Long-Term Outcome of One-Piece Implants. Part I: Implant Characteristics and Loading Protocols. A Systematic Literature Review with Meta-Analysis

José M. Barrachina-Díez, DDS[1]/Esam Tashkandi, BDS, MS, FDS RCS, PhD[2]/
Susanne Stampf, Dr rer nat[3]/Wael Att, DDS, Dr Med Dent, PhD[4]

Purpose: *The aim of this systematic review was to evaluate the long-term clinical performance of one-piece implants.* ***Materials and Methods:*** *An electronic MEDLINE search complemented by a manual search was conducted to identify randomized and prospective cohort studies on one-piece implants. Additional inclusion criteria were: a mean follow-up period of at least 5 years and an inception cohort where more than 80% of the enrolled patients remained in the study at the 5- or 10-year observation point.* ***Results:*** *Sixty-six studies from an initial yield of 597 titles were selected, and the data were extracted. Of the full-text articles examined, 46 were excluded from the final analysis. A total of 20 articles were finally selected. All studies were published between 1995 and 2011. Two different study designs were included: 4 randomized controlled trials and 16 prospective cohort studies. The studies were analyzed and classified according to the follow-up period, the type of implant surface, the type of edentulism, the type of loading protocol, and the type of setting. The meta-analysis of the included studies showed an implant survival rate for one-piece, one-part implants of 96.79% (95% CI: 94.04% to 98.71%) after 5 years. In one-piece, two-part implants, the survival rate was slightly higher: 98.16% (95% CI: 96.48% to 99.31%) after 5 years and 96.83% (95% CI: 93.12% to 99.24%) after 10 years.* ***Conclusion:*** *Within the limits of this systematic review, it can be concluded that high long-term survival rates can be observed with one-piece implants. Further randomized clinical trials are needed to provide more information about the outcome of different variables associated with one-piece implants.*
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Key words: *dental implant, flapless, longitudinal study, nonsubmerged, one-piece, single stage*

Implant dentistry has been in constant development since the introduction of dental implants by Brånemark in the 1970s.[1] Several improvements have been seen in many implant-related aspects, such as surfaces, thread designs, and placement protocols. However, two main designs have remained clearly differentiated: two-piece implants, introduced and developed by Brånemark and colleagues,[1,2] and one-piece implants, introduced and developed by Schroeder and colleagues in the 1980s.[3–5]

By definition, a two-piece implant is an implant consisting of an implant body and a separate abutment. During the first surgical procedure, the top portion of the implant body is placed at the level of the alveolar crest. The gingival tissues are reapproximated for primary closure over the top of the implant in the so-called conventional submerged technique. After a healing period of 3 to 6 months, stage-two surgery is performed, in which a healing or restorative abutment is connected to the implant body, leaving an implant-abutment interface (microgap) at the bone level. The submerged approach was believed to be mandatory for obtaining successful osseointegration by avoiding the influence of the oral flora and mechanical stresses during the healing process. However, animal[6–8] and clinical studies[9–13] demonstrated that osseointegration was equally obtained when connecting the abutment to conventionally submerged two-piece implants during the initial surgery, thus avoiding a second surgical procedure.

[1]Assistant Professor, Department of Prosthodontics, School of Dentistry, Albert-Ludwigs University, Freiburg, Germany.
[2]Associate Professor, Department of Prosthodontics, School of Dentistry, King Saud University, Riyadh, Saudi Arabia.
[3]Research Assistant, Department of Medical Biometry and Statistics, University Medical Center Freiburg, Freiburg, Germany.
[4]Associate Professor, Department of Prosthodontics, School of Dentistry, Albert-Ludwigs University, Freiburg, Germany.

Correspondence to: Dr José M. Barrachina Díez, Department of Prosthodontics, School of Dentistry, Hugstetterstrasse 55, 79106, Freiburg, Germany. Email: jose.maria.barrachina.diez@uniklinik-freiburg.de

In addition to two-piece implants, there are other types of implants with a one-piece design. The term "one-piece implant" is often misunderstood in the literature. One-piece implants are generally considered to be implants where the bone-anchoring portion, the soft tissue traversing portion, and the prosthetic abutment are all in one piece.[14] However, one-piece implants are also defined as implants by which the anchorage unit and the contiguous transmucosal component are manufactured as one piece.[15] The definition is ambiguous, as two kinds of implants can have a transmucosal abutment as an integral part of the implant: one-part implants, where there is no gap between the implant body and the abutment, and two-part implants, which have a gap between the implant body and the abutment at the soft tissue level, located approximately 2 to 3 mm coronal to the alveolar crest.

The absence of a microgap between the implant and the prosthetic abutment at the level of the bone crest offers one-piece implants many clinical and technical advantages compared to two-piece implants. As demonstrated in an animal study by Hermann and coworkers, more crestal bone resorption will occur during healing when the microgap is located at or below the alveolar crest.[16] Approximately 2 mm of crestal bone is resorbed apical to the microgap following placement of implants with nonsubmerged healing or following abutment connection of implants with submerged healing.[16]

One-piece implants are generally placed in a nonsubmerged approach. This means that implant placement is performed in a single surgical procedure, with no need for surgical reopening. Compared with a two-stage procedure, the patient has more comfort due to the fewer number of surgeries and has a reduced healing period. From a prosthetic point of view, an implant shoulder at the level of the soft tissue offers many advantages, since it is easily accessible for prosthetic procedures such as impression taking and offers an excellent basis for cemented implant restorations.[17,18] Moreover, due to its design, one-piece implants have their transmucosal surface unaltered during all the prosthetic procedures, since abutment reconnection is avoided (one-piece, one-part implants) or it is performed at the supra- or marginal mucosa level (one-piece, two-part implants). This avoids trauma to the soft tissue, which could result in a more apical position of the connective tissue and be responsible for additional marginal bone resorption.[19,20]

Despite the multiple advantages from biologic, clinical, and technical points of view, there is no clear information regarding the long-term performance of this type of implant design.

This systematic review aims to evaluate the long-term clinical performance of one-piece implants. The review was divided into two papers. The first systematic review focused on the implant characteristics and the loading protocols. A second systematic review about one-piece implants focusing on the prosthetic characteristics and the technical and biologic complications will be presented in a separate paper.

MATERIALS AND METHODS

Search Strategy

An electronic search for clinical trials on one-piece implants from 1966 until June 2012 was performed using MEDLINE and PubMed with no language restriction. The search terminology included: "dental implant" [MeSH], "one-piece," "one-piece implant," "monotype implant," "conical implant," "monoblock implant," "longitudinal study [MeSH]," "non-submerged," "implant design," "esthetics," "microgap," "biologic width," "bone remodeling," "flapless," "one-stage," "single stage," and "peri-implantitis."

Hand-searching of the bibliographies of all full-text articles and related reviews, selected from the electronic search was also performed. References appraised in related systematic reviews were also considered. In addition, hand-searching was conducted in the following journals: *Clinical Implant Dentistry and Related Research*; *Clinical Oral Implants Research*; *European Journal of Implantology*; *Implant Dentistry*; *International Journal of Oral and Maxillofacial Implants*; *International Journal of Oral and Maxillofacial Surgery*; *International Journal of Periodontics & Restorative Dentistry*; *International Journal of Prosthodontics*; *Journal of Clinical Periodontology*; *Journal of Dental Research*; *Journal of Oral Rehabilitation*; *Journal of Periodontology*; *Journal of Prosthetic Dentistry*; *Journal of Prosthodontics*; *Journal of Oral Surgery*; *Oral Medicine*, *Oral Pathology*; and *Quintessence International*.

