Systematic Review of the Survival Rate and Incidence of Biologic, Technical, and Esthetic Complications of Single Implant Abutments Supporting Fixed Prostheses

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Purpose: *To assess the 5-year survival rate and number of technical, biologic, and esthetic complications involving implant abutments.* ***Materials and Methods:*** *Electronic (Medline) and hand searches were performed to assess studies on metal and ceramic implant abutments. Relevant data from a previous review were included. Two reviewers independently extracted the data. Failure and complication rates were analyzed, and estimates of 5-year survival proportions were calculated from the relationship between event rate and survival function. Multivariable robust Poisson regression was used to compare abutment characteristics.* ***Results:*** *The search yielded 1,558 titles and 274 abstracts. Twenty-four studies were selected for data analysis. The survival rate for ceramic abutments was 97.5% (95% confidence interval [CI]): 89.6% to 99.4%) and 97.6% (95% CI: 96.2% to 98.5%) for metal abutments. The overall 5-year rate for technical complications was 11.8% (95% CI: 8.5% to 16.3%), 8.9% (95% CI: 4.3% to 17.7%) for ceramic and 12.0% (95% CI: 8.5% to 16.8%) for metal abutments. Biologic complications occurred with an overall rate of 6.4% (95% CI: 3.3% to 12.0%), 10.4% (95% CI: 1.9% to 46.7%) for ceramic, and 6.1% (95% CI: 3.1% to 12.0%) for metal abutments.* ***Conclusions:*** *The present meta-analysis on single-implant prostheses presents high survival rates of single implants, abutments, and prostheses after 5 years of function. No differences were found for the survival and failure rates of ceramic and metal abutments. No significant differences were found for technical, biologic, and esthetic complications of internally and externally connected abutments.* Int J Oral Maxillofac Implants 2014;29(Suppl):99–116. doi: 10.11607/jomi.2014suppl.g2.2

Key words: *biologic complications, ceramics, complication rates, esthetic complications, failures, implant abutments, implant prostheses, metal, survival, systematic review, technical complications, titanium, zirconia*

Today, partially edentulous individuals represent the main group of patients requiring treatment in daily dental practice. Therefore, oral implants are the predominant treatment modality for the rehabilitation of these patients.[1] Using implants, fixed partial dentures can be applied in situations where removable dentures would previously have been necessary.[2–4] In addition, more treatment options that preserve the tooth structure are possible by replacing missing single teeth with dental implants.[5] Since most of the patients provided with oral implants are between 40 and 50 years of age, promising long-term survival rates for implants and prostheses are expected both by the clinician and the patient to ensure the longevity of the prosthesis.[6–8] The definition "long-term" has been specified as a follow-up of at least 5 years.[9] Thus, survival rates and the incidence of biologic, technical, and esthetic events should be based on mean observation periods of at least 5 years.[10]

Several years ago, hierarchies of evidence were developed as aid for the interpretation and evaluation of research findings.[11] As evidence, systematic reviews were ranked to be excellent in terms of effectiveness, appropriateness, and feasibility. An evidence level of "excellent" equates with the strongest scientific basis

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for clinical practice along with the least risk of error.[11] Consequently, systematic reviews are an optimal tool for the development of practice guidelines and clinical recommendations.

A recent systematic review confirmed single implants to be a successful treatment method with survival rates of 97.2% at 5 years and 95.2% at 10 years.[12] However, implant survival rates are not the only essential consideration when advising the patient on different treatment options. Prosthetic and implant abutment outcomes need to be considered as well. Different kinds of abutments are available with respect to material (metal and ceramic) and shape (prefabricated and customized, both with various internal designs). At this time, metal abutments are classified as the "gold standard," although high-strength zirconia abutments are being utilized more widely and may be an adequate alternative to metal abutments for the clinical use. The results of a previous systematic review showed similar outcomes for ceramic and metal abutments.[13] However, the results need to be interpreted with caution due to a high variation in the number of analyzed abutments and differing numbers of studies and follow-up times.

Since the use of ceramic abutments has spread within the last few years, an increase in clinical studies might thus be expected. An update of the available most recent clinical data may help the clinician decide upon the most ideal abutment in each individual situation.

The aim was to systematically review the existing dental literature on the survival rates of metal and ceramic abutments supporting single implant crowns with a mean observation period of at least 3 years. In addition, the occurrence of negative biologic, technical, and esthetic events was evaluated for metal and ceramic abutments.

MATERIALS AND METHODS

The PICO (population, intervention, comparison, outcome) question was stated as follows: For single-tooth implant prostheses in anterior and posterior locations, are there differences in survival/performance based on technical, biologic, and esthetic outcomes as influenced by material and design?

Search Strategy

The present systematic review was performed as an update of a previously published systematic review with the same objectives.[13]

A Medline (PubMed) search was performed for clinical studies published in dental journals from January 1, 2009 up to April 30, 2012. The search was limited to English, German, French, Dutch, and Korean language publications (Table 1).

Search Terms

The following search terms were grouped to the three main subjects (implants, abutments, and material) and linked with "and" as follows:

Implants

"Dental Implants, Single-Tooth" [MeSH] AND "dental implants" AND "dental implant* single tooth" AND "single tooth implant*" AND "single implant" AND "dental implant" AND "single tooth implant" AND "single tooth implants" AND "single implants" AND "Denture, Partial, Fixed" [MeSH] AND "Dental Prosthesis Design" [MeSH] AND "fixed restoration" AND "Denture Design" [MeSH] AND "implant*" AND "fixed prosthodontic" AND "fixed partial denture" AND "fixed prosthodontics" AND "fixed partial dentures" AND "dental implants" [MeSH] AND "Dental Prosthesis, Implant-Supported" AND "fixed dental prosthesis" AND "fixed dental prostheses".

Abutments

"Dental Abutments" [MeSH] AND "implant abutment" AND "implant* reconstruct*" AND "implant* abutment*" AND "implant abutments" AND "abutment*" AND "dental abutment*".

Material

"Titanium" [MeSH] AND "Gold" [MeSH] AND "ceramics" [MeSH] AND "aluminum" [MeSH] AND "Zirconium" [MeSH] AND "ceramic*" AND "titan*" AND "metal*" AND "zirconi*" AND "gold*" AND "alumin*" AND "metals" [MeSH].

Thereafter, the search results from the three subject groups were combined with each other using "OR." The electronic search was complemented by manual searching of the bibliographies of the most recent systematic reviews[12,14,15] and of all included publications.

Inclusion Criteria

The criteria for study inclusion were:

- Studies with at least 10 included patients
- Clinical studies only
- Studies with a mean follow-up of at least 3 years (unless there was an immediate negative effect)
- Studies reporting on details and outcomes of implant abutments
- Studies reporting on partially edentulous patients receiving implant-supported single crowns

Exclusion Criteria

Reports based on patient chart reviews, questionnaires, or interviews were excluded as were case reports and multiple publications on the same patient cohort.

Table 1 Systematic Search Strategy

Focus question	**For single-tooth implant reconstructions in anterior and posterior locations are there differences in survival/performance based on technical, biologic, and esthetic outcomes as influenced by material, design, and fabrication?**
Search strategy	
Population	Patients with single-implant reconstructions
Intervention or exposure	Single implants with a mean follow-up of 3 y
Comparison	Abutment material (metal vs ceramic)
Outcome	Survival rate of implants, abutments, reconstructions
Search combination	*Implants:* "Dental Implants, Single-Tooth" [MeSH] AND "dental implants" AND “dental implant* single tooth” AND “single tooth implant*” AND "single implant" AND "dental implant" AND "single tooth implant" AND "single tooth implants" AND "single implants" AND “Denture, Partial, Fixed” [MeSH] AND “Dental Prosthesis Design” [MeSH] AND "fixed restoration" AND “Denture Design” [MeSH] AND “implant*” AND "fixed prosthodontic" AND "fixed partial denture" AND "fixed prosthodontics" AND "fixed partial dentures" AND “dental implants” [MeSH] AND “Dental Prosthesis, Implant-Supported” AND “fixed dental prosthesis” AND “fixed dental prostheses” *Abutments:* “Dental Abutments” [MeSH] AND "implant abutment" AND “implant* reconstruct*” AND “implant* abutment*” AND "implant abutments" AND “abutment*” AND “dental abutment*” *Material:* "Titanium" [MeSH] AND “Gold” [MeSH] AND “ceramics” [MeSH] AND “aluminum” [MeSH] AND “Zirconium” [MeSH] AND “ceramic*” AND “titan*” AND “metal*” AND “zirconi*” AND “gold*” AND “alumin*” AND “metals” [MeSH] Thereafter, the search results from the three subject groups were combined with each other using “OR”
Database search	
Electronic	PubMed, Cochrane Central Register of Controlled Trials (CENTRAL)
Journals	*Clinical Oral Implants Research, International Journal of Oral Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery, Clinical Implant Dentistry and Related Research, Implant Dentistry, Journal of Implantology, Journal of Periodontology, Journal of Clinical Periodontology, Clinical Oral Investigation, Dental Materials, International Journal of Prosthodontics, European Journal of Oral Implantology*
Selection criteria	
Inclusion criteria	Studies with at least 10 included patients Clinical studies only Studies with a mean follow-up of at least 3 years; studies reporting on details and outcomes of implant abutments Studies reporting on partially edentulous patients receiving implant-supported single crowns
Exclusion criteria	Reports based on patient chart reviews, questionnaires, or interviews Case reports

CT, controlled trial; RCT, randomized controlled trial; NR, not reported.

