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Review Article

A systematic review of the prognosis of short (< 10 mm) dental implants placed in the partially edentulous patient

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Abstract

Aim: This study evaluated, through a systematic review of the literature, the estimated implant survival rate of short (< 10 mm) dental implants installed in partially edentulous patients.

Materials and methods: A systematic search was conducted in the electronic databases of MEDLINE (1980–October 2009) and EMBASE (1980–October 2009) to identify eligible studies. Two reviewers independently assessed the methodological quality of the articles using specific study design-related quality assessment forms.

Results: Twenty-nine methodologically acceptable studies were selected. A total of 2611 short implants (lengths 5–9.5 mm) were analysed. An increase in implant length was associated with an increase in implant survival (from 93.1% to 98.6%). Heterogeneity between studies was explored by subgroup analyses. The cumulative estimated failure rate of studies performed in the maxilla was 0.010 implants/year, compared with 0.003 found in the studies in the mandible. For studies that also included smokers, the failure rate was 0.008 compared with 0.004 found in studies that excluded smokers. Surface topography and augmentation procedure were not sources of heterogeneity.

Conclusion: There is fair evidence that short (< 10 mm) implants can be placed successfully in the partially edentulous patient, although with a tendency towards an increasing survival rate per implant length, and the prognosis may be better in the mandible of non smoking patients.

Key words: bone augmentation; dental implants; implant length; implant survival; partially edentulous; posterior zone; short implants; smoking; surface topography; systematic review

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Short implants are increasingly used for the prosthetic solution of the extremely resorbed posterior zone of partially edentulous patients. However, there is no consensus in the literature on the definition of a short implant. Some authors consider 10 mm the minimal length for predictable success; thus, they consider any implant < 10 mm in length as short (Morand & Irinakis 2007). Others defined an implant length of 10 mm also as a short implant (Das Neves et al. 2006). Because an implant can be placed at different levels, a short implant has also been defined as an implant with a designed intra-bony length of 8 mm or less (Renouard & Nisand 2006).

Several authors have provided an overview of the literature of short implants in a narrative or a structured review. Hagi et al. (2004) showed that, when applying 6 and 7 mm implants, short implants with a press-fit shape and a sintered porous surface geometry revealed the best performance. Das Neves et al. (2006) analysed the treatment outcome of longitudinal studies using Brånemark and compatible implants of 7, 8.5 and 10 mm implants and concluded that short implants should be considered as an alternative treatment to advanced bone augmentation surgeries. Renouard and Nisand (2006) performed a structured review

Conflicts of interest and source of funding statement

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of the impact of implant length and diameter on survival rates in fully and partially edentulous patients and their review demonstrated a trend towards an increased failure rate with short- and wide-diameter implants. Two recent reviews have been published in which short implants were compared with conventional implants. Kotsovilis et al. (2009) concluded from their systematic review that the placement of short ($\leqslant 8$ mm or < 10 mm) rough-surface implants is not a less efficacious treatment modality compared with the placement of conventional ($\geqslant 10$ mm) rough-surface implants. Romeo et al. (2010) concluded that the recent literature has demonstrated a similar survival rate for short and standard implants. But some important confounders need to be studied in future studies as they might be a key factor for the success in the use of short implants.

In the past, short implants have been associated with lower survival rates (Lee et al. 2005, Romeo et al. 2010). There are several presumed reasons for the lower survival rate of short implants in the posterior maxilla or mandible. Firstly, compared with longer implants with a comparable diameter, there is less bone to implant contact when short implants are used, simply because there is less implant surface. Secondly, short implants are mostly placed in the posterior zone, where the quality of the alveolar bone is relatively poor, especially in the maxilla (type III or IV, Lekholm & Zarb 1985). Thirdly, often, a very outsized crown has to be made to reach occlusion, because of the extensive resorption in the posterior region, which causes a higher ($<1->2$) crown to implant ratio. Crown to implant ratios between 0.5 and 1 were proposed to prevent peri-implant bone stress, crestal bone loss and eventually implant failure (Haas et al. 1995, Rangert et al. 1997, Glantz & Nilner 1998). But the most recent systematic review on two studies on crown to implant ratios concluded that the ratio does not influence the peri-implant crestal bone loss (Blanes 2009).