Selection of Studies

Titles and abstracts were initially screened by three independent reviewers (JB, ET, WA) for possible inclusion in the review. Full-text analysis of selected studies was performed against the inclusion criteria. Disagreement regarding data extraction was resolved by discussion. The search strategy of this literature review is presented in Fig 1.

Inclusion Criteria

- Randomized controlled clinical trials, prospective cohort studies.
- An inception cohort where more than 80% of the enrolled patients remained in the study at the 5- or 10-year observation point.

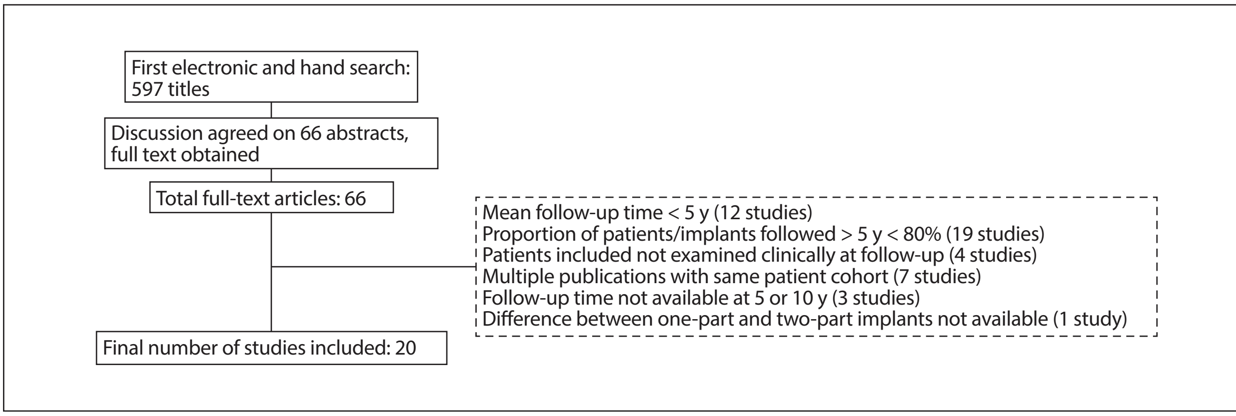


Fig 1 Search strategy.

Exclusion Criteria

- Retrospective cohort studies, case reports, case studies.
- Animal studies.
- Laboratory studies.
- The patients included were not examined clinically at follow-up.
- Multiple reports on the same cohort with the same observation period. In case of papers with the same patient base within the same time frame, the authors included the paper that was most relevant to the purposes of the systematic review.
- Studies with different implant systems or implant types and no clear distinction made between them.
- Prospective studies reporting life-tables were analyzed with respect to the proportion of patients/implants that were followed > 50 years. Publications were excluded if less than 80% of the initial subject sample was examined at 5 or 10 years or if breakdown of data corresponding to 5 or 10 years of observation could not be achieved.

A list of excluded studies and the reason for exclusion (Appendix 1) is available in the online version of this article at www.quintpub.com/journals.

Data Extraction

The studies were first divided into two groups according to their observation period: 5-year follow-up and 10-year follow-up. Information on the study type, year of publication, implant system, number of patients included in the study, age range and mean age of the patients, setting of the implant placement (university, private practice), and dropout rate of patients was retrieved from all included studies. In studies where one-piece implants were compared to other implant systems, only one-piece implants were considered for the analysis.

The studies were also classified following the implant characteristics and loading protocols in 5- and 10-year follow-up groups. Thus, a second table was developed including the number of one-piece implants at the beginning of the study, the number of one-piece implants that survived after 5 or 10 years, the number of dropout implants, the number of failed implants, the implant location and the implant length and diameter. The type of implant surface was also extracted from the included studies. Only two types of implant surfaces were found in one-piece implants: TPS (titanium plasma-sprayed) and SLA (sandblasted, large grit, acid-etched) surfaces. With regards to the type of edentulism, studies were divided into complete, partial, or single-tooth edentulism. Concerning the loading protocol, studies were classified into immediate (dental implants connected to the prosthesis within 1 week subsequent to implant placement), early (dental implants connected to the prosthesis between 1 week and 2 months subsequent to implant placement), or conventional loading (dental implants not connected to prosthesis and allowed a healing period of more than 2 months after implant placement). This classification followed the recommendation of the Cochrane Report by Esposito and coworkers and the 4th ITI Consensus Conference.[21]

Quantitative Data Synthesis (Statistical Analysis)

The meta-analysis was conducted using the "meta" package of the software R (version 2.15.0, R Project).

Implant survival rates were calculated by dividing the number of survived implants after 5 or 10 years by the total number of implants at the beginning of the study. In cases where the observation period was not completed due to reasons such as death of the patient, change of address, refusal to participate, nonresponse, chronic illnesses, etc, the number of implants dropped out was completely removed from the total analysis. The studies comparing different loading protocols, different implant surfaces, or with different type of reconstructions (eg, overdentures, single crowns) were split up to reduce the heterogeneity in the meta-analysis.

The population, intervention, comparisons, outcomes (PICO) format was used to define focused clinical questions with clear inclusion criteria.[41] The question to be answered was: Is there a difference in the implant survival rate at 5 and 10 years between one-part and two-part, one-piece implants?

The PICO criteria were as follows:

- Population or participants: Patients treated with one-piece implants
- Intervention: One-piece, one-part implants followed up after 5 and 10 years
- Comparison: One-piece, two-part implants followed up after 5 and 10 years
- Outcome: Implant survival

To answer research questions regarding the systematic literature search, forest plots for illustrating results were applied (Figs 2 to 7). Since considerable heterogeneity between studies could be partially detected, random effects models were applied instead of fixed models to detect statistically significant differences in implant survival rates between several defined groups (eg, different loading protocols). These models are used to approximate pooled estimates for specific groups of estimates found in literature. Therefore, the inverse variance method (Freeman-Tukey double arcsine transformation) was generally applied. In studies where the number of participants was less than 10, the arcsine transformation was applied instead. To quantify heterogeneity, the Q statistic and the corresponding *P* value were calculated. A *P* value less than .05 indicated a statistically significant heterogeneity.

RESULTS

Included Studies

A total of 597 studies were identified in the literature, of which 66 were selected for full-text screening. Forty-six studies were excluded; 12 studies had a mean follow-up period of less than 5 years.[42–53] In 19 studies, the dropout rate of patients or implants was above 20% after 5 or 10 years.[17,54–70] In 4 studies, the patients were not examined clinically at follow-up.[71–74] Seven studies had the same patient cohort already reported in another previously included publication.[75–81] In 3 studies, the follow-up time was not available at the 5- or 10-year interval,[82–84] 1 study did not differentiate between one-part and two-part one-piece implants.[85] The hand search did not provide any additional publications. A total of 20 studies met the inclusion criteria and were included in the meta-analysis (Fig 1).

All studies were published between 1995 and 2011. Four studies were randomized controlled trials (RCTs) and the 16 remaining were prospective cohort studies. The vast majority of one-piece implants reported were two-part. The studies included a total of 1,450 patients between 15 and 91 years of age. The majority of studies were mainly conducted in an institutional environment, such as a university. The dropout rate for patients varied between 0% and 20% (if dropout was greater than 20% the study was excluded from the review). Two studies did not report the dropout rate of patients (Table 1).

