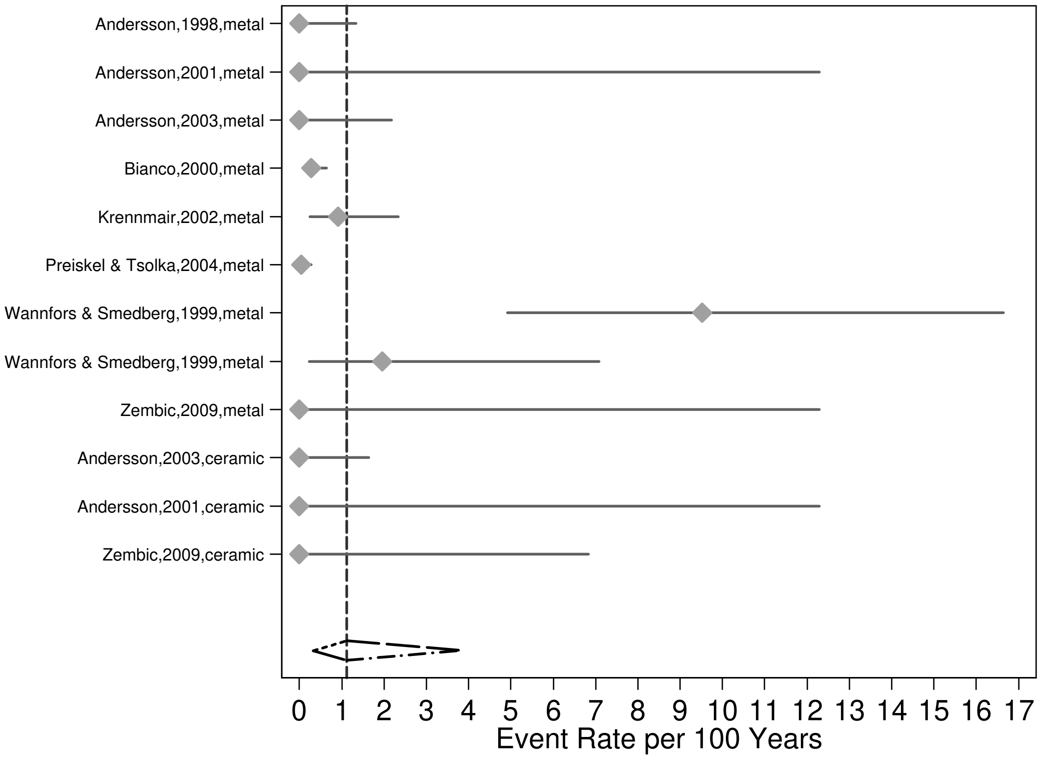

Fig. 6 - Annual rates (per 100 years) for esthetic complications at implant abutments