To avoid the use of short implants, the extremely resorbed bone can be augmented using a bone-grafting technique. This modification in the patient's anatomy makes it possible to insert a longer implant, but an extra surgical intervention also leads to greater patient morbidity, higher costs and a longer treatment period. Esposito et al. (2010) concluded, from their systematic review on augmentation procedures of the maxillary sinus, that ''Short implants (5–8 mm) may be as effective and cause fewer complications than longer implants placed using a more complex technique.'' And from their systematic review on horizontal and vertical bone augmentation techniques for dental implant treatment, Esposito et al. (2009) concluded that ''Short implants appear to be a better alternative to vertical bone grafting of resorbed mandibles. Complications, especially for vertical augmentation, are common''.

New developments of the different implant systems, especially regarding the surface micro-topography and chemistry, have resulted in higher survival rates of short implants (Hagi et al. 2004, Renouard & Nisand 2006, Kotsovilis et al. 2009, Romeo et al. 2010). The implant surface used to be a smooth turned surface, but nowadays, different techniques, e.g., acid-etching, grit blasting and titanium plasma spraying, have altered the micro-topography of the implant surface by making the surface rougher. Application of these techniques results in a tremendously enlarged implant surface. Recent developments have been at the level of nano-topography (Meirelles et al. 2008a, b).

To our knowledge, no systematic review with meta-analyses to determine the role of possible predictors has been performed on short (<10 mm) endosseous implants in partially edentulous patients. Hence, the objective of this article was to systematically assess the clinical outcome of short implants (<10 mm) in partially edentulous patients and to evaluate the sources of heterogeneity between studies by subgroup analyses (viz., length, surface topography, smoking, implant location (mandible *versus* maxilla) and bone augmentation procedure).

Materials and Methods

Data identification and selection

A MEDLINE and EMBASE search from January 1980 to October 2009 was conducted to identify studies on short endosseous implants in partially edentulous patients. In the present study, an implant of length <10 mm was defined as a short implant, regardless of the level of placement. A search strategy was set up in duplicate and independently by the first author and by an expert in searching literature databases. The electronic search was carried out by applying the following free text words and the applied thesaurus (MeSH): # 1 Search dental implant OR dental implants OR dental implantation OR endosseous dental implantation OR endosseous implant OR endosseous implants OR endosseous implantation, # 2 Search short* OR short-length OR short OR short length OR length, # 3 Search # 1 AND # 2 NOT (case-report OR case report OR case reports) NOT review NOT animal. To complete the search, we checked the reference lists in the literature obtained for additional relevant articles. No language restrictions were applied.

Two reviewers (G.T and L.D.H) evaluated the relevance of the studies by a first selection based on the title and abstract. Disagreement about whether a study should be included for full inspection was resolved by a consensus discussion. Full-text documents were obtained for all possibly relevant articles. One reviewer (G.T) read the full-text documents of all relevant articles and selected the articles for further methodological appraisal using the inclusion and exclusion criteria described below. To test the quality of the data extraction, a second reviewer (L.D.H), who was blinded to data extraction of the first reviewer, again extracted the data of a random subset of 25% of the included articles to see whether there was a consensus in extracting data. There was an excellent agreement between the two reviewers ($\kappa > 0.95$) for the extraction of the data.

Inclusion criteria:

- Study design: randomized-controlled trial or prospective cohort study.
- Patients: partially edentulous.
- Follow-up: > 1 year.
- Implant length: < 10 mm.
- Minimum total number of short implants (< 10 mm) placed in the assessed implant cohort of a particular study: five (when two implants of length 6 mm and three implants of length 7 mm were placed, the study was also included).

Exclusion criteria:

- Study design: retrospective study, case report, review, non-clinical studies, explanation of technique or manual.

- Implants: (alumina)–zirconium implants or mini-implants for orthodontic anchorage.
- Suprastructures: cantilever constructions.
- Subjects: animals.

Validity assessment

Two reviewers (G.T and L.D.H) assessed the methodological quality using the forms ''quality assessment of a cohort study'' and ''quality assessment of a randomized clinical trial'' developed by the Dutch Cochrane Centre, a centre of the Cochrane Collaboration (Tables 1 and 2). These two validity tools consist of eight and nine items, which have to be scored with a plus, a minus or a question mark. It was decided that studies scoring four or more plusses were considered methodologically acceptable. The two observers independently generated a score for the articles included. No blinding for author, institute or journal was performed.

Missing data

When not all needed data were provided in the publication, the author was sent an e-mail for further details. Non-responders were sent a reminder and a postal letter.

Statistical analysis

The pre-consensus degree of agreement between the two reviewers (G.T and L.D.H) regarding eligible studies was expressed as a percentage of agreement of Cohen's unweighted κ.