The studies were also classified following the implant characteristics and loading protocols at 5- and 10-year follow-up. The studies included a total of 3,556 one-piece implants, of which 3,338 were two-part implants and 218 were one-part implants. The majority of the implants were placed in native bone. Three studies included implants placed in grafted sites.[23,31,35] A first meta-analysis comparing the studies with implants placed in native bone and those placed in augmented bone showed no statistical differences between groups. Therefore, the three studies reporting implants placed in augmented bone were included in the meta-analysis for the other variables, such as implant surface, loading protocol, and implant location. Regarding the implant surface, only two different surfaces could be found in studies on one-piece implants: TPS and SLA. Most of the studies reported one-piece implants with a TPS surface, whereas two studies compared one-piece implants with TPS and SLA implant surfaces.[23,25] As far as loading protocols are concerned, the majority of studies reported a delayed loading protocol. Two studies compared delayed and early protocols,[24,25] and only three studies reported an immediate loading protocol.[27,29,36] Finally, the majority of studies did not differentiate between one-piece implants placed in the maxilla and those placed in the mandible. Seven studies with a 5-year follow-up and one study with a 10-year follow-up reported one-piece implants placed exclusively in the mandible. On the other hand, only three studies with a 5-year follow-up reported one-piece implants placed in the maxilla (Table 2).

Meta-analysis

Implant Survival Rate of One-Piece Implants: One-Part vs Two-Part. The meta-analysis of the 20 studies included (1 study on one-piece one-part implants and 19 studies on one-piece two-part implants) showed an implant survival rate for one-piece one-part implants of 96.79% (95% CI: 94.04% to 98.71%) after 5 years. In one-piece two-part implants, the survival rate after 5 years

Table 1 Study and Patient Characteristics

Study	Study design	Implant system	Type of one-piece implant	No. of patients included	Age range	Mean age	Setting	Dropouts (%)
5-year follow-up								
Gallucci et al 2009[22]	Prospective	ITI ss, hs	Two-part	45	34–78	59.5	University	0
Bornstein et al 2008[23]	Prospective	ITI	Two-part	56	19–74	53.86	University	10.7
Fischer et al 2008[24]	RCT	ITI ss	Two-part	24	NR	64	University/ private practice	4.2
Roccuzzo et al 2008[25]	RCT	ITI	Two-part	32	26–59	NR	University	15.6
Heijdenrijk et al 2006[18]	RCT	Not specified	Two-part	20	NR	58	University	6.7
Bornstein et al 2005[26]	Prospective	ITI ss	Two-part	51	NR	NR	University	NR
Mau et al 2003[27]	RCT	ITI	Two-part	174	30–82	60.3	Private practice	1.1
Chiapasco and Gatti 2003[28]	Prospective	ITI	Two-part	82	42–87	58.6	University	9.8
Andersen et al 2002[29]	Prospective	ITI	Two-part	8	17–28	21	University	0
Behneke et al 2002[30]	Prospective	ITI ss	Two-part	100	42–86	62.2	University	17
Buser et al 2002[31]	Prospective	ITI	Two-part	40	NR	NR	University	7.6
Hellem et al 2001[32]	Prospective	ITI hs	Two-part	46	40–70	57.7	University	6.5
Behneke et al 2000[33]	Prospective	ITI ss	Two-part	55	17–81	44.2	University	14
Weber et al 2000[34]	Prospective	ITI hs, hc	Two-part	46	NR	NR	University	13
Buser et al 1997[35]	Prospective	ITI ss, hs, hc, rds	Two-part	269	15–91	52	University	6.3
Wismeyer et al 1995[36]	Prospective	ITI	One-part	64	NR	53.6	University	0
10-year follow-up								
Roccuzzo et al 2012[37]	Prospective	ITI	Two-part	112	NR	45	Private practice	12.5
Meijer et al 2009[38]	Prospective	ITI ss	Two-part	30	38–74	52.8	University	13.3
Blanes et al 2007[39]	Prospective	ITI ss, hc, ss, rds	Two-part	109	32.6–80.2	60.6	University	19.2
Karoussis et al 2003[40]	Prospective	ITI hs	Two-part	53	NR	NR	University	NR

NR = not reported; RCT = randomized controlled trial; ss = solid screw; hs = hollow screw; hc = holow cylinder; rds = reduced-diameter, solid screw.

was slightly higher: 98.16% (95% CI: 96.48% to 99.31%). This difference, however, was not statistically significant (P = .3073, random effects model) (Figs 2a and 2b).

After 10 years, the implant survival rate for the five one-piece, two-part implant studies was of 96.83% (95% CI: 93.12% to 99.24%). However, no comparison could be made with one-piece, one-part implants as no 10-year follow-up studies were available for this type of design (Figs 2a and 2b).

Comparison of Implant Surfaces: TPS vs SLA. No statistical difference was found between one-piece implants with TPS implant surfaces and those with SLA

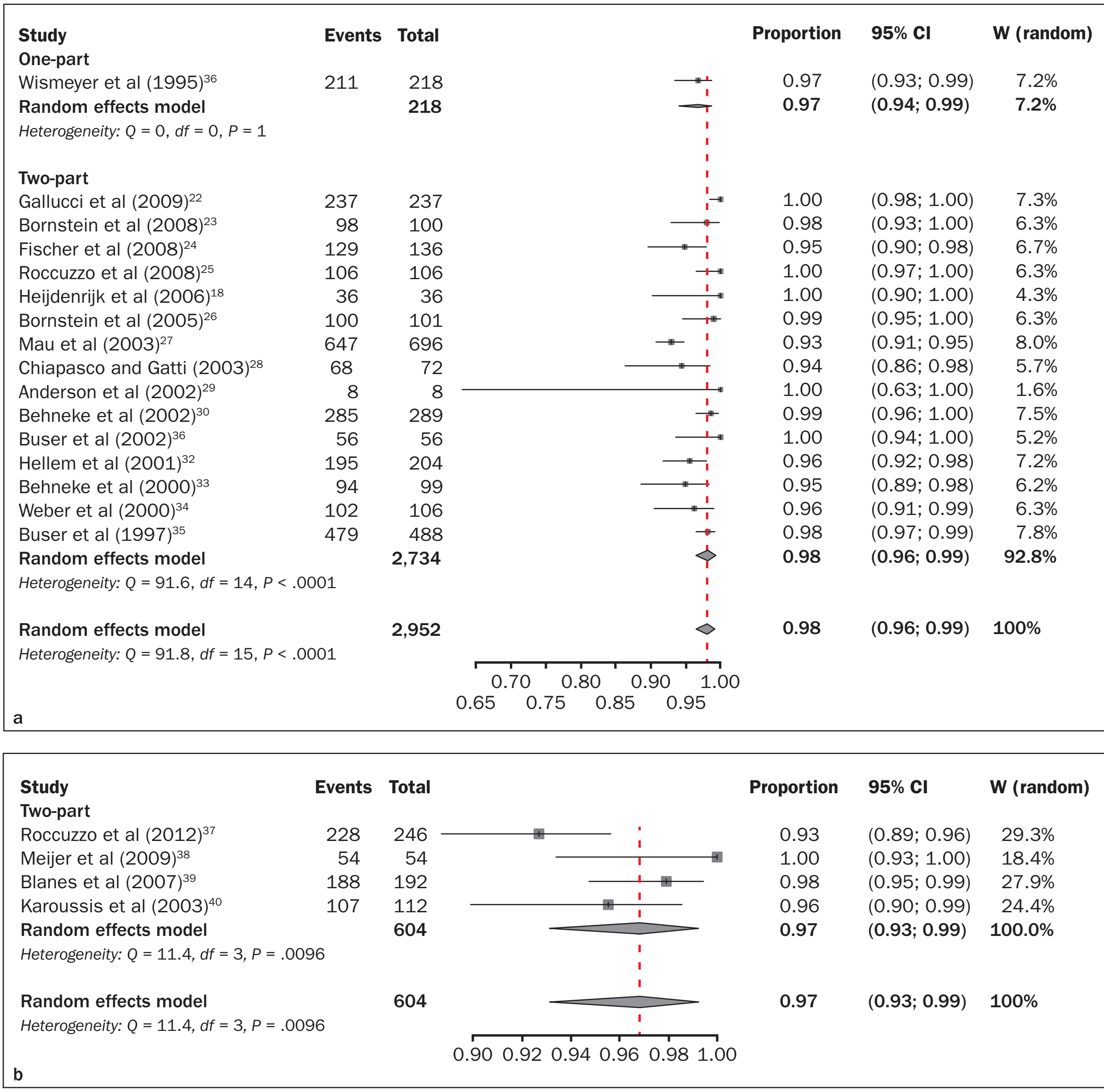
Table 2 Implant Characteristics and Loading Protocols