Figures, Tables and Legends – LABORATORY STUDIES

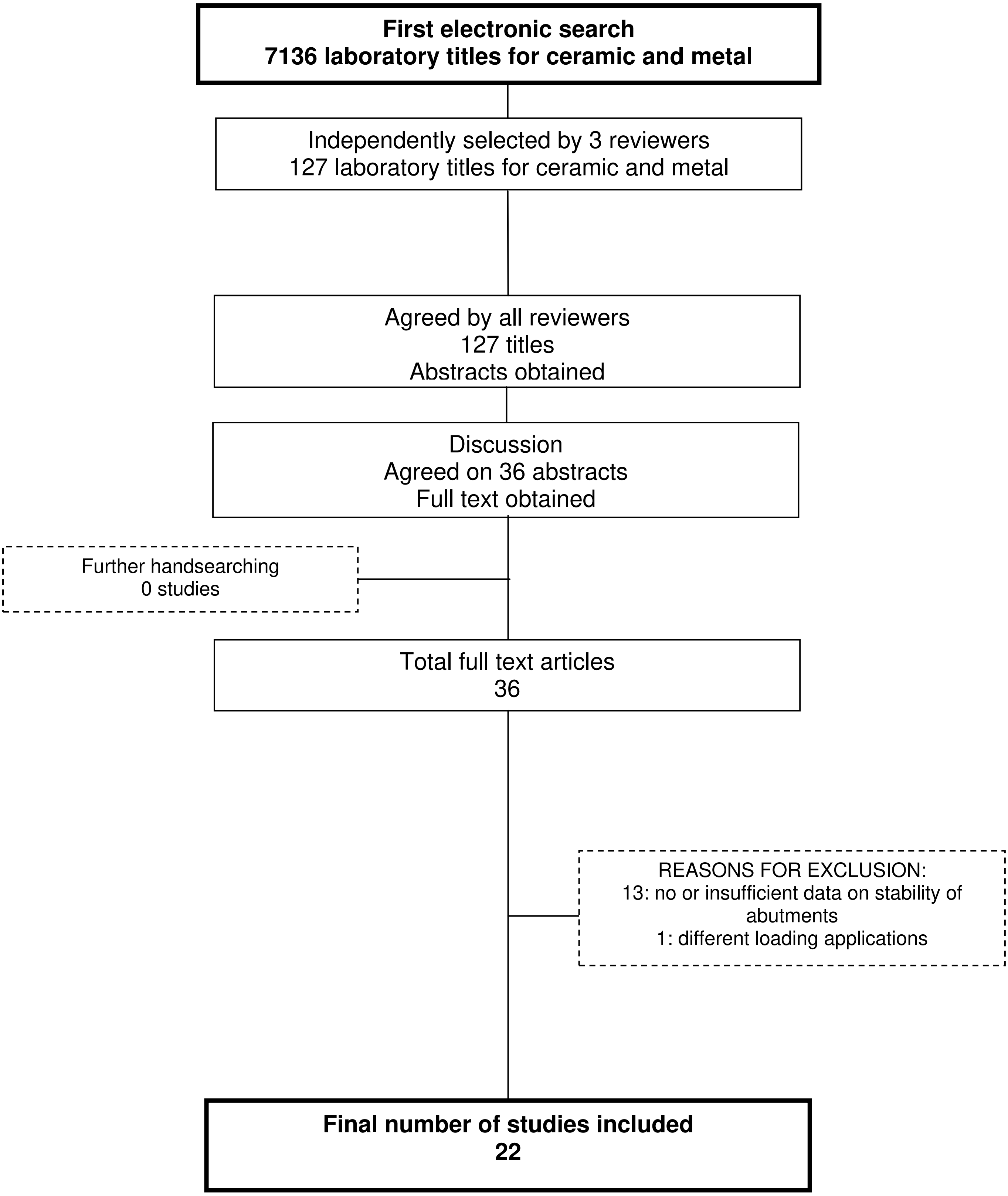

Fig. 7 - Search strategy of the laboratory studies

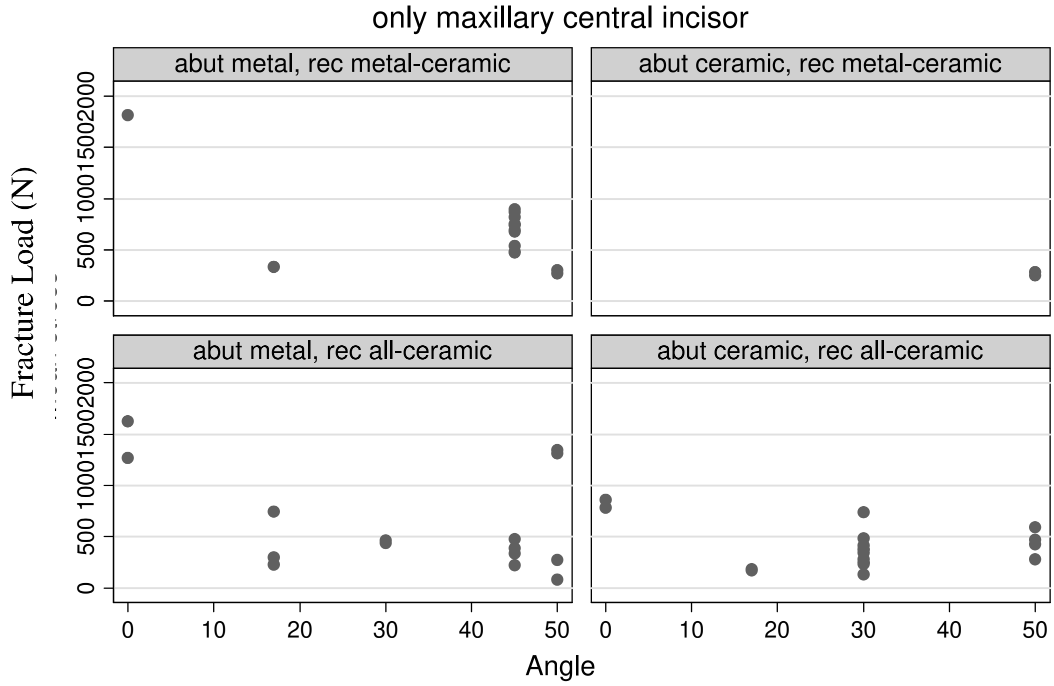

Fig. 8 - Fracture load (N) with respect to abutment/reconstruction material and angle of load application (°)