For each study, the estimated failure rate per year and the estimated implant survival rate after 2 years (%) were assessed. In this systematic review, an implant failure was defined as each implant from a cohort that was removed because of loss of integration, implant mobility, symptoms as pain, neuropathies, paraesthesia or violation of the mandibular canal or psychological reason (Albrektsson et al. 1986). The estimated failure rate was calculated by dividing the number of events (implant failures) by the total implant exposure time. The total exposure time was calculated by taking the sum of (Pjetursson et al. 2008):

1. The exposure time of implants that could be followed for the entire observation time.
2. The exposure time up to a failure of implants that were lost during the observation time.
3. The exposure time up to the end of the observation time for implants that did not complete the observation period due to reasons such as death, change of address, refusal to participate in the follow-up, chronic illnesses, missed appointments and work commitments.

Table 1. Quality assessment of a cohort study

Item	+	−	?
1. Are the characteristics of the comparative study groups clearly described?			
2. Can selection bias be excluded sufficiently?			
3. Is the intervention clearly described? Are all patients treated according to the same intervention?			
4. Are the outcomes clearly described? Are the methods used to assess the outcome adequate?			
5. Is blinding used to assess the outcome? If not, does this have any effect on the evaluation of the results?			
6. Is the duration of the follow-up sufficient?			
7. Can selective loss-to-follow-up be excluded sufficiently?			
8. Are the most important confounders or prognostic factors identified?			

Four or more plusses = methodologically acceptable.

Table 2. Quality assessment of a randomized-controlled trial (RCT)

Item	+	−	?
1. Was the intervention assignment randomized?			
2. The person who included the patients should not be informed about the randomization order. Was that the case?			
3. Were the patients blinded for treatment?			
4. Were the practitioners blinded for treatment?			
5. Were the evaluators blinded for treatment?			
6. Were the groups comparable at the beginning of the trial? If not, were the analyses corrected for this?			
7. Are there relatively enough patients available for complete follow-up? If not, can selective loss-to-follow-up be excluded sufficiently?			
8. Are the included patients analyzed in the group in which they were randomized?			
9. Are the groups, besides the intervention, treated likewise?			

Four or more plusses = methodologically acceptable.

When the exposure time was not given separately for the short implants or the follow-up was not a closed period but had dispersal over years, a percentage (given by the number of short implants) of the total implant exposure time of all the implants was taken as the best available approximation. Exclusion of studies because their follow-up was not a closed period or also because longer implants were studied was not preferred. For the calculation of the estimated survival rate after 2 years, the total number of events was considered to follow a Poisson's distribution.

Summary estimates of the annual failure were calculated for different implant lengths in a stratified analysis. The different lengths of 5, 6, 7, 8, 8.5, 9 and 9.5 mm were studied. Sources of heterogeneity were explored using stratified analyses for the determinants surface topography, location (maxilla *versus* mandible), smoking and bone augmentation procedures. The results of smooth turned surfaces were compared with roughened surfaces (i.e. dual acid-etched or titanium plasma sprayed) and the failures of short implants in the maxilla were compared with the mandible. Smokers were divided into two groups; (1) only non-smokers included in the study; (2) no restrictions about smoking habits; non-smokers, moderate and heavy smokers ($\geqslant$15 cigarettes/day) were included in the study. Whether an augmentation procedure was performed simultaneously with placing the implant was scored as (1) no augmentation procedure; (2) augmentation performed that might be either local sinus floor elevation surgery, a local covering of a fenestration of the implant surface or a local covering of an dehiscence of the implant surface.

In order to assess the heterogeneity of the studies included, Cochrane's Q statistic and associated *p*-value and the I^2-

test were calculated. I^2 quantified no heterogeneity by 0%, mild heterogeneity by $<30\%$, moderate heterogeneity by 30–60% and notable heterogeneity by $>60\%$. Standard errors were calculated to obtain 95% confidence intervals (CIs) of the estimated failure rates.

Two-year survival proportions were calculated via the relationship between estimated failure rate and survival function S, $S(T) = \exp(-T \times \text{failure rate})$, by assuming constant failure rates (Kirkwood & Sterne 2003a, b). The 95% CIs for the survival proportions were calculated using the 95% confidence limits of the event rates.

Analyses were performed using the statistical software package ''meta-analysis'' (comprehensive meta-analysis version 2.2, Biostat, Englewood, NJ, USA, 2005, http://www.meta-analysis.com).