Study	Baseline	Dropouts	Failures	Remaining	Length (mm)	Diameter (mm)	Surface	Type of edentulism	Implant location	Loading protocol
5-year follow-up										
Gallucci et al 2009[22]	237	0	0	237	8–16	NR	TPS	Complete	Mandible	Delayed
Bornstein et al 2008[23]	111	11	2	98	6–12	4.1, 4.8	TPS/SLA	Partial	Maxilla	Delayed
Fischer et al 2008[24]	142	6	7	129	8–12	4.1	SLA	Complete	Maxilla	Early/ delayed
Roccuzzo et al 2008[25]	127	11	0	106	NR	NR	TPS/SLA	Partial	Maxilla/ mandible	Early/ delayed
Heijdenrijk et al 2006[18]	40	4	0	36	NR	4.1	TPS	Complete	Mandible	Delayed
Bornstein et al 2005[26]	104	3	1	100	8–12	4.1, 4.8	SLA	Partial	Maxilla/ mandible	Early
Mau et al 2003[27]	704	8	49	647	14	3.5	TPS	Complete	Mandible	Immedi-ate
Chiapasco and Gatti 2003[28]	84	12	4	68	> 9	3.3–4.8	TPS	Complete	Mandible	Immedi-ate
Andersen et al 2002[29]	8	0	0	8	12, 14	3.3, 4.1	TPS	Single-tooth	Maxilla	Immedi-ate
Behneke et al 2002[30]	340	51	4	285	8–16	3.3, 4.1	TPS	Complete	Mandible	Delayed
Buser et al 2002[31]	61	5	0	56	NR	NR	TPS	Partial	Maxilla/ mandible	Delayed
Hellem et al 2001[32]	216	12	9	195	NR	NR	TPS	Complete	Mandible	Delayed
Behneke et al 2000[33]	114	15	5	94	8–12	3.3, 4.1	TPS	Partial	Maxilla/ mandible	Delayed
Weber et al 2000[34]	112	6	4	102	NR	NR	TPS	Partial	Maxilla/ mandible	Delayed
Buser et al 1997[35]	536	48	9	479	NR	NR	TPS	Complete/ partial	Maxilla/ mandible	Delayed
Wismeyer et al 1995[36]	218	NR	7	211	8–16	4	TPS	Complete	Mandible	Immedi-ate
10-year follow-up										
Roccuzzo et al 2012[37]	246	NR	18	228	8–12	3.3, 4.1, 4.8	TPS	Partial	Maxilla/ mandible	Delayed
Meijer et al 2009[38]	60	6	0	54	NR	4.1	TPS	Complete	Mandible	Delayed
Blanes et al 2007[39]	247	44	4	188	6–12	NR	TPS	Partial	Maxilla/ mandible	Delayed
Karoussis et al 2003[40]	112	NR	5	107	NR	NR	TPS	Partial	Maxilla/ mandible	Delayed

NR = not reported; TPS = titanium plasma sprayed; SLA = sandblasted, large grit, acid-etched.

implant surfaces in 5-year follow-up studies ($P = .3849$). One-piece implants with SLA surfaces showed a survival rate of 99.23% (95% CI: 95.99% to 99.94%) compared to 97.94% (95% CI: 96.07% to 99.22%) in implants with TPS surfaces (Figs 3a and 3b).

After 10 years, only studies on TPS implant surfaces could be found. The implant survival rate for one-piece implants with TPS surfaces after 10 years was of 97.18% (95% CI: 93.01% to 99.51%) (Figs 3a and 3b).