Study Selection

All obtained titles and abstracts were checked for inclusion by two independent reviewers (SK and AZ). In case the abstract was not available, a full text article was acquired. On the basis of the chosen abstracts, full-text articles were selected for independent assessment by the reviewers. If the information in title and abstract was insufficient for inclusion or exclusion, full-text articles were also obtained. In case of any disagreement regarding inclusion, a decision was made by the three reviewers by consensus. The agreement among the three reviewers for the inclusion of full-text articles was subsequently calculated by Cohen kappa coefficient. In addition, 16 publications on single implant prostheses were included for analysis from the previous review.[13]

Data Extraction

A data extraction sheet was used by two reviewers (SK, AZ) to extract the relevant data from the included papers. Information on several parameters was recorded including: author(s), study design, year of publication, mean follow-up time, implant system, number of abutments, abutment material, drop-outs, and survival rates, as well as the incidence of biologic, technical, and esthetic complications of abutments. Disagree-

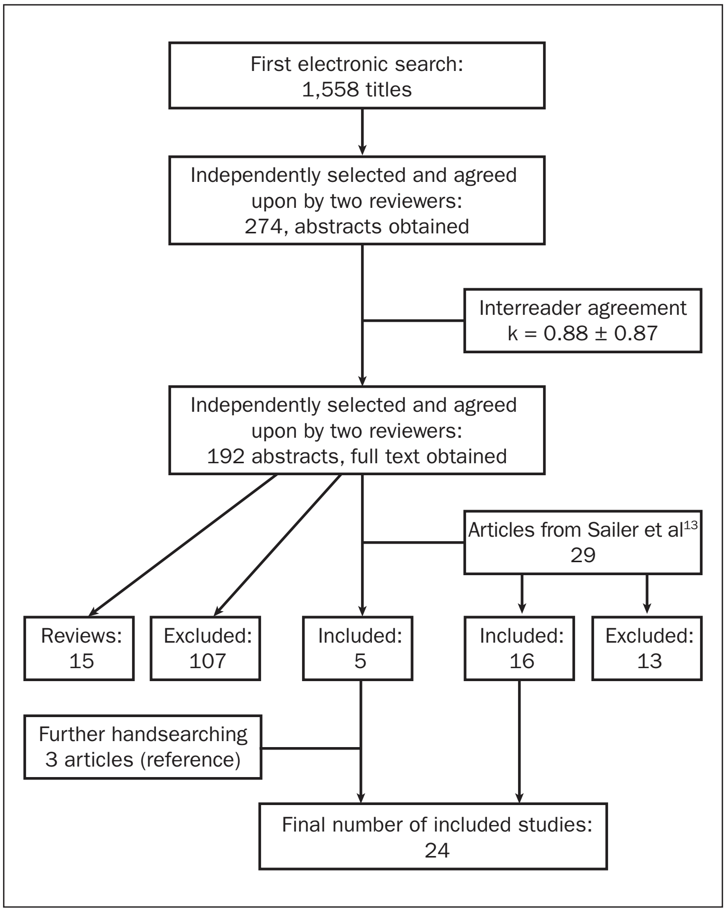

Fig 1 Search strategy.

ment regarding data extraction was resolved by consensus. The number of events and the corresponding total exposure time of the prostheses were calculated. In case the publication did not provide sufficient information, the corresponding authors of the respective publications were contacted via email. Additionally, the data from included studies on single implant crowns from the previous review were extracted.[13]

Survival was defined as the abutment/implant prosthesis remaining in situ for the observation period with or without modifications.

Technical complications included abutment fracture, abutment screw fracture, abutment screw loosening, misfit at the implant-abutment junction (gap), fracture of the implant prosthesis, chipping of the veneering ceramic, and loosening of the implant prosthesis.

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

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

Statistical Analysis

Failure and complication rates were calculated by dividing the number of events (failures or complications) as the numerator by the total time of the prostheses being under observation as the denominator. The numerator could usually be extracted directly from the publication. If all patients/prostheses had a fixed follow-up time point, this was taken as the observation period for all. Otherwise, the total observation time was calculated by taking the sum of the following: *(1)* exposure time of prostheses that could be followed for the full observation period; *(2)* exposure time up to failure of the prostheses that were lost due to failure; and *(3)* exposure time up to the end of observation time for prostheses that did not complete the observation period for reasons such as death, change of address, refusal to participate, nonresponse, 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 prostheses were calculated by dividing the total number of events by the total abutment exposure time in years. For additional analysis, the total number of events was considered to be Poisson distributed for a given sum of abutment exposure years and robust Poisson regression with a logarithmic link-function and total exposure time per study as an offset variable was used.[16] Robust Poisson regression allowed for the calculation of standard errors and 95% confidence intervals (CI), which incorporated heterogeneity among studies.

Five-year survival proportions were calculated via the relationship between event rate and survival function S(T) by assuming constant event rates[17]:

$$S(T) = \exp(-T \times \text{event rate})$$

For the 5-year survival, T was equal to 5.

The 95% CIs for the survival proportions were calculated by using the 95% CIs of the event rates. Multivariable robust Poisson regression was used to formally compare construction subtypes and to assess other study characteristics and to estimate event rate ratios and their 95% CIs. All analyses were performed using Stata, version 12.

Table 2 Characteristics of the Included Studies

Study	Year of publication	Study design	Total no. of included patients	Age range	Mean age	Setting	Mean follow-up (y)	Drop-out (%)
Avivi-Arber and Zarb[18]	1996	Prospective CT	41	14.5–3.9	33.5	University	4	5
Henry et al[19]	1996	Prospective CT	92	NR	NR	Multicenter	5	8
Andersson et al[20]	1998	Prospective CT	57	NR	32	Specialist clinic	5	5
Scheller et al[21]	1998	Multicenter prospective CT	82	14–73	35	Multicenter	5	25
Levine et al[22]	1999	Retrospective	129	NR	NR	Multicenter	3.3	19
Wannfors and Smedberg[23]	1999	Prospective	69	17–72	26	Specialist clinic	3	3
Bianco et al[24]	2000	Retrospective CT	214	16–70	NR	Multicenter	8	9
Andersson et al[25]	2001	RCT	15	17–49	32	Specialist clinic	3	0
Krennmair et al[26]	2002	Retrospective	112	NR	31.3	Private practice and university	3	NR
Muche et al[27]	2003	Retrospective	76	NR	45	University	3	NR
Glauser et al[28]	2004	Prospective CT	27	26–75	44	University	4.1	9
Romeo et al[29]	2004	Prospective CT	250	20–67	NR	University	3.9	NR
Brägger et al[30]	2005	Prospective cohort study	127	19–78	49.3	University	10	NR
Vigolo et al[31]	2006	Prospective RCT	20	NR	NR	University	4	0
Canullo[32]	2007	Prospective cohort study	25	25–70	NR	Private practice	3.3	NR
Cooper et al[33]	2007	Prospective cohort study	48	NR	30.6	University	3	9
MacDonald et al[34]	2009	Prospective	20	NR	43.5	University	8	3
Vigolo and Givani[35]	2009	Prospective	144	25–55	37	Private practice	5	0
Bonde et al[36]	2010	Retrospective	51	19–79	43	University	10	3
Urdaneta et al[37]	2010	Retrospective	81	28–92	58.7	Specialist clinic	5.9	27
Ekfeldt et al[38]	2011	Retrospective	25	NR	NR	Specialist clinic	3–5	NR
Visser et al[39]	2011	Prospective	93	18–63	33	University	5	1
Gotfredsen[40]	2012	Prospective	20	18–59	33	University	10	5
Zembic et al[41]	2013*	Prospective RCT	22	23–59	41.3	University	5.6	4

*Available ahead of print in 2012.

RESULTS

The search strategy is presented in Fig 1. The Medline search provided a total of 1,558 titles. After screening of all titles, both reviewers agreed upon 274 abstracts. Finally, 24 full-text articles reporting on the clinical performance of implant abutments were selected (Table 2). Three out of 24 studies were gained through the hand search and 16 articles were retrieved from the previous review. The studies were published from 1996 until 2012. The inter-reviewer agreement for the inclusion of the studies was $\kappa = 0.88 \pm 0.87$ (Cohen kappa coefficient).