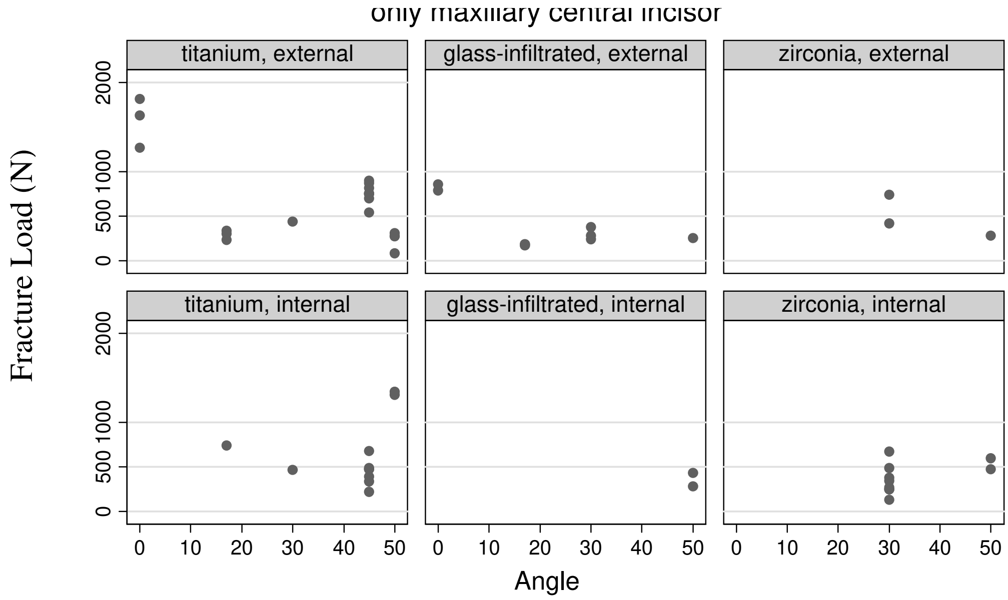

Fig. 9 - Fracture load (N) with respect to type of implant-abutment connection, abutment material (titanium, glass-infiltrated alumina, zirconia) and angle of load application (°)

See Appendix:

Table 8 - Characteristics of the included laboratory studies and mean fracture strength of the tested abutments.

Author	Year	Implant Type	Abutment Type	Abutment Material	Implant-abutment connection	Reconstruction	Location	Reconstruction Material	Chewing simulation (cycles)	Load at angle (°)	Loading point	Mean Fracture Load (N)	Mean Bending Moment (Ncm)
Andersson et al.	1994	Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	metal-ceramic		50	incisal edge	272	224
		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	alumina-ceramic		50	incisal edge	271	241
		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	glass-ceramic		50	incisal edge	82	69
Att et al. (J Prosthet Dent)	2006	Nobel Replace	Esthetic	titanium	internal	SC	maxillary incisor	alumina-ceramic	1200000	50	palatal	1344	
		Nobel Replace	Esthetic Alumina	alumina	internal	SC	maxillary incisor	alumina-ceramic	1200000	50	palatal	429	
		Nobel Replace	Esthetic Zirconia	zirconia	internal	SC	maxillary incisor	alumina-ceramic	1200000	50	palatal	470	
Att et al. (J Oral Rehab)	2006	Nobel Replace	Esthetic	titanium	internal	SC	maxillary incisor	zirconia-ceramic	1200000	50	palatal	1310	
		Nobel Replace	Esthetic Alumina	alumina	internal	SC	maxillary incisor	zirconia-ceramic	1200000	50	palatal	283	
		Nobel Replace	Esthetic Zirconia	zirconia	internal	SC	maxillary incisor	zirconia-ceramic	1200000	50	palatal	593	
Balfour & O'Brien	1995	not indicated	not indicated	titanium	external hexagon					30		756	
		not indicated	not indicated	titanium	internal octagon					30		587	
		not indicated	not indicated	titanium	internal hexagon					30		814	
Butz et al.	2005	Osseotite 3i	ZiReal	zirconia with titanium insert	external hexagon	SC	maxillary incisor	metal	1200000	50	palatal	281	
		Osseotite 3i	CerAdapt	alumina	external hexagon	SC	maxillary incisor	metal	1200000	50	palatal	253	
		Osseotite 3i	GingiHue	titanium	external hexagon	SC	maxillary incisor	metal	1200000	50	palatal	305	
Castellon, Paulino	2003	Spline Zimmerdental	PureForm	titanium	internal	SC	maxillary incisor	alumina-zirconia ceramic	5000000	17	incisal edge	742.9	
Cho et al.	2002	Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	metal-ceramic		0	incisal edge	1812	