Results

Data identification and selection

The MEDLINE and EMBASE search identified 960 and 393 publications, respectively. A total of 164 publications were eligible for full-text analysis. Checking references in the literature obtained did yield one additional publication (Becker et al. 1999). Of the 165 publications, 61 publications fulfilled the inclusion criteria. Methodological assessment of these 61 eligible publications revealed 39 methodologically acceptable publications. The inter-reviewer agreement on the methodological appraisal was measured using an unweighted κ: 0.83. Disagreement was generally caused by slight differences in interpretation and was easily resolved in a consensus discussion. Unfortunately, eight eligible articles had to be excluded from the meta-analysis because the contacted authors did not respond on either of the attempts for obtaining more details about the study. Furthermore, one author did not want to engage in reanalyses of his data. In addition, the data of one study were published twice; the data of the most recent publication were included (Glauser et al. 2003, 2005). Finally, a total of 29 publications were selected for data analysis. Figure 1 outlines the algorithm of the study selection procedure.

The 29 eligible publications included a total of 28 prospective cohort and one randomized-controlled trial (RCT). The RCT included in this systematic review focused on submerged *versus* non-submerged healing of endosseous implants and not on implant length. The mean follow-up of the 29 publications was 3.7 years (range 1.6–8.1 years). The first study was published in 1993, and the latest in 2009. The median year of publication was 2003. The 29 studies included a total of 2611 short implants (lengths 5, 6, 7, 8, 8.5, 9 and 9.5 mm). An overview of all studies included is given in Table 3. This table is ranked by implant length (from 5 to 9.5 mm). A study can be mentioned twice or more times in Table 3 as a variety of implant lengths can be used in a particular study, e.g. in the study of Corrente et al. (2009) 10 implants of length 5 mm and 38 of length 7 mm were placed. The summary of the estimated survival rate after 2 years for the different implant length was 93.1% (95% CI: 79.7–100%) for 5 mm, 97.4% (95% CI: 94.4–100%) for 6 mm implants, 97.6% (95% CI: 96.3–98.8%) for 7 mm implants, 98.4% (95% CI: 97.8–99.0%) for 8 mm implants, 98.8% (95% CI: 98.2–99.6%) for 8.5 mm implants, 98.0% (95% CI: 96.4–99.%) for 9 mm implants and 98.6% (95% CI: 94.6–100%) for 9.5 mm implants.

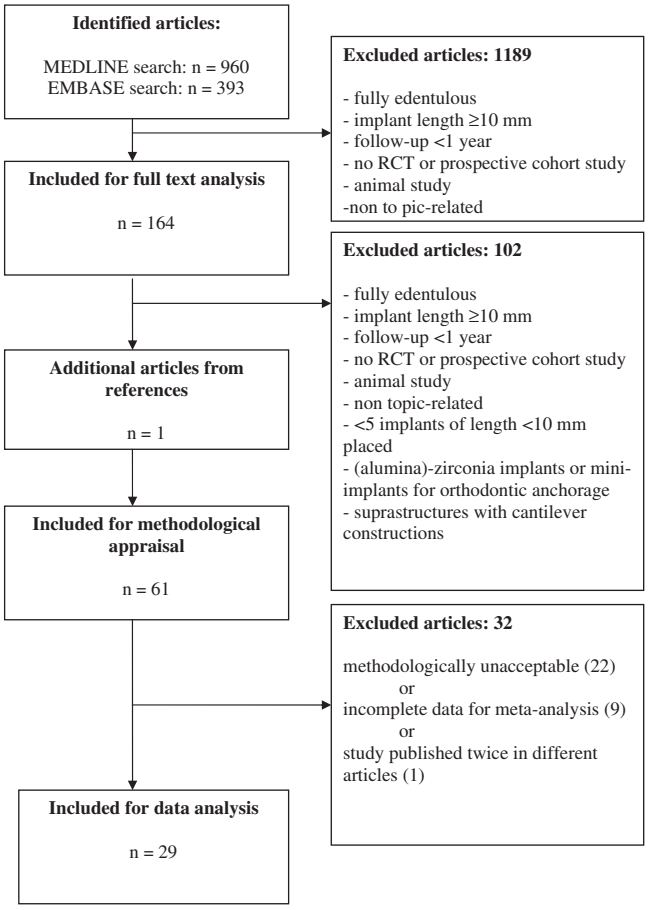

Fig. 1. Algorithm of the study selection procedure.