Excluded Studies

One hundred twenty-two studies were excluded due to the following reasons: mean observation period less than 3 years (n = 27), no detailed information on abutments (n = 42), no detailed results on abutments (n = 6), data obtained from patient chart reviews (n = 3), splinted crowns (n = 8), case reports (n = 19), reviews (n = 15), or mixed data on FPDs and single implant crowns (n = 2).

Included Studies

Among the selected full-text articles, three studies[25,31,41] were randomized clinical trials (RCTs) comparing different abutment materials (zirconia vs titanium, alumina vs

Table 3 Characteristics of Abutment and Prostheses

Study	Year of publication	Implant system	Implant diameter	Location	Total abutments
Avivi-Arber and Zarb[18]	1996	Nobel Biocare	3.75, 4.0	Incisor, canine, premolar, molar	42
Henry et al[19]	1996	Nobel Biocare	NR	NR	96
Andersson et al[20]	1998	Nobel Biocare	NR	51 incisors, 1 canine, 13 premolars	65
Scheller et al[21]	1998	Nobel Biocare	3.75, 4.0	87 maxilla, 12 mandible	65
Levine et al[22]	1999	Straumann	3.5, 4.1	22 anterior, 135 posterior	157
Wannfors and Smedberg[23]	1999	Nobel Biocare	NR	40% max incisor, 20%–30% max lateral incisor, 15%–20% max canine, 5 implants in mandible	76
Bianco et al[24]	2000	Nobel Biocare	NR	anterior and posterior	229
Andersson et al[25]	2001	Nobel Biocare	3.75, 4.0	17 incisors, 2 canines, 1 premolar	10
Andersson et al[25]	2001		NR	NR	10
Krennmair et al[26]	2002	Frialit 2	NR	NR	146
Muche et al[27]	2003	3i	NR	NR	205
Glauser et al[28]	2004	Nobel Biocare	3.75, 4.0	25 incisors, 14 canines, 15 premolars	36
Romeo et al[29]	2004	Straumann	Narrow, regular, wide	Anterior, posterior	121
Brägger et al[30]	2005	Straumann	NR	NR	69
Vigolo et al[31]	2006	3i	3.75, 4.0	16 maxilla, 4 mandible, 0 anterior, 20 posterior	20
Vigolo et al[31]	2006	3i	3.75, 4.0	16 maxilla, 4 mandible, 0 anterior, 20 posterior	20
Canullo[32]	2007	TSA implants	NR	Anterior and posterior	30
Cooper et al[33]	2007	Astra Tech	NR	Incisor, canine	43
MacDonald et al[34]	2009	Endopore	3.5, 4.1	13 posterior, 7 anterior	17
Vigolo and Givani[35]	2009	3i	wide	Only molars	182
Bonde et al[36]	2010	Nobel Biocare	3.3 (4), 3.75 (51)	42 anterior, 13 premolars, 49 maxilla, 6 mandible	52
Urdaneta et al[37]	2010	Bicon	3.3–6.0	NR	326
Ekfeldt et al[38]	2011	Nobel Biocare	3.3–5.0	NR	40
Visser et al[39]	2011	Straumann	4.1	Anterior maxilla	92
Gotfredsen[40]	2012	Astra Tech	4.5	18 anterior, 2 posterior	19
Zembic et al[41]	2013*	Nobel Biocare	3.75	2 anterior, 16 posterior	18
Zembic et al[41]	2013*	Nobel Biocare	3.75	2 anterior, 8 posterior	10

*Available ahead of print in 2012. NR, not reported.

titanium, and titanium vs gold). Seventeen studies had a prospective design, seven studies were retrospective.

In total, 12 studies were performed at a university setting, 5 studies in a specialist clinic, 2 in private practice, and 1 both at university and private practice. Four studies were multicenter studies.

Overall, 1,877 patients with 2,999 abutments were involved in the included studies. Out of these, 139 (7.4%) patients and 813 (27%) abutments were dropouts and thus not followed. Six studies did not report the patient dropout rate. The mean age of all patients was 41 years, ranging from 14 to 92 years.

Abutment material	Abutment type	Fixation torque	Abutment connection	Prosthesis material	Cemented implants	Screw-retained implants
Titanium	NR	NR	External hexagon	Metal-ceramic or metal-acrylic, 1 all-ceramic	NR	NR
Titanium	NR	NR	External hexagon	NR	NR	NR
Titanium	NR	NR	External hexagon	62 all-ceramic, 3 metal-ceramic	65	0
Titanium	Prefabricated	32	External hexagon	16 porcelain fused to metal, 81 full ceramic	97	0
Titanium	NR	32	Internal	NR	76	81
Gold	Customized, prefabricated	32	External hexagon	36 gold-resin, 35 gold-ceramic, 9 all-ceramic	36	44
Titanium	NR	NR	External hexagon	Metal, metal-ceramic, all-ceramic	203	31
Alumina	NR	NR	External hexagon	All-ceramic	10	0
Titanium	NR	10–32	External hexagon	All-ceramic	10	0
Titanium	NR	NR	Internal	Metal-ceramic, all-ceramic	93	53
Metal	NR	35	External hexagon	Metal-ceramic	5	200
Zirconia	NR	32	External hexagon	All-ceramic	54	0
Titanium	NR	NR	Internal	Metal-ceramic	NR	NR
Metal (titanium, gold-alloy)	NR	32	Internal	NR	67	2
Titanium	Customized	35	External hexagon	Metal-ceramic	20	0
Gold	Customized	35	External hexagon	Metal-ceramic	20	0
Zirconia	NR	15	Internal	All-ceramic	30	0
Titanium	NR	32	Internal	Metal-ceramic, all-ceramic	54	0
Titanium	Prefabricated	NR	External hexagon	Metal-ceramic	0	20
Titanium	Customized	32	External hexagon	Metal-ceramic	182	0
Titanium	Prefabricated	NR	External hexagon	All-ceramic	55	0
Titanium	NR	NR	Internal	228 gold-resin, 82 metal-ceramic, 16 all-ceramic	326	0
Zirconia	Customized	35	External hexagon	40 all-ceramic (25 one-piece)	15	25
Titanium abutment with gold coping screwed onto it	Customized	15	Internal	All-ceramic	92	0
Titanium	Prefabricated, customized	15	Internal	Metal-ceramic	19	0
Zirconia	Customized	32	External hexagon	All-ceramic	16	2
Titanium	Customized	32	External hexagon	Metal-ceramic	10	0

In the above-mentioned three RCTs, the outcomes were compared for 10 alumina and 10 titanium abutments, 20 gold and 20 titanium abutments, and 18 zirconia and 10 titanium abutments.[25,31,41]

The majority of studies (13) reported on anterior and posterior abutment locations.[18,20,22,24,25,28,29,31,32,34,36,40,41] Three studies reported on anterior abutment locations only.[23,33,39] One study described posterior abutment locations only.[35] Seven studies did not state the exact location of the abutments with regard to anterior or posterior.[19,21,26,27,30,37,38]

Table 4 Failed Abutments and Prostheses

Study	Year of publication	Total no. of abutments/ prostheses	Mean follow-up	Abutment material	Prosthesis material
Avivi-Arber and Zarb[18]	1996	42	4	Titanium	Metal-ceramic or metal-acrylic, 1 all-ceramic
Henry et al[19]	1996	96	5	Titanium	NR
Andersson et al[20]	1998	55	5	Titanium	62 all-ceramic, 3 metal-ceramic
Scheller et al[21]	1998	65	5	Titanium	16 meta-ceramic, 81 all-ceramic
Levine et al[22]	1999	157	3.3	Titanium	NR
Wannfors and Smedberg[23]	1999	76	3	Gold	36 gold-resin, 35 gold-ceramic, 9 all-ceramic
Bianco et al[24]	2000	229	8	Titanium	Metal, metal-ceramic, all-ceramic
Andersson et al[25]	2001	10	3	Alumina	All-ceramic
Andersson et al[25]	2001	10	3	Titanium	All-ceramic
Krennmair et al[26]	2002	146	3	Titanium	Metal-ceramic, all-ceramic
Muche et al[27]	2003	205	3	Metal	Metal-ceramic
Glauser et al[28]	2004	36	4.1	Zirconia	All-ceramic
Romeo et al[29]	2004	121	3.9	Titanium	Metal-ceramic
Brägger et al[30]	2005	69	10	Metal (titanium, gold-alloy)	NR
Vigolo et al[31]	2006	20	4	Titanium	Metal-ceramic
Vigolo et al[31]	2006	20	4	Gold	Metal-ceramic
Canullo[32]	2007	30	3.3	Zirconia	All-ceramic
Cooper et al[33]	2007	43	3	Titanium	Metal-ceramic, all-ceramic
MacDonald et al[34]	2009	17	8	Titanium	Metal-ceramic
Vigolo and Givani[35]	2009	182	5	Titanium	Metal-ceramic
Bonde et al[36]	2010	52	10	Titanium	All-ceramic
Urdaneta et al[37]	2010	326	5.9	Titanium	228 gold-resin, 82 metal-ceramic, 16 all-ceramic
Ekfeldt et al[38]	2011	40	3-5	Zirconia	40 all-ceramic (25 one-piece)
Visser et al[39]	2011	92	5	Titanium abutment with gold coping	All-ceramic
Gotfredsen[40]	2012	19	10	Titanium	Metal-ceramic
Zembic et al[41]	2013*	18	5.6	Zirconia	All-ceramic
Zembic et al[41]	2013*	10	5.6	Titanium	Metal-ceramic