		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	InCeram		0	incisal edge	1269	
		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	glass-ceramic		0	incisal edge	1628	
		Brånemark	Celay AC-12	glass-infiltrated alumina	external hexagon	SC	maxillary incisor	InCeram		0	incisal edge	858	
		Brånemark	Celay AC-12	glass-infiltrated alumina	external hexagon	SC	maxillary incisor	glass-ceramic		0	incisal edge	786	
		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	metal-ceramic		17	palatal	333	
		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	InCeram		17	palatal	298	
		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	glass-ceramic		17	palatal	231	
		Brånemark	Celay AC-12	glass-infiltrated alumina	external hexagon	SC	maxillary incisor	InCeram		17	palatal	182	
		Brånemark	Celay AC-12	glass-infiltrated alumina	external hexagon	SC	maxillary incisor	glass-ceramic		17	palatal	170	
Erneklint et al.	1998	Astra ST	Abutment ST	titanium	internal	SC	maxillary incisor	alumina-ceramic		45	incisal edge	390	269
		Astra ST	Abutment ST	titanium	internal	SC	maxillary incisor	In-Ceram		45	incisal edge	475	321
		Astra ST	Abutment ST	titanium	internal	SC	maxillary incisor	pressed glass-ceramic		45	incisal edge	221	158
		Astra ST	Abutment ST	titanium	internal	SC	maxillary incisor	layered glass-ceramic		45	incisal edge	339	227
		Astra ST	Abutment ST	titanium	internal	SC	maxillary incisor	metal-ceramic		45	incisal edge	676	476
Erneklint et al.	2006	Astra	UniAbutment 20°	titanium	internal	bulb-shaped specimen		metal		30		1327	
		Astra	UniAbutment 20°	titanium	internal	bulb-shaped specimen		metal		30		1280	
		Astra	UniAbutment 20°	titanium	internal	bulb-shaped specimen		metal		30		1570	

		Astra	UniAbutment 45°	titanium	internal	bulb-shaped specimen		metal		30		528	
		Astra	UniAbutment 45°	titanium	internal	bulb-shaped specimen		metal		30		456	
		Astra	UniAbutment 45°	titanium	internal	bulb-shaped specimen		metal		30		529	
Gehrke et al.	2006	Dentsply, XIVE	Cercon	zirconia	internal	spherical caps	maxillary incisor		5000000	30	incisal edge	268.8	
		Dentsply, XIVE	Cercon	zirconia	internal	spherical caps	maxillary incisor		no ageing	30	incisal edge	672	
Khraisat et al.	2004	Brånemark	CeraOne	titanium	external hexagon	SC		metal	1000000	30	perpendicular 11.5mm from block surface	305.8	
		Brånemark	CeraOne	titanium	external hexagon	SC		metal	500000	30		313.6	
		Brånemark	CeraOne	titanium	external hexagon	SC		metal		30		316.7	
Leutert et al.	2009	Straumann Bonelevel	CARES	titanium	internal	SC	maxillary incisor	glass-ceramic		30	palatal	466	419.4
		Straumann Bonelevel	CARES	zirconia	internal	SC	maxillary incisor	glass-ceramic		30	palatal	249.8	224.8
		Astra	ZirDesign	zirconia	internal	SC	maxillary incisor	glass-ceramic		30	palatal	344.5	292.8
		Straumann Standard	Zirabut	zirconia	internal	SC	maxillary incisor	glass-ceramic		30	palatal	131	118
Norton M	2000	Astra	UniAbutment	titanium	internal					90	4mm distant from impl-abutm conn		550,7
		Straumann	ITI Conical abutment	titanium	internal					90	3-point bending test!		326.9
Sailer et al.	2009	Straumann Standard	CARES	zirconia	internal-metallic insert	SC	maxillary incisor	all-ceramic		30	palatal	377.7	283.3
		Brånemark	Procera	zirconia	external hexagon	SC	maxillary incisor	all-ceramic		30	palatal	416.4	291.5
		Replace	Procera	zirconia	internal-metrallic insert	SC	maxillary incisor	all-ceramic		30	palatal	484.9	351.5