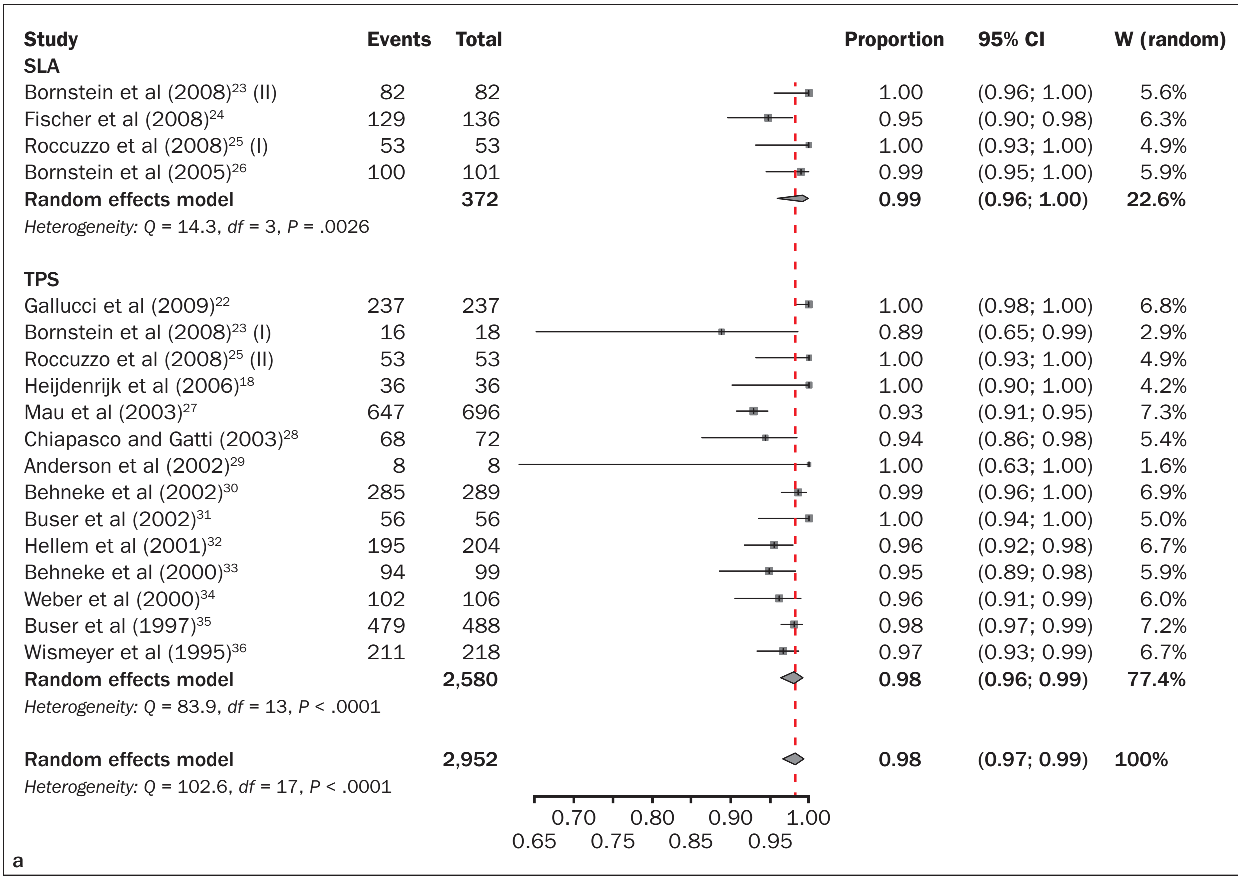


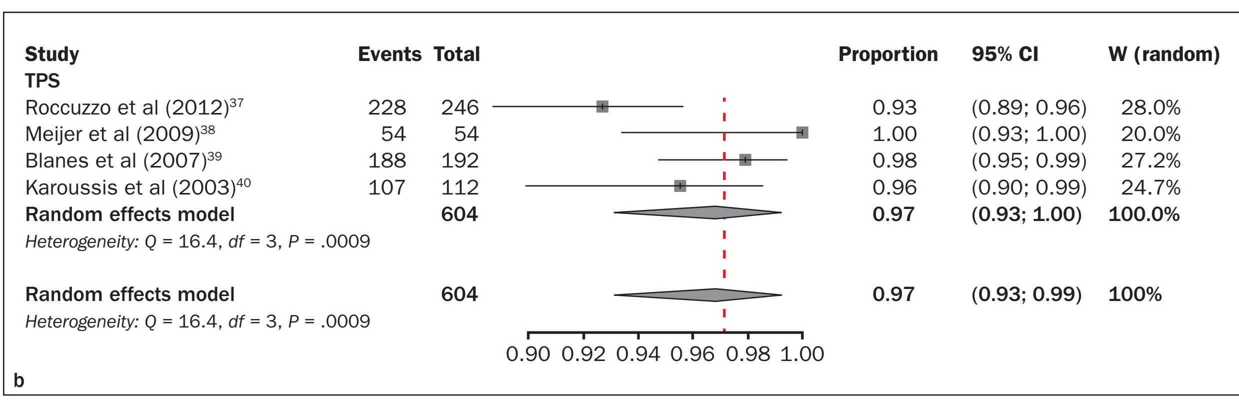
Figs 2a and 2b Implant survival rates of one-piece, one-part and two-part implants after *(a)* 5 and *(b)* 10 years. Q statistic = measure of heterogeneity; df = degrees of freedom.

Comparison of Loading Protocols: Immediate vs Early vs Delayed. Excellent results were obtained with all types of loading protocols after 5 years in function. With immediate loading, one-piece implants obtained a survival rate of 95.07% (95% CI: 91.82% to 97.54%); in early loading protocols, 98.66% (95% CI: 94.27% to 99.99%); whereas in delayed loading protocol, the survival rate obtained was of 98.58% (95% CI: 97.13% to 99.53%). The immediate loading protocol had a statistically lower survival rate compared to the delayed loading protocol ($P = .0143$) (Figs 4a and 4b).

After 10 years, only four studies with delayed loading protocols could be included. The implant survival rate for these studies was of 97.18% (95% CI: 93.01% to 99.51%). No 10-year follow-up studies with early or immediate loading protocol could be located (Figs 4a and 4b).

Comparison of Type of Edentulism: Complete vs Partial/Single-Tooth. The implant survival rates of one-piece implants placed in completely edentulous patients and those placed in partially edentulous patients, including single-tooth, were statistically not

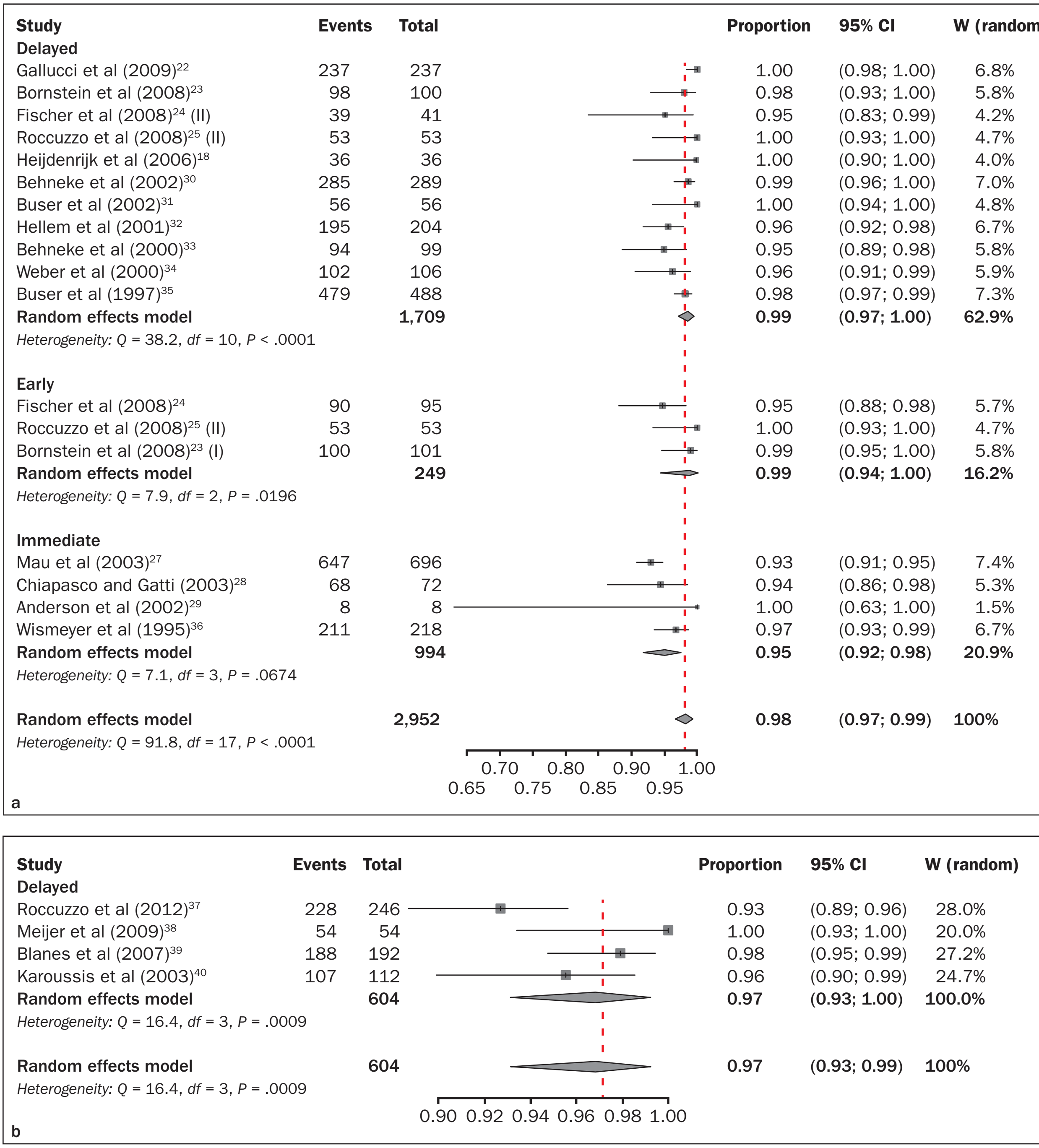




Figs 3a and 3b Comparison of implant survival rates in one-piece implants according to the implant surface after *(a)* 5 and *(b)* 10 years: TPS vs SLA. Bornstein[23] and Rocuzzo[25] compared different loading protocols, different implant surfaces, or different types of reconstructions, and therefore were split up (I, II) in order to reduce the heterogeneity in the meta-analysis. Q statistic = measure of heterogeneity; df = degrees of freedom.

significant (*P* = .3319). After 5 years, one-piece implants placed in completely edentulous patients had an implant survival rate of 97.42% (95% CI: 94.57% to 99.24%), whereas those placed in partially edentulous patients obtained an implant survival rate of 98.80% (95% CI: 96.71% to 99.86%) (Figs 5a and 5b).