*Available ahead of print in 2012. Total summary estimate (95% CI, random-effects Poisson regression) for total exposure time: 11,089; estimated abutment failure rate per 100 abutment years: 0.48 (0.30–0.77); estimated prosthesis failure rate per 100 prosthesis years: 0.91 (0.62–1.32); estimated 5-year abutment failure rate per 100 abutment years: 2.37% (1.49–3.77); estimated 5-year prosthesis failure rate per 100 prosthesis years: 4.42% (3.06–6.37).

The studies reported on eight commercially available implant systems: Brånemark System (Nobel Biocare), Astra Tech Dental Implants System (Astra Tech), ITI Dental Implants System (Straumann), 3i Implants (Implant Innovations), Endopore Implants (Innova Corporation), TSA Implants (Impladent), Frialit 2 Implants (Friatek), and Bicon Dental Implants (Bicon) (Table 3).

Thus, nine studies evaluated implant systems with internal implant-abutment connections (Astra Tech, Straumann, Bicon, Frialit 2, and TSA Implants), and the remaining 15 studies evaluated implants with external implant-abutment connections (Brånemark System, 3i, and Endopore Implants) (Table 3). In total, 1,003 internally connected abutments (30 zirconia and 973 metal abutments) were evaluated and 1,183 externally connected abutments (94 zirconia, 10 alumina, and 1,079 metal abutments).

Abutment Survival

A total of 2,186 abutments were followed with a mean observation period of 5.5 years. Altogether, 134 ceramic abutments and 2,052 metal abutments were evaluated at follow-up in the included studies (Table 4).

Only two studies did not report on abutment failures.[18,22] Out of the 22 studies reporting abutment failures, two ceramic abutments (1.5%) and 45 metal abutments (2.2%) were lost, resulting in an estimated

No. of failures (abutments)	No. of failures (prostheses)	Total abutment/prosthesis exposure time
NR	NR	168
8	8	480
0	4	275
1	8	325
0	4	518
4	7	228
5	NR	1,832
2	NR	30
0	1	438
2	0	615
3	1	468
0	0	690
5	5	80
5	5	80
0	0	129
0	0	136
0	0	910
3	3	520
0	1	1,923
0	0	460
3	3	190
3	16	30
0	0	148
3	11	99
0	2	160
2	2	101
1	1	56

5-year failure rate of 2.5% (95% CI: 0.6% to 10.4%) for ceramic and 2.4% (95% CI: 1.5% to 3.8%) for metal abutments (Table 4). The failure rate of all abutments per 100 abutment years amounted to 0.48% (95% CI: 0.30% to 0.77%) (Table 4 and Fig 2). The overall estimated 5-year abutment survival rate was 97.6% (95% CI: 96.2% to 98.5%) (Table 4 and Fig 2).

Ceramic abutments showed survival of 97.5% (95% CI: 89.6% to 99.4%) at 5 years and did not differ significantly from metal abutments, which showed 97.6% survival (95% CI: 96.2% to 98.5%).

In total, six abutments fractured, two internally connected zirconia abutment (Replace Select, Nobel Biocare), two externally connected alumina abutments (Brånemark, Nobel Biocare), and three titanium abutments that were internally connected to Bicon implants.[25,37,38]

Sixty-eight abutments could not be evaluated due to implant loss as reported in 13 studies (2 ceramic, 66 metal abutments).[19,21,23,24,26,27,29,30,33,36,37,39,41] For the remaining abutments, no reason for loss was mentioned.

There was no difference in the occurrence of abutment failures for implants with internal compared to external implant-abutment connection (rate ratio = 1.0; 95% CI: 0.4 to 2.6).

Implant Survival

Since it is logical to assume that implant survival signals abutment survival, it is reasonable to use implant survival as secondary measure.

All included studies except for two[28,32] reported on the survival rates of implants. Overall, the estimated 5-year implant survival rate for single implants amounted to 96.9% (95% CI: 95.6% to 97.8%). Sixty-nine out of 2,186 followed-up implants were lost. The estimated 5-year failure rate for single implants amounted to 3.1% (95% CI: 2.2% to 4.4%).

The 5-year survival rate was similar for implants supporting metal abutments (96.9%; 95% CI: 95.6% to 97.8%) and implants supporting ceramic abutments (95.8%; 95% CI: 83.7% to 99.0%). Implants restored with ceramic abutments failed more often at 5 years (4.2%; 95% CI: 1.0% to 16.3%).

There was no difference in the occurrence of implant failures for implants with internal compared to external implant-abutment connection (rate ratio = 1.0; 95% CI: 0.5 to 2.0). The estimated implant failure per 100 implant years was 0.64% (95% CI: 0.5% to 0.9%) (Fig 3).

Prosthesis Survival

All studies reported on the survival rates of the prostheses. The reasons for failure or refabrication, respectively, were mainly major fracture or insufficient esthetics.

The estimated 5-year survival rate of single-implant prostheses was 95.6% (95% CI: 93.6% to 96.9%) (Fig 4). The failure rate for prostheses on ceramic abutments was less than for prostheses on metal abutments (2.6%; 95% CI: 0.6% to 11.3% vs 4.5%; 95% CI: 3.1% to 6.6%). This difference was not significant.

The rate of lost prostheses was similar for internal and external implant-abutment connections (rate ratio = 0.9; 95% CI: 0.4 to 2.1) (Table 4).

Technical Complications

Several technical complications were reported in 21 studies. The overall estimated 5-year rate for technical complications was 11.8% (95% CI: 8.5% to 16.3%) (Table 5; Fig 5).

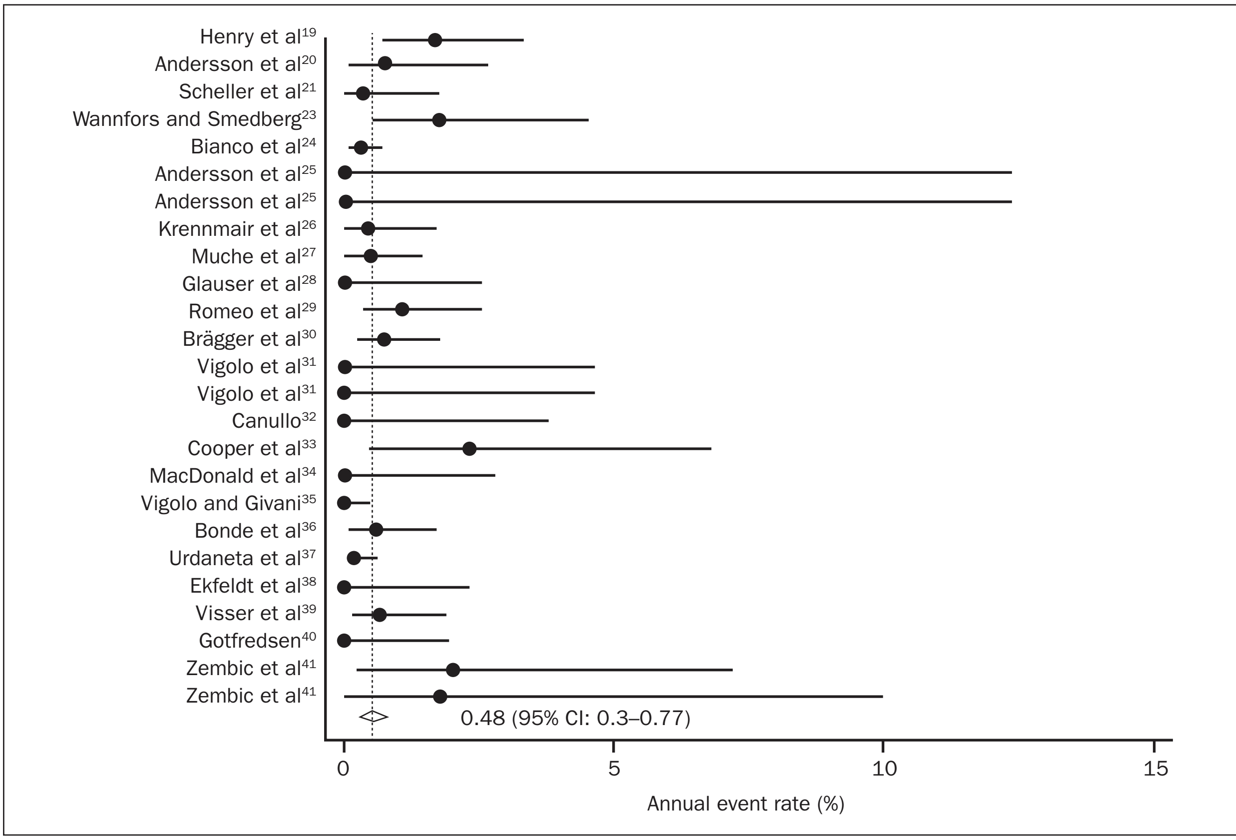

Fig 2 Annual abutment failure rates (per 100 years).