Sources of heterogeneity between included studies

Sources of heterogeneity were explored in a sensitivity analysis with post hoc subgroup analyses. The main question behind these analyses was not to see whether there were subgroups to be found, but merely to check whether the results would vary between these subgroups. These so-called stratified analyses were run for implant surface topography (rough *versus* machined), location (mandible *versus* maxilla), smoking status (smokers were excluded *versus* smokers were included) and augmentation procedure (not performed simultaneously with placing the implants *versus* performed simultaneously with placing the implants). The overall results of all implant lengths showed a similar estimated failure rate for the different surface topographies: 0.008 (95% CI: 0–

Table 3. Overview of the studies included and annual failure and survival rates grouped by implant length

Study	Year of publications	Total no. of implants	Implant length (mm)	Surface topography	Location	Smoking status	Augmentation procedure	Mean follow-up time (years)	No. of failure	Total implant exposure time (months)	Estimated implant failure rate (per year)	Estimated implant survival rate after 2 years (%)
Corrente et al.	2009	10	5	Rough	Maxilla	Moderate included	Yes	1.7	0	193	0.030	94.2
Deporter et al.	2001b	2	5	Rough	Maxilla	Excluded	Yes	2	0	77	0.072	86.6
Summary estimate (95% CI) of 5 mm implant											*0.036* (0–0.114)	*93.1* (79.7–100)
Pjetursson et al.	2009	7	6	Rough	Maxilla	Included	Unknown	3.2	3	234	0.134	76.5
Nedir et al.	2004	5	6	Rough	Maxilla	Included	Yes	4.4	0	189	0.031	94.0
Nedir et al.	2004	1	6	Rough	Mandible	Included	Yes	4.4	0	38	0.136	76.2
Tawil and Younan	2003	16	6	Machined	Mandible	Unknown	Unknown	2.5	0	1335	0.004	99.2
Mericske-Stern et al.	2001	5	6	Rough	Both arches	Moderate included	Unknown	4.3	0	230	0.025	95.1
Brocard et al.	2000	16	6	Rough	Both arches	Included	Yes	3.9	3	720	0.050	90.5
Becker et al.	1999	2	6	Machined	Mandible	Moderate included	Unknown	1.6	0	68	0.081	85.0
Becker et al.	1999	5	6	Machined	Maxilla	Moderate included	Unknown	1.6	1	171	0.070	86.9
Summary estimate (95% CI) of 6 mm implant											*0.013* (0–0.029)	*97.4* (94.4–100)
Corrente et al.	2009	38	7	Rough	Maxilla	Moderate included	Yes	1.7	1	731	0.016	96.8
Glauser et al.	2005	1	7	Rough	Both arches	Included	Yes	4	0	32	0.158	72.9
Beschnidt et al.	2003	4	7	Rough	Both arches	Included	Yes	5.3	1	226	0.053	89.9
Tawil and Younan	2003	27	7	Machined	Mandible	Unknown	Unknown	2.5	5	2252	0.027	94.7
Davarpanah et al.	2002	96	7	Rough	Both arches	Moderate included	No	2.7	4	4243	0.011	97.8
Deporter et al.	2001b	44	7	Rough	Maxilla	Excluded	Yes	2	0	1703	0.004	99.2
Deporter et al.	2001a	32	7	Rough	Mandible	Excluded	Unknown	2.7	0	1088	0.005	99.0
Testori et al.	2001	3	7	Rough	Maxilla	Moderate included	No	3.6	1	147	0.082	84.9
Testori et al.	2001	4	7	Rough	Mandible	Moderate included	No	3.6	0	196	0.030	94.2
Polizzi et al.	2000	2	7	Rough	Both arches	Included	Unknown	3	0	57	0.095	82.7
Becker et al.	1999	1	7	Machined	Mandible	Moderate included	Unknown	1.6	0	34	0.150	74.1
Becker et al.	1999	5	7	Machined	Maxilla	Moderate included	Unknown	1.6	3	171	0.211	65.6
Gunne et al.	1999	37	7	Machined	Both arches	Unknown	Unknown	7.3	4	3601	0.013	97.4
Lekholm et al.	1999	22	7	Machined	Maxilla	Unknown	Unknown	8.1	4	1999	0.024	95.3
Lekholm et al.	1999	79	7	Machined	Mandible	Unknown	Unknown	8.1	2	7316	0.003	99.3
Bahat	1993	126	7	Machined	Maxilla	Unknown	Unknown	2.5	12	3818	0.038	92.7
Summary estimate (95% CI) of 7 mm implant											*0.012* (0.006–0.019)	*97.6* (96.3–98.8)
Pjetursson et al.	2009	157	8	Rough	Maxilla	Included	Unknown	3.2	2	5238	0.004	99.0
Degidi et al.	2006	10	8	Rough	Both arches	Moderate included	Unknown	2	0	120	0.111	80.1
Romeo et al.	2006	111	8	Rough	Both arches	Excluded	No	6.4	4	8525	0.006	98.8
Ferrigno et al.	2006	103	8	Rough	Both arches	Moderate included	Yes	5	4	5784	0.008	98.4
Cecchinato et al.	2004	33	8	Rough	Both arches	Included	Unknown	2	4	737	0.065	87.7
Nedir et al.	2004	35	8	Rough	Maxilla	Included	Minor	4.4	0	1321	0.005	99.0
Nedir et al.	2004	62	8	Rough	Mandible	Included	Minor	4.4	0	2340	0.003	99.4
Romeo et al.	2004	72	8	Rough	Both arches	Moderate included	No	3.9	6	5479	0.013	97.4
McGlumphy et al.	2003	2	8	Rough	Maxilla	Moderate included	Unknown	5	0	104	0.055	89.6
McGlumphy et al.	2003	18	8	Rough	Mandible	Moderate included	Unknown	5	2	985	0.024	95.2
Tawil and Younan	2003	7	8	Machined	Maxilla	Unknown	Unknown	2.5	1	584	0.021	95.9
Tawil and Younan	2003	20	8	Machined	Mandible	Unknown	Unknown	2.5	0	1668	0.004	99.2