Only one study with a 10-year follow-up could be found on completely edentulous patients, which reported an implant survival rate of 100% (95% CI: 96.84% to 100%). Three studies were included on partially edentulous patients, which obtained an implant survival rate of 95.57% (95% CI: 91.70% to 98.32%).



Figs 4a and 4b Comparison of implant survival rates in one-piece implants depending on loading protocol after *(a)* 5 and *(b)* 10 years: Immediate vs early vs conventional. Bornstein,[23] Fischer,[24] and Rocuzzo[25] compared different loading protocols, different implant surfaces, or different types of reconstructions, and therefore were split up (I, II) in order to reduce the heterogeneity in the meta-analysis. Q statistic = measure of heterogeneity; df = degrees of freedom.

However, these differences in survival rates were statistically not significant (*P* = .0548) (Figs 5a and 5b).

Comparison of Implant Location: Maxilla vs Mandible. The implant survival rate at 5 years for one-piece implants placed in the maxilla was very similar (96.85% [95% CI: 93.27% to 99.11%]) to that for the mandible (97.73% [95% CI: 94.62% to 99.11%]). There were no statistical differences between the maxilla and mandible (*P* = .6483). No studies could be found on one-piece implants placed in the maxilla after a 10-year follow-up (Figs 6a and 6b).

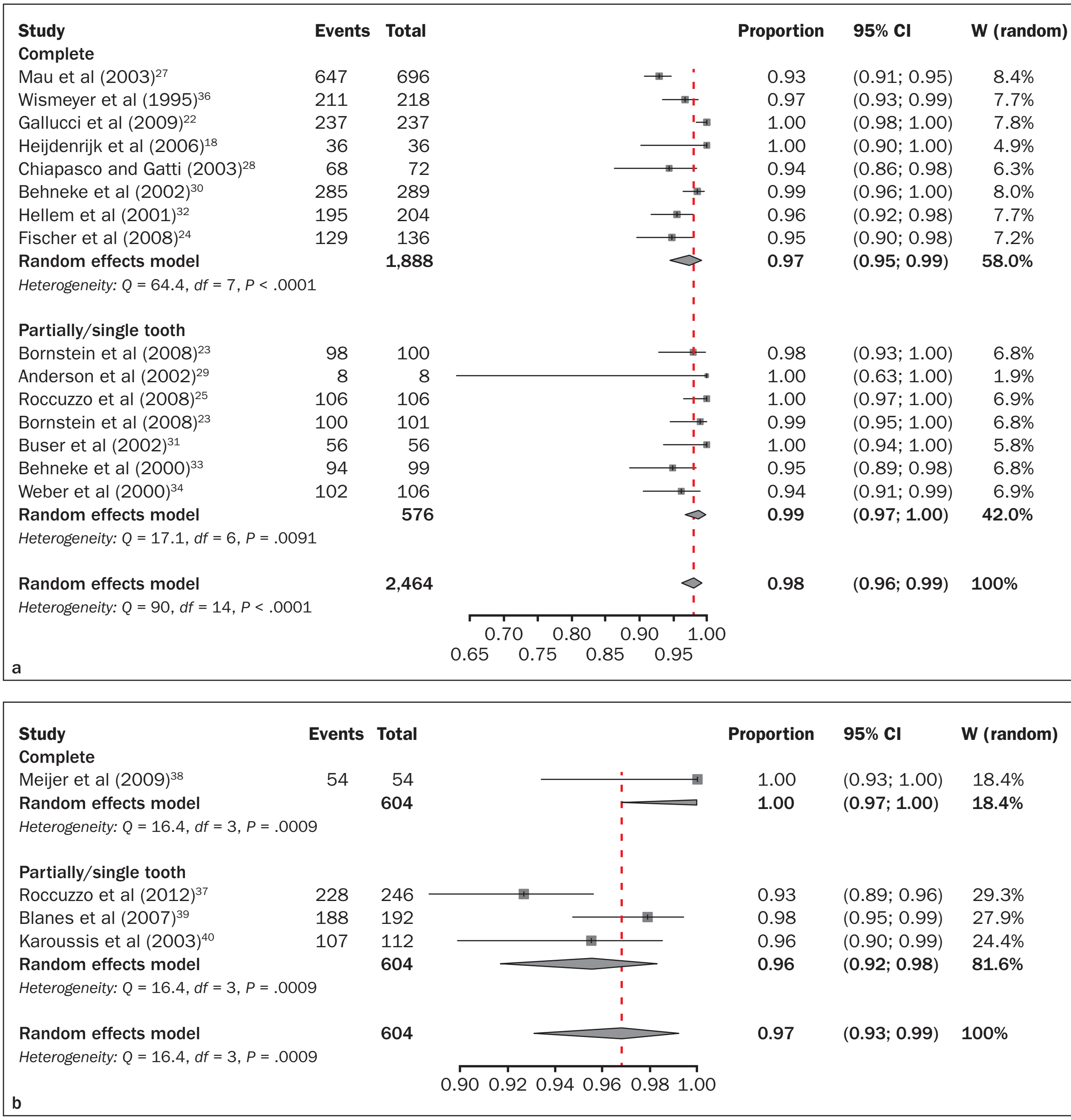
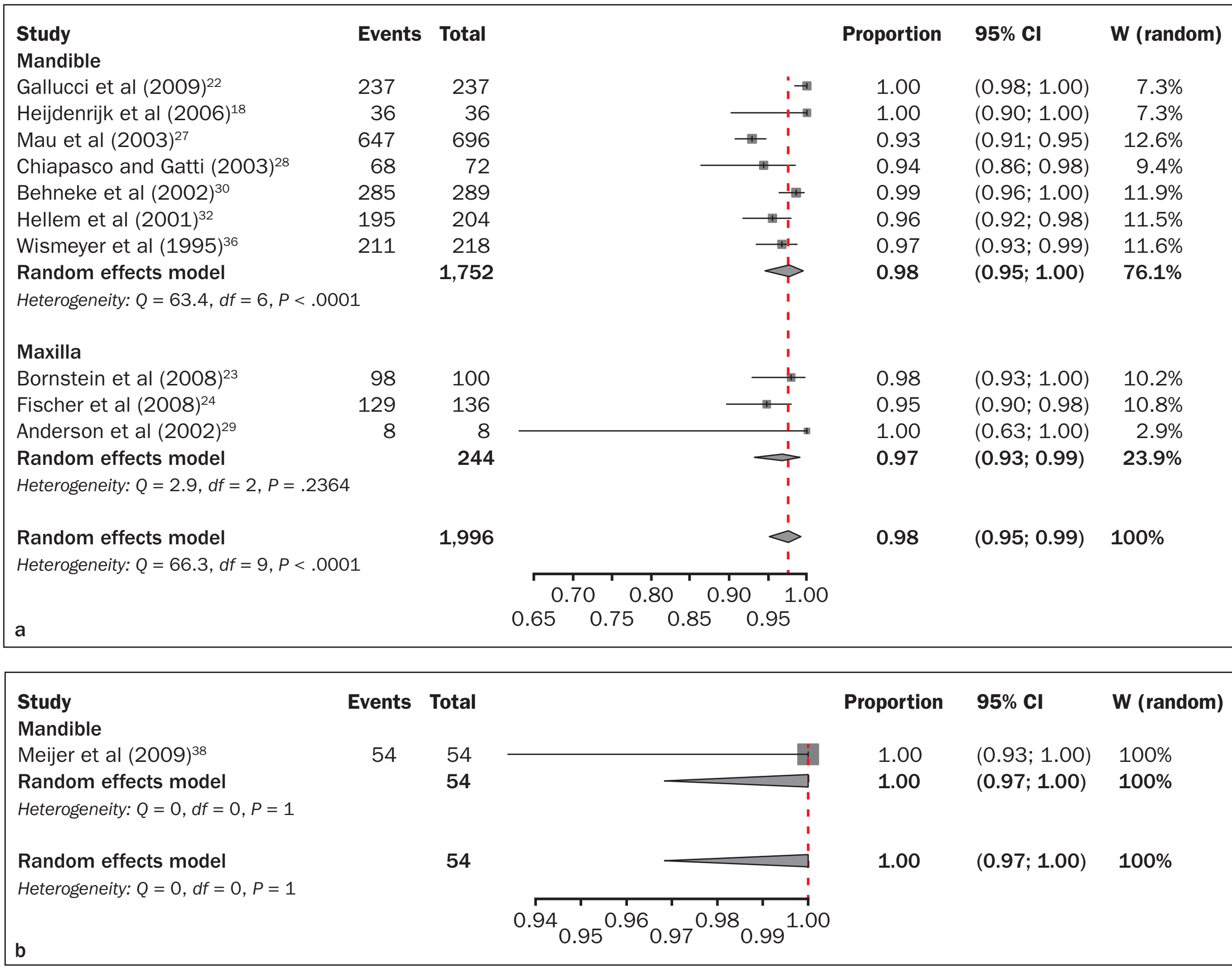