There was no significant difference with respect to the technical complication rate for ceramic and metal abutments. The estimated 5-year technical complication rate for ceramic abutments added up to 8.9% (95% CI: 4.3% to 17.7%), whereas it was 12.0% (95% CI: 8.5% to 16.8%) for metal abutments. The rate of technical complications was found to be 1.3 times (rate ratio = 1.3; 95% CI: 0.7 to 2.4) higher for implants with external implant-abutment connection than with internal implant-abutment connection.

The most common technical complication was abutment screw loosening, which was reported for 4.6% of the abutments. In total, 99 abutment screws were found loose (2 ceramic and 97 metal abutments). One of the studies was an outlier with 29.1% abutment screw loosening.[19] In that study, Brånemark gold abutment screws were used. The second most common technical complication was crown loosening, reported in 13 studies with an incidence of 4.3% (93 loosened crowns out of 2,186 evaluated crowns). In total, 9 loosened crowns were metal-ceramic and 6 were all-ceramic crowns, while 8 studies did not specify the prosthesis material of loose crowns.[18,19,22,24,26,30,33,37] Metal abutments supported all loosened crowns.The third most common complication was chipping of the veneering ceramic, which was evident in 2.7% of the abutments supporting single implant crowns (55 crowns supported by metal abutments and 4 crowns supported by ceramic abutments).

Misfit was reported in seven studies and occurred at 20 out of 2,186 implant-abutment connections (1 ceramic and 19 metal abutments).[20,23,24,32,38,39,41] Abutment fractures were found in 0.2% of abutments reported from two studies.[37,38] In one study, three abutment fractures occurred at internally connected titanium abutments with a narrow neck part connecting to Bicon implants.[37] The other retrospective study described a broken customized CAD/CAM zirconia abutment after 2 months (Procera, Nobel Biocare).[38] This abutment type is externally connected to the implant. The incidence of abutment screw fractures was low at 5 years with 0.2% and was reported at externally connected metal abutments only.[18,19,27]

Biologic Complications

Biologic complications (from a total of 2,186 abutments) affected both soft and hard tissue (Table 6). Fistulae (n = 5), general peri-implant soft tissue inflammations (n = 5), mucositis (n = 3), and bleeding (n = 2)

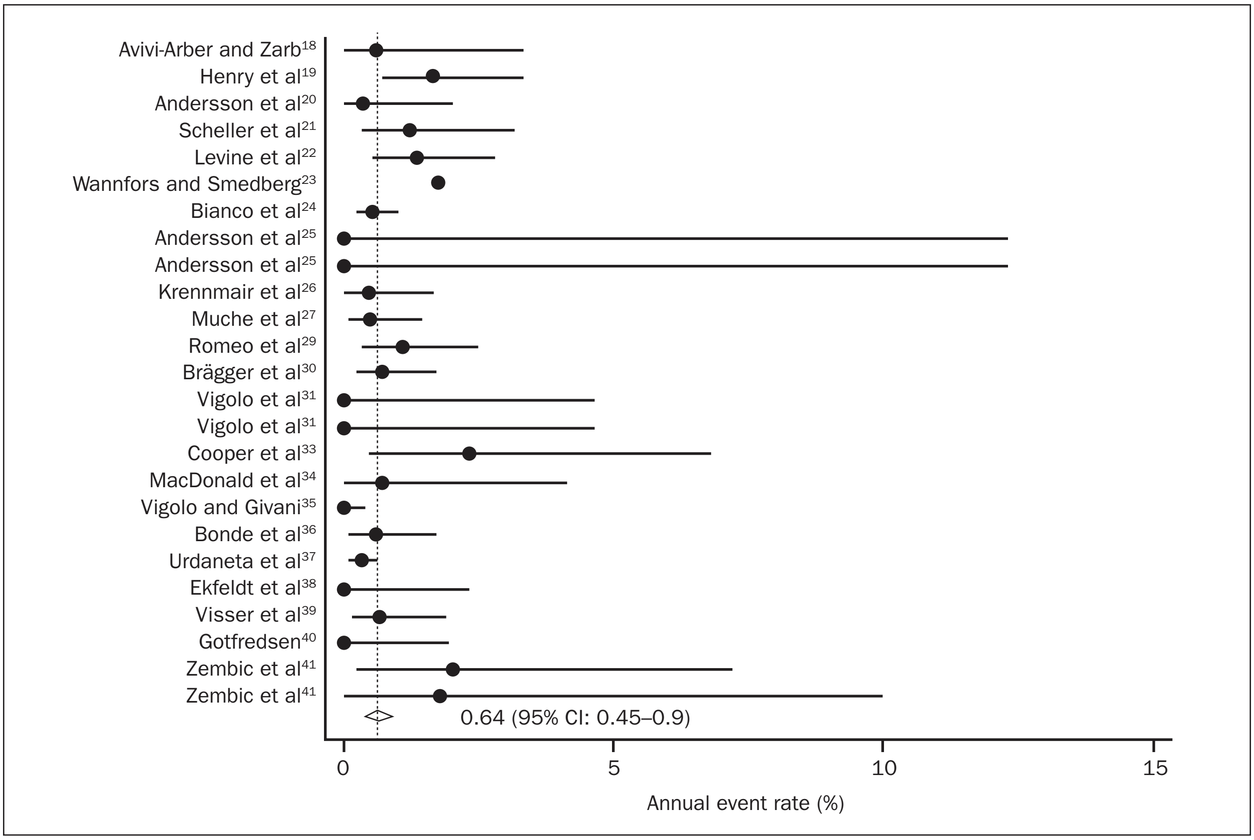

Fig 3 Annual implant failure rates (per 100 years).