		Straumann Standard	ZiraBut	zirconia	internal	SC	maxillary incisor	all-ceramic		30	palatal	245.7	184.3
Strub & Gerds	2003	Steri-Oss	Novostil	titanium	external hexagon	SC	maxillary incisor	metal		45	palatal	537	
		Steri-Oss	Anatomic	titanium	external hexagon	SC	maxillary incisor	metal		45	palatal	817	
		Steri-Oss	Straight HL	titanium	external hexagon	SC	maxillary incisor	metal		45	palatal	893	
		IMZ Twin	Esthetic	titanium	internal	SC	maxillary incisor	metal		45	palatal	473	
		Osseotite 3i	Hexed gold UCLA	titanium	external hexagon	SC	maxillary incisor	metal		45	palatal	743	
		Steri-Oss	Novostil	titanium	external hexagon	SC	maxillary incisor	metal	1200000	45	palatal	694	
		Steri-Oss	Anatomic	titanium	external hexagon	SC	maxillary incisor	metal	1200000	45	palatal	750	
		Steri-Oss	Straight HL	titanium	external hexagon	SC	maxillary incisor	metal	1200000	45	palatal	868	
		IMZ Twin	Esthetic	titanium	internal	SC	maxillary incisor	metal	1200000	45	palatal	484	
		Osseotite 3i	Hexed gold UCLA	titanium	external hexagon	SC	maxillary incisor	metal	1200000	45	palatal	750	
Sundh & Sjögren	2007	Straumann	SynOcta	titanium	internal					90		370	
		Straumann	Denzir M	magnesia-zirconia	internal	ceramic copy		ceramic		90		430	
		Straumann	Denzir	zirconia	internal	ceramic copy		ceramic		90		470	
		Straumann	SynOcta In-Ceram	glass-infiltrated alumina	internal	ceramic copy		ceramic		90		410	
Steinebrunner et al.	2008	Brånemark	CeraOne	titanium	external hexagon	SC	molar	metal		30	eccentrical to occlusal surface	782	
		Nobel Replace	Easy-Abutment	titanium	internal	SC	molar	metal		30	eccentrical to occlusal surface	1542	
		Brånemark	CeraOne	titanium	external hexagon	SC	molar	metal	1200000	30	eccentrical to occlusal surface	729	
		Nobel Replace	Easy-Abutment	titanium	internal	SC	molar	metal	1200000	30	eccentrical to occlusal surface	1439	

Tripodakis et al.	1995	Brånemark	InCeram abutment veneered	glass-infiltrated alumina	external hexagon	screw retained SC	maxillary incisor	all-ceramic		30	incisal edge	236	
		Brånemark	InCeram prototype	glass-infiltrated alumina	external hexagon	SC	maxillary incisor	all-ceramic		30	incisal edge	373	
		Brånemark	CeraOne	titanium	external hexagon	SC	maxillary incisor	all-ceramic		30	incisal edge	440	
Wiskott et al.	2004	Straumann analogues	Octa+InCeram	glass-infiltrated alumina	internal - metallic insert				1000000	90	perpendicular 11.3mm from block surface	54.5	
		Straumann analogues	Octa+Gold	gold	internal				1000000	90	perpendicular 11.3mm from block surface	58.8	
		Straumann analogues	Standard	titanium	internal				1000000	90	perpendicular 11.3mm from block surface	55	
Wiskott et al.	2007	Replace Select	Easy-Abutment	titanium	internal				1000000	90	perpendicular 11.3mm from block surface	71.8	
		Replace Select	Esthetic Alumina	alumina	internal - metallic insert				1000000	90	perpendicular 11.3mm from block surface	57.2	
		Replace Select	Esthetic Zirconia	zirconia	internal - metallic insert				1000000	90	perpendicular 11.3mm from block surface	56.4	
Wolf et al.	2008	3i	GinigHue	titanium	external hexagon	SC	molar	glass-ceramic		0	occlusal surface	2072	
		3i	ZiReal	zirconia	external hexagon	SC	molar	glass-ceramic		0	occlusal surface	1921	
		3i	GinigHue	titanium	external hexagon	SC	molar	glass-ceramic		0	occlusal surface	2836	
		3i	ZiReal	zirconia	external hexagon	SC	molar	glass-ceramic		0	occlusal surface	2517	
Yildirim et al.	2003	Brånemark	CerAdapt	alumina	external hexagon	SC	maxillary incisor	glass-ceramic		30	palatal	280.1	
	2003	Brånemark	Wohlwend	zirconia	external hexagon	SC	maxillary incisor	glass-ceramic		30	palatal	737.6	