Fig 5a and 5b Comparison of implant survival rates in one-piece implants according to the type of edentulism after *(a)* 5 and *(b)* 10 years: Complete vs partial/single-tooth. Q statistic = measure of heterogeneity; df = degrees of freedom.

Comparison of Setting: Private Practice vs University. One-piece implants placed in university settings obtained a higher survival rate at 5 years (98.51% [95% CI: 97.26% to 99.39%]) compared with implants placed in private practice (92.96% [95% CI: 90.94% to 94.74%]). After 10 years, the implant survival rate for one-piece implants placed at universities [98.01% (95% CI: 95.19% to 99.72%)] was still higher compared to those placed in private practice (92.68% [95% CI: 89.06% to 95.64%]). These differences were statistically significant both at 5 and 10 years ($P < .0001$ and $P = .0157$, respectively), although only two studies were found regarding a private practice setting (Figs 7a and 7b).



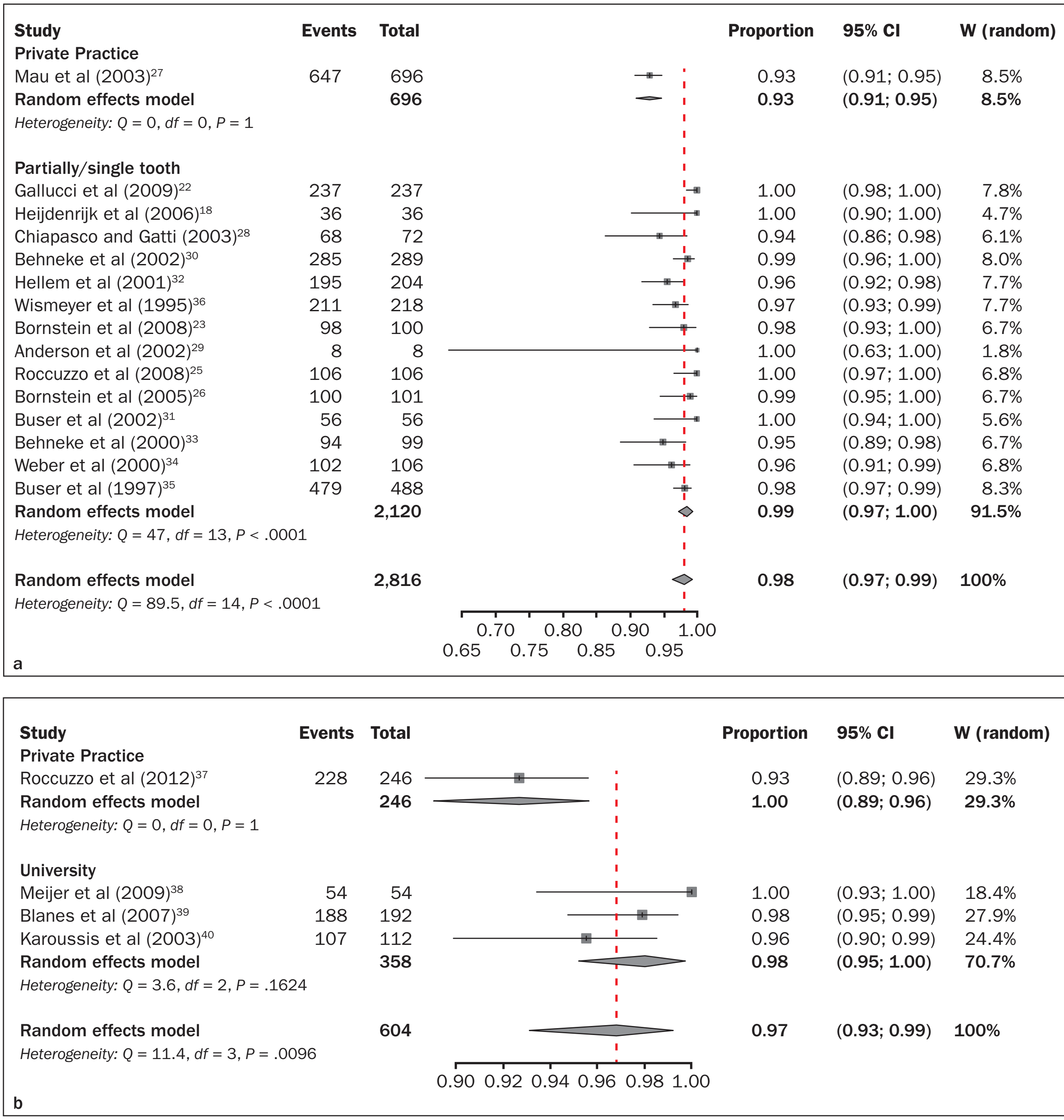
Figs 6a and 6b Comparison of implant survival rates in one-piece implants according to the implant location after *(a)* 5 and *(b)* 10 years: Maxilla vs mandible. Q statistic = measure of heterogeneity; df = degrees of freedom.