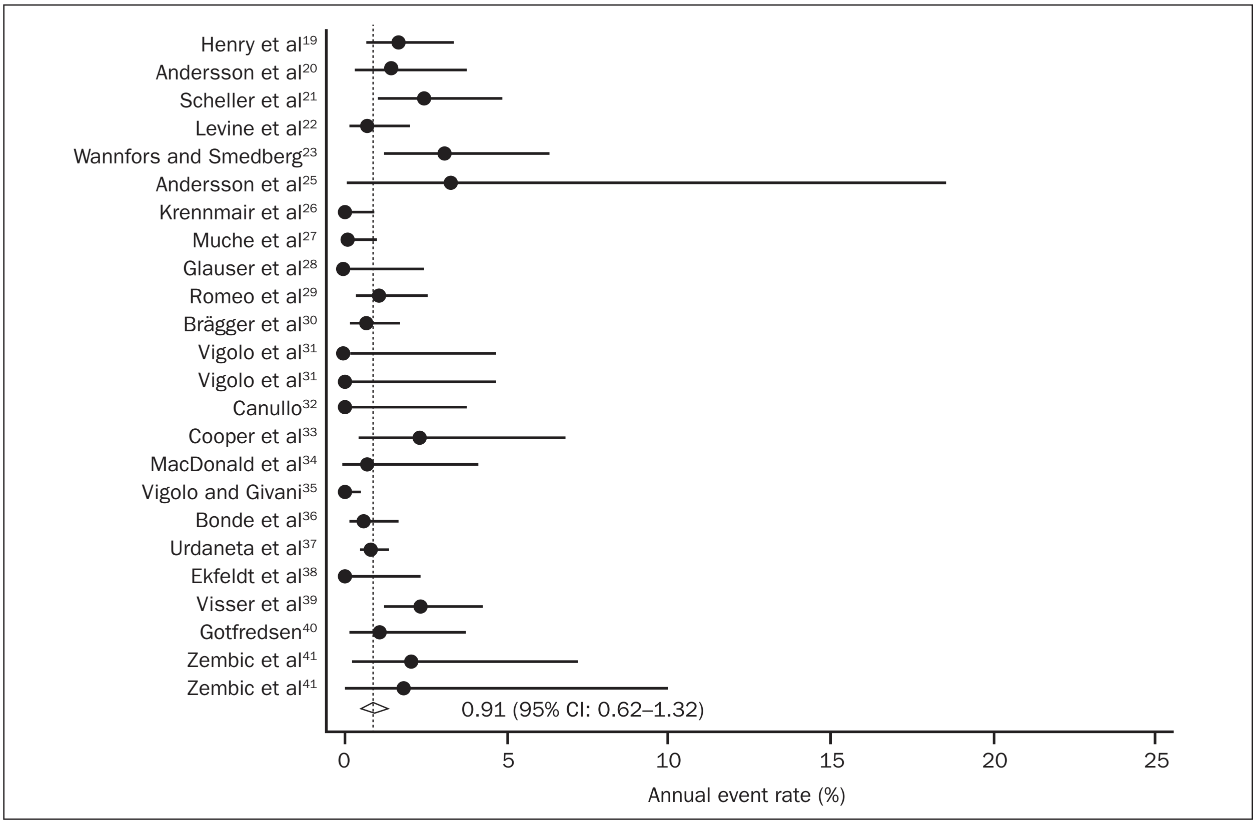

Fig 4 Annual prosthesis failure rates (per 100 years).

Table 5 Technical Complications Occurring in Abutments and Prostheses

Study	Year of publication	Total no. of abutments/ prostheses	Abutment fractures	Misfit	Screw fractures	Abutment screw loosening	Chipping	Crown loosen-ing
Avivi-Arber and Zarb[18]	1996	42	NR	NR	2	NR	5	1
Henry et al[19]	1996	96	0	NR	1	28	NR	13
Andersson et al[20]	1998	55	NR	1	NR	1	NR	NR
Scheller et al[21]	1998	65	NR	NR	NR	4	7	3
Levine et al[22]	1999	157	0	NR	0	4	NR	18
Wannfors and Smedberg[23]	1999	76	NR	8	NR	14	2	NR
Bianco et al[24]	2000	229	NR	9	NR	22	3	13
Andersson et al[25]	2001	10	2	NR	0	0	0	0
Andersson et al[25]	2001	10	0	NR	0	0	0	0
Krennmair et al[26]	2002	146	0	NR	0	5	1	12
Muche et al[27]	2003	205	0	NR	1	8	2	NR
Glauser et al[28]	2004	36	0	NR	NR	2	3	NR
Romeo et al[29]	2004	121	NR	NR	0	0	2	4
Brägger et al[30]	2005	69	0	NR	0	2	3	1
Vigolo et al[31]	2006	20	0	NR	0	0	0	0
Vigolo et al[31]	2006	20	0	NR	0	0	0	0
Canullo[32]	2007	30	0	0	0	0	1	0
Cooper et al[33]	2007	43	0	NR	0	0	3	2
MacDonald et al[34]	2009	17	0	NR	0	3	0	3
Vigolo and Givani[35]	2009	182	NR	NR	0	0	0	0
Bonde et al[36]	2010	52	0	NR	0	3	3	3
Urdaneta et al[37]	2010	326	3	NR	NR	NR	18	18
Ekfeldt et al[38]	2011	40	1	1	0	NR	NR	0
Visser et al[39]	2011	92	NR	1	NR	1	1	NR
Gotfredsen[40]	2012	19	0	NR	0	2	2	2
Zembic et al[41]	2013*	18	0	0	0	0	0	0
Zembic et al[41]	2013*	10	0	0	0	0	3	0

*Available ahead of print in 2012. Total summary estimate (95% CI, random-effects Poisson regression) for technical complications: 2.5 (1.8–3.6); estimated 5-year failure rate for technical complications: 11.8% (8.5–16.3). NR, not reported.

were described with regard to the soft tissue.[19,20,31,36,38] With regard to hard tissue, peri-implantitis (n = 14), pocket probing depths ≥ 5 mm (n = 1), and bone loss of more than 2 mm was mentioned in nine studies.[19–21,24,30,34,38–40] A peri-implant abscess was a rare event and found only in one study.[40]

The estimated 5-year rate for biologic complications was 6.4% (95% CI: 3.3% to 12.0%). The biologic failure rate per 100 abutment years ranged from 0.7% to 2.6% (Fig 6). The incidence of biologic events was almost twice as high for ceramic abutments compared to metal abutments (10.4%; 95% CI: 1.9% to 46.7% vs. 6.1%; 95% CI: 3.1% to 12.0%) (Table 6 and Fig 6). Even though, there was no significant difference ($P > .05$) between metal and ceramic abutments.

The rate of biologic complications was found to be two times (rate ratio = 2.0, 95%; CI: 0.4 to 8.9) higher for implants with external implant-abutment connection than with internal implant-abutment connection. This difference did not reach statistical significance ($P > .05$).

Esthetic Complications

Esthetic outcomes were reported in several studies in a nonstandardized way. Whereas some studies used questionnaires for patients to rate the esthetic outcome, other studies evaluated the esthetic outcome of the crowns by dentists and patients subjectively.[20,23,26,38–40] In addition, some studies evaluated the papilla height and/or peri-implant mucosal color.[34,42]

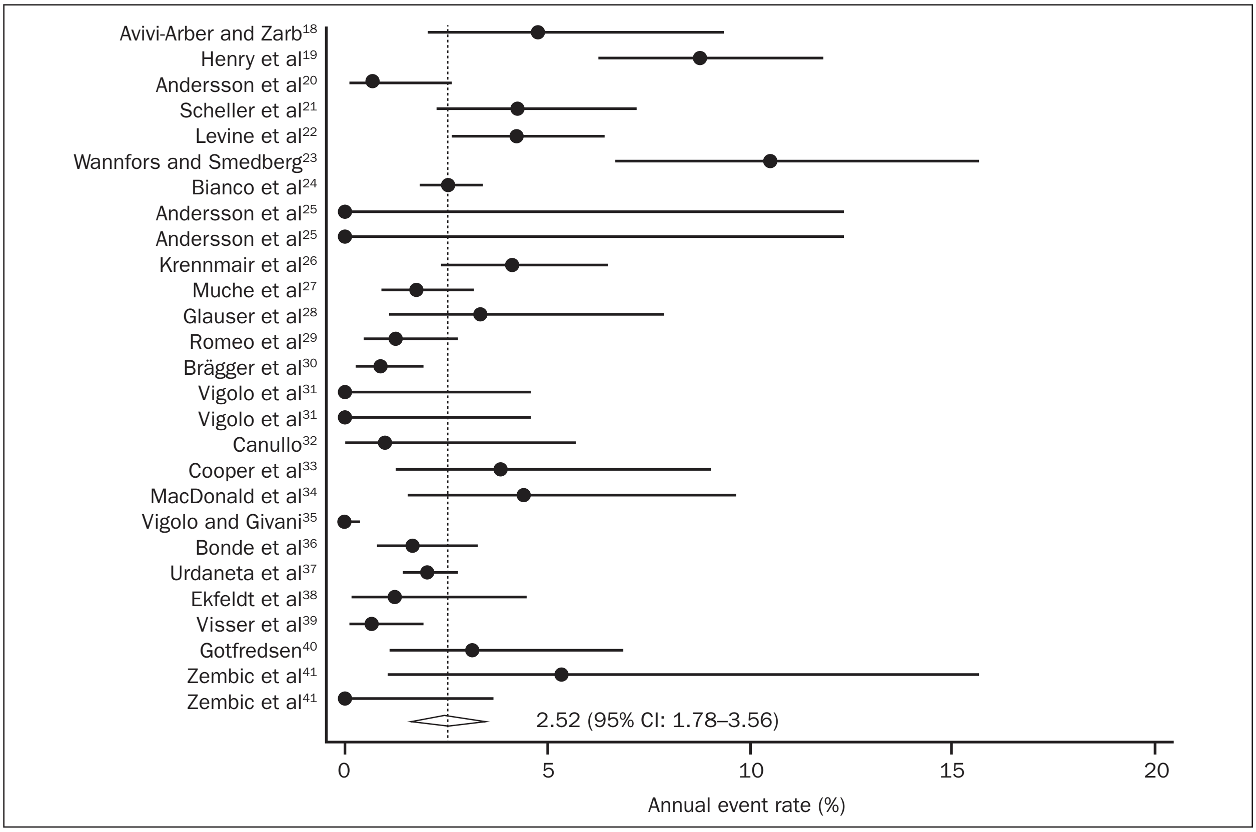

Fig 5 Annual rates for technical complications at ceramic and metal abutments (per 100 years).

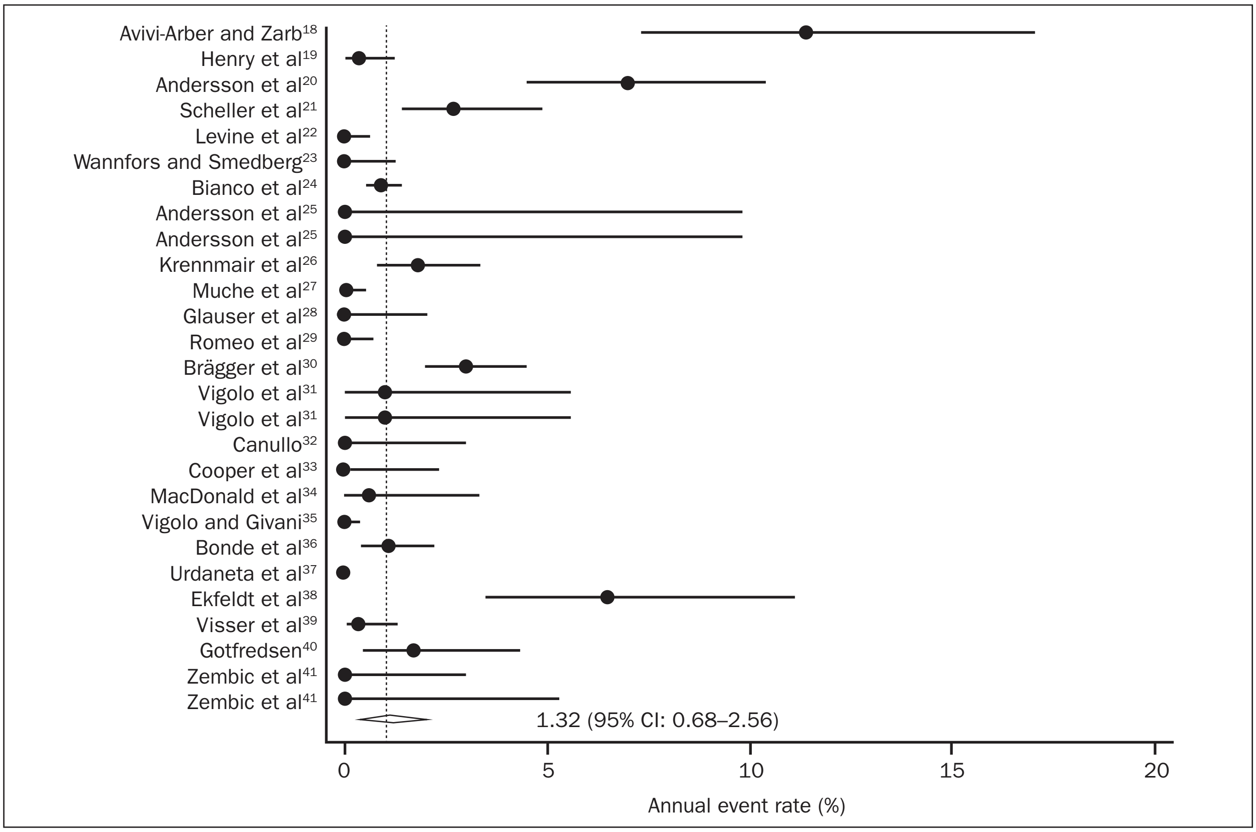

Fig 6 Annual rates for biologic complications at ceramic and metal abutments (per 100 years).

Table 6 No. of Biological and Esthetic Complications at Abutments/Prostheses and Estimated 5-Year Failure Rrate

Study	Year of publication	Total no. of abutments/ prostheses	Bone loss (> 2 mm)	Soft tissue complication	Recession	Biologic complications	Esthetic complications
Avivi-Arber and Zarb[18]	1996	42	NR	7	5	12	NR
Henry et al[19]	1996	96	1	NR	NR	1	NR
Andersson et al[20]	1998	55	11	1	NR	12	0
Scheller et al[21]	1998	65	4-8	5	NR	0	1
Levine et al[22]	1999	157	4	NR	NR	4	NR
Wannfors and Smedberg[23]	1999	76	0	NR	NR	NR	7
Bianco et al[24]	2000	229	6	2	2	10	5
Andersson et al[25]	2001	10	0	0	0	0	0
Andersson et al[25]	2001	10	0	0	0	0	0
Krennmair et al[26]	2002	146	0	1	4	5	4
Muche et al[27]	2003	205	NR	NR	NR	NR	NR
Glauser et al[28]	2004	36	0	0	NR	0	NR
Romeo et al[29]	2004	121	NR	NR	NR	NR	NR
Brägger et al[30]	2005	69	13	NR	NR	13	NR
Vigolo et al[31]	2006	20	0	0	0	1	NR
Vigolo et al[31]	2006	20	0	0	0	1	NR
Canullo[32]	2007	30	NR	0	NR	0	NR
Cooper et al[33]	2007	43	0	0	0	0	NR
MacDonald et al[34]	2009	17	1	NR	NR	0	NR
Vigolo and Givani[35]	2009	182	0	NR	NR	NR	NR
Bonde et al[36]	2010	52	0	NR	NR	7	NR
Urdaneta et al[37]	2010	326	NR	NR	NR	NR	NR
Ekfeldt et al[38]	2011	40	3	NR	1	9	0
Visser et al[39]	2011	92	NR	NR	1	1	4
Gotfredsen[40]	2012	19	1	1	NR	2	NR
Zembic et al[41]	2013*	18	0	0	0	0	0
Zembic et al[41]	2013*	10	0	0	0	0	0

*Available ahead of print in 2012. Total summary estimate (95% CI, random-effects Poisson regression) for biologic complications: 1.32 (0.68–2.56); total summary estimate (95% CI, random-effects Poisson regression) for esthetic complications: 0.19 (0.08–0.47); estimated 5-year failure rate for biologic complications: 6.4% (3.3–12.0); estimated 5-year failure rate for esthetic complications: 0.94% (0.38–2.30). NR, not reported.

The overall estimated 5-year esthetic complication rate for single-implant prostheses was 0.9% (95% CI: 0.4% to 2.3%) (Fig 7). Esthetic problems occurred in 1.0% (95% CI: 0.4% to 2.5%) of all implant prostheses supported by metal abutments. No esthetic complications were reported in the five studies using ceramic abutments. The instrumented color analysis of mucosal tissues found a tissue color change both for metal and ceramic abutments.[13,41] However, no perceivable difference between titanium and zirconia abutments was visually observed when the thickness of the mucosa exceeded 2 mm.

The rate of negative esthetic events was found to be 1.3 times higher (rate ratio = 1.3; 95% CI: 0.2 to 8.1, $P > .05$) at prostheses with external implant-abutment connection than with internal. This difference did not reach statistical significance.

DISCUSSION

The 5-year survival rate of single implant abutments was 98%. Thus, both ceramic and metal abutments survived at a rate of more than 95% at 5 years.