DISCUSSION

This systematic review and meta-analysis demonstrates excellent implant survival rates for one-piece implants in long-term clinical performance. Implant survival rates of 96.79% could be observed for one-piece, one-part implants after a 5-year follow-up, whereas for one-piece, two-part implants, the implant survival rates observed after 5 and 10 years were 98.16% and 96.83%, respectively. These results are comparable with other systematic reviews reporting implant survival rates for one-piece and two-piece implants after 5- and 10-year follow-up.[86–88]

Is implant survival rate a valid criterion to evaluate the long-term performance of implants? The term "implant survival" is defined as an implant remaining "in situ" with or without modifications. Albrektsson and Zarb suggested that each and every implant should be evaluated as part of a four-grade scale representing success, survival, unaccounted for, and failure.[89] The studies in the present review included implants that failed before and after loading, dropouts, and surviving implants. Comparison with respect to success rates is more difficult because of the wide variety of study protocols. Most studies agreed that the individual implant can be designated as successful if there is absence of pain, inflammation, mobility, and peri-implant radiolucency. Others, however, recommend an extended success analysis with predefined thresholds for bone level changes and clinical parameters. These differing success criteria[35,40,90–92] compromise comparisons between studies. For this reason, success rates were not included in the present review.

Apart from the heterogeneity in success criteria, many other factors impede a proper comparison of the data between studies. The constant evolution in



Figs 7a and 7b Comparison of implant survival rates in one-piece implants depending on the setting after *(a)* 5 and *(b)* 10 years: Private practice vs university. Q statistic = measure of heterogeneity; df = degrees of freedom.

materials and techniques could be partially responsible for this phenomenon. For instance, the present review included two different implant surfaces: TPS (titanium plasma-sprayed) and SLA (sandblasted, large grit, acid-etched) surfaces. According to the manufacturer, implants with an SLA surface have an improved osseointegration compared to the TPS surface, with a significantly increased bone-to-implant contact.[93] Furthermore, they can reduce the healing period to only 6 weeks after implant placement compared to 12 weeks in implants with a TPS surface.[93] However, the present review demonstrated no statistical difference in the implant survival rate between both implant surfaces after 5 years.

No statistical differences were observed in the implant survival rates between one-piece implants placed in completely edentulous patients and those placed in partially edentulous patients, including single-tooth edentulism. Furthermore, no differences could be found between one-piece implants placed in the maxilla compared to those placed in the mandible. There is a general trend in the literature for better results in favor of the mandible,[34,35,94] although some studies have also documented equal or better results for maxillary implants compared to mandibular implants.[95,96] The results of the present meta-analysis showed slightly better implant survival rates for one-piece implants placed in the edentulous mandible compared to those placed in edentulous maxilla. These results must be interpreted with caution, as only one study could be included with a long-term follow-up for one-piece implants placed in edentulous maxillae.[24]

With regard to the loading protocol, this systematic review included three types of loading protocols: immediate, early, and conventional. Immediate loading obtained the lowest implant survival rates, with a significant statistical difference compared to the delayed loading protocol on long-term performance. This is in accordance with other systematic reviews focusing exclusively on loading protocols.[97,98] Due to the low number of well-documented studies in the literature with a long-term follow-up, the present review could not analyze separately the loading protocol for edentulous or partially edentulous maxillae and mandibles with removable or fixed prosthetic designs.

The studies were mainly conducted in an institutional environment, such as universities or specialized implant clinics. Only two studies were performed exclusively in a private practice and obtained a statistically significantly lower implant survival rate compared to implants placed at university or by experienced practitioners. The initial learning curve of the operator and an extended patient selection criteria could be responsible for the lower implant survival rates.[28]

The excellent implant survival rates observed for one-piece implants in the present systematic review should be interpreted with caution. On the one hand, great heterogeneity was detected between the included studies, which led the authors to employ a random effects model instead of a fixed effects model. Heterogeneity in the assessment of marginal bone loss or other clinical parameters among the studies resulted in implant survival being the only outcome measure considered in this review. On the other hand, the great majority of the included studies presented strict patient selection criteria. Without strict patient selection criteria, the survival rates reported in the present review would not have been achieved. Increased failure rates have to be expected in patients exhibiting risk factors such as systemic diseases causing wound healing problems, heavy smoking, increased periodontal susceptibility, and anatomical factors such as poor bone density or extreme atrophy.[99]

Another limitation of this review was that due to the great heterogeneity between studies, no difference was identified in the meta-analysis between hollow screws, hollow cylinders, and solid screws. Compared to hollow-body implants, solid screws offer advantages with regard to fracture resistance and accessibility for peri-implantitis therapy and have replaced them in the market.[33] However, hollow-body implants have shown excellent results after long-term evaluation,[100] and many studies included in the review yielded no difference between solid-screw and hollow-body implants.[17,22,34,35,67,68,78] To provide more information about the outcome of different variables associated with one-piece implants, further randomized clinical trials are needed. Moreover, standardized success criteria should be established to properly compare studies.

CONCLUSIONS

Within the limits of this systematic review, it can be concluded that high long-term survival rates can be observed with one-piece implants both of one-part and two-part design. No differences were found between different loading protocols, different implant surfaces, or between completely and partially edentulous patients.

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The authors have no conflicts of interest to declare.

Appendix 1 is included in the online version of this article which is available at www.quintpub.com/journals.

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Appendix 1 List of excluded studies and the reason for exclusion

Mean follow up time < 5 years	
Oliva et al 2010[42]	
Bischof et al 2006[43]	
Parel et al 2005[44]	
Nedir et al 2004[45]	
Levine et al 2002[47]	
Mericske-Stern 2002[46]	
Gatti et al 2000[48]	
Moberg et al 1999[49]	
Ellegaard et al 1997[50]	
ten Bruggenkate et al 1990[51]	
d'Hoedt et al 1989[52]	
Babbush et al 1986[53]	
Patients included not examined clinically at follow-up	
Pjetursson et al 2005[71]	
Timmerman et al 2004[72]	
Bragger et al 1998[73]	
Spiekermann et al 1995[74]	
Multiple publications with same patient cohort	
Roccuzzo et al 2010[80]	
Blanes et al 2007[78]	
Stoker et al 2007[75]	
Bragger et al 2005[81]	
Karoussis et al 2004a[76]	
Karoussis et al 2004b[77]	
Meijer et al 2004[79]	
Proportion of patients/implants followed > 5/10 y < 80%	
Fischer et al 2012[56]	
Fischer et al 2011[57]	
Cochran et al 2011[58]	
Cochran et al 2009[59]	
Jung et al 2008[54]	
Kim et al 2008[60]	
Cochran et al 2007[61]	
Telleman et al 2006[62]	
Bianchi et al 2004[66]	
Fugazzotto et al 2004a[64]	
Fugazzotto et al 2004b[65]	
Hartman et al 2004[63]	
Ferrigno et al 2002[95]	
Romeo et al 2002[67]	
Brocard et al 2000[68]	
Buser et al 1999[17]	
ten Bruggenkate et al 1998[69]	
Leimola-Virtanen et al 1995[55]	
Mericske-Stern et al 1993[70]	
Follow-up time not available at 5/10 y	
Romeo et al 2006[82]	
Ledermann 1984[83]	
Forster 1984[84]	
Difference between one-part/two-part not available	
Mericske-Stern et al 1994[85]	