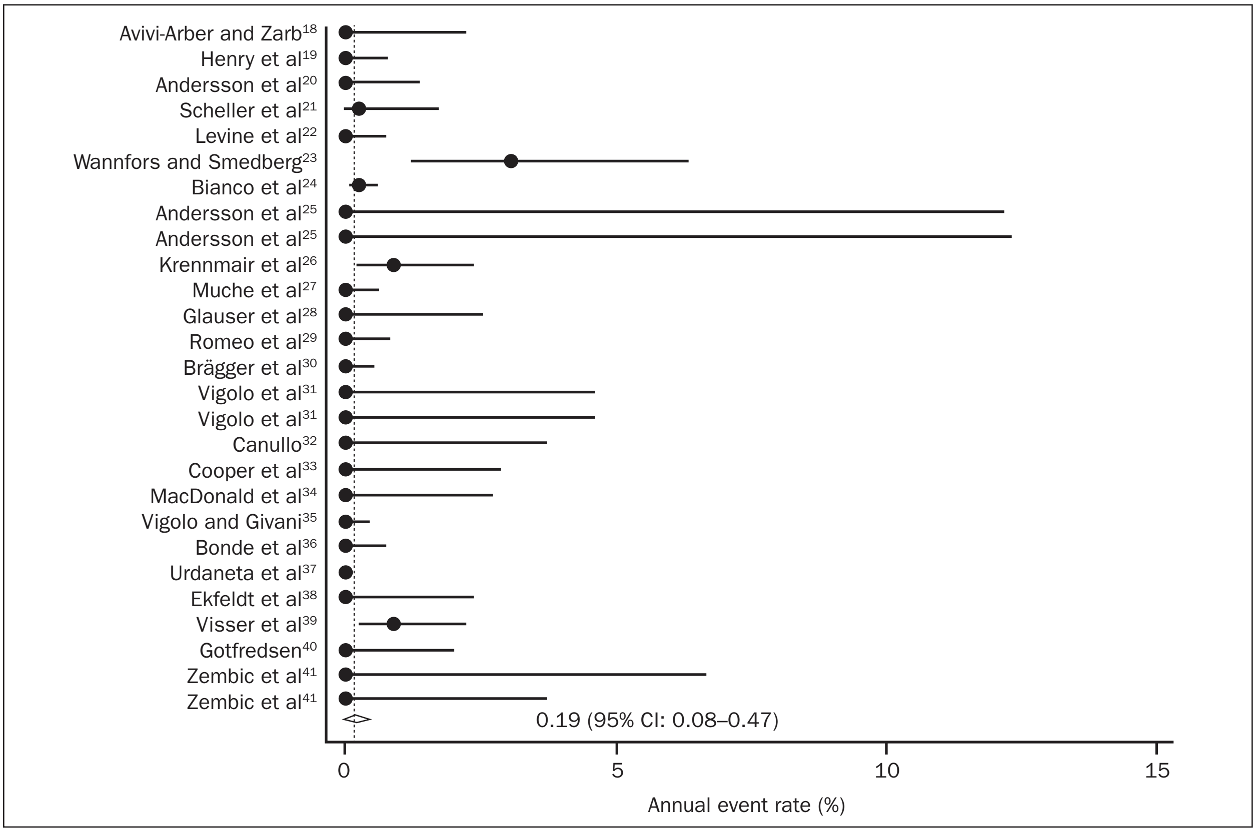

Fig 7 Annual rates for esthetic complications at ceramic and metal abutments (per 100 years).

The most common complications at 5 years were technical complications (11.8%), followed by biologic complications (6.4%). Esthetic complications were fewest and occurred in 0.9% at 5 years.

Implant Survival

The overall 5-year implant survival rate of single implants amounted to 96.9% based on this systematic review. This result is in accordance with the results of two systematic reviews on single implants reporting 5-year survival rates of 96.4% and 97.2%, respectively.[12,13] With today's optimized implant surfaces and configurations, most of the implant failures are likely to occur before loading.[12] Thus, not many failures are expected to happen at 5 years of clinical function. This might explain the positive implant survival rates found in the existing studies.

Abutment Survival

The present results correspond to the results of a previous systematic review on implant abutments, also reporting an estimated 5-year abutment survival rate of 98%.[13] Most of the evaluated abutments were metal abutments (n = 2,052). From the 134 ceramic abutments, mainly zirconia abutments were evaluated (124 zirconia, 10 alumina abutments). In total, six abutments fractured, one externally connected zirconia abutment, two externally connected alumina abutments, and three titanium abutments being internally connected to Bicon implants.[25,37,38]

Alumina abutments were the first generation of ceramic abutments. Previous studies demonstrated a failure rate between 1.9% and 7% after 1 to 5 years of clinical use.[25,43,44] In the above-mentioned RCT alumina abutments were compared with the "gold standard" titanium and showed a lower survival rate of 93% compared to 100% for titanium abutments.[25] This explains the introduction of a stronger substitute material.

The subsequently developed high-strength ceramic zirconia showed superior mechanical properties with much higher bending strength and fracture toughness compared to alumina.[45] Thus, a superior clinical behavior for zirconia might be expected and zirconia might even serve as an alternative to metal in various indications. However, clinical studies on zirconia abutments are scarce (only four studies in this review). When zirconia and titanium abutments were compared in a RCT, the survival rate for both materials was 100% after 5 years of function.[41] Other studies with a shorter follow-up confirm these positive results for zirconia abutments.[28,32,46–48]

Two internally connected zirconia abutments fractured within 2 months in a retrospective study.[38] Among several factors influencing the stability of zirconia abutments, the abutment wall thickness is discussed as being critical.[49] A minimum abutment wall thickness of 0.5 mm was recommended for zirconia abutments, especially when using CAD/CAM techniques.[50] The fractured abutment consisted of an internal insert of titanium to adapt to the implant.[38] The abutment wall thickness might have been insufficient, which might have caused the fractures after a short period of only 2 months.

No clinical long-term data are available for zirconia abutments. Taking the nature of ceramics into account, one might assume fatigue fractures over time.[51] On the other hand, the fatigue performance of zirconia is likely increased through its behavior called "transformation toughening" which causes a resistance to crack growth compared to other polycrystalline ceramics.[52] This might explain the positive clinical results for zirconia abutments thus far.

Metal abutments are still considered the "gold standard" due to high survival rates and excellent physical properties.[20] When gold and titanium abutments were compared in a RCT there were no significant differences with regard to survival and peri-implant bone and soft tissue parameters after 4 years of clinical service.[31]

Three internally connected titanium abutments fractured in one study.[37] These abutments are constructed for specially configured locking-taper implants (Bicon) containing a thin neck part, which might be prone to fracture. Furthermore, the crown-to-implant ratio is increased in this implant-abutment configuration, which might increase the stress at the weakest point, ie, the thin abutment neck part, and thus contribute to its fracture.

Usually, fractures of metal abutment are a rare event and were estimated to occur in only 0.07% at 5 years.[13] The only additional fractures were limited to one specific implant system (Bicon implants).[37]

It has to be taken into account that the number of observed metal abutments (n = 2,052) was much higher than of ceramic abutments (n = 134). On one hand, this might explain why no significant difference between the outcomes of ceramic and metal abutments was calculated. On the other hand, the results have to be interpreted with caution. It may be recommended that the application of ceramic abutments should be selective and not generalized for every situation.

There was no difference in the occurrence of abutment failures for implants with internal compared to external implant-abutment connection. In contrast, a tendency towards less risk for fracture was observed with abutments having an internal implant-abutment connection in the previous review.[13]

Technical Complications

The most common technical complication found was abutment screw loosening (4.6%), mostly observed with metal abutments. This finding is in agreement with several other studies.[12,13,53,54] The high rate for abutment screw loosening in the present study might partly be explained by one study, which reported 29.1% of screw loosenings and used the first generation of Brånemark gold abutment screws, known for this problem.[19] The majority of the abutment screws loosened in externally connected abutments (n = 85) compared to internally connected ones (n = 14). The tendency of less screw loosening at internal implant-abutment connections is supported by other studies.[13,55,56] A recent systematic review on abutment screw loosening for single-implant restorations did not find a difference with internally compared to externally connected implants.[57] The authors concluded that abutments screw loosening is irrespective of the implant-abutment geometry and occurs rarely, provided that a proper antirotational torque is applied.[57]

The second most common technical complication was crown loosening (4.3%). Metal abutments supported all loosened crowns. The cement used was not evaluated. Since in some parts of the world there is a preference for the use of provisional cement for implant prostheses, one might speculate that a high rate of crown loosening is plausible.

The chipping rate of veneering ceramics (2.7%) in the present study was less than reported in previous systematic reviews (4%) at 5 years.[12,13]

Biologic and Esthetic Complications

There is a lack of classification for the report of biologic complications. Consequently, negative events were reported in a non-standardized way and comparison of the studies was impeded. There was a trend for a higher incidence of biologic complications with ceramic abutments (10.4%) compared to metal abutments (6.1%), but without statistical significance. This finding is rather unusual. Animal studies demonstrated a comparable soft tissue integration of alumina, zirconia, and titanium.[58–60] Other studies found even fewer inflammatory cells in the epithelium around zirconia than titanium and gold, and finally less bacterial adhesion at zirconia clinically.[61–64]

Another systematic review indicated a similar soft tissue complication rate of 7.1% after 5 years.[12] Even though the proportion of biologic complications at externally connected abutments was found to be 1.7 times that of internally connected abutments, the type of connection did not have a significant influence on the estimated rate of biologic complications ($P > .05$).

In contrast to the results of a previous review, the incidence of recession in the present study was higher at metal abutments.[13] The reason for this observation remains unclear. The present review indicated no esthetic failures with prostheses on ceramic abutments. This finding is in accordance with a previous review and RCT where less soft tissue discoloration was found for ceramic abutments.[13,54]

There is a large heterogeneity among the studies concerning the evaluation of the esthetics, due to a lack of standardization. The scientific value of the estimated 5-year esthetic complication rate is rather low. Standardized esthetic parameters, such as the pink and white esthetic score[65,66] are thus strongly advisable and should be applied more often in future studies on implant prostheses.

CONCLUSIONS

The present meta-analysis on single implant prostheses presents high survival rates of single implants, abutments and prostheses after 5 years of function.

There are no performance differences in technical or biologic outcomes for ceramic and metal abutments. The only significant finding pertaining to esthetics was a difference in tissue color with both metal and ceramic abutments, which was greater for metal abutments up to 2 mm mucosal thickness.

Similarly, no differences were found for either external or internal implant-abutment connections. The incidence of technical complications is higher than for either esthetic or biologic complications.

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