Table 3. (Contd.)

Study	Year of publications	Total no. of implants	Implant length (mm)	Surface topography	Location	Smoking status	Augmentation procedure	Mean follow-up time (years)	No. of failure	Total implant exposure time (months)	Estimated implant failure rate (per year)	Estimated implant survival rate after 2 years (%)
Mericske-Stern et al.	2001	44	8	Rough	Both arches	Moderate included	Unknown	4.3	3	2025	0.018	96.5
Brocard et al.	2000	232	8	Rough	Both arches	Included	Yes	3.9	15	10440	0.017	96.6
Buser et al.	1997	389	8	Rough	Both arches			2	12	14532	0.010	98.0
Summary estimate (95% CI) of 8 mm implant											*0.008* (0.005–0.011)	*98.4* (97.8–99.0)
Glauser et al.	2005	4	8.5	Rough	Both arches	Included	Yes	4	0	130	0.044	91.6
Sullivan et al.	2005	21	8.5	Rough	Both arches	Moderate included	No	3.6	1	1095	0.011	97.8
Farzad et al.	2004	7	8.5	Machined	Both arches	Unknown	Unknown	3.9	0	328	0.018	96.5
Beschnidt et al.	2003	12	8.5	Rough	Both arches	Included	Yes	5.3	1	678	0.018	96.5
Tawil and Younan	2003	2	8.5	Machined	Maxilla	Unknown	Unknown	2.5	0	167	0.035	93.2
Tawil and Younan	2003	44	8.5	Machined	Mandible	Unknown	Unknown	2.5	2	3670	0.002	99.6
Davarpanah et al.	2002	189	8.5	Rough	Both arches	Moderate included	No	2.7	11	8354	0.016	96.9
Davarpanah et al.	2001	56	8.5	Rough	Both arches	Unknown	No	3	2	1905	0.013	97.4
Testori et al.	2001	8	8.5	Rough	Maxilla	Moderate included	No	3.6	0	393	0.015	97.0
Testori et al.	2001	14	8.5	Rough	Mandible	Moderate included	No	3.6	0	687	0.009	98.2
Polizzi et al.	2000	8	8.5	Rough	Both arches	Included	Unknown	3	1	226	0.053	89.9
Becker et al.	1999	17	8.5	Machined	Mandible	Moderate included	Unknown	1.6	0	581	0.010	98.0
Becker et al.	1999	7	8.5	Machined	Maxilla	Moderate included	Unknown	1.6	0	239	0.024	95.3
Grunder et al.	1999	31	8.5	Rough	Both arches	Included	No	2.4	0	884	0.007	98.6
Summary estimate (95% CI) of 8.5 mm implant											*0.006* (0.002–0.009)	*98.8* (98.2–99.6)
Degidi et al.	2009	21	9	Rough	Both arches	Moderate included	No	5	0	1260	0.008	98.4
Degidi et al.	2006	39	9	Rough	Both arches	Moderate included	Unknown	2	0	468	0.012	97.6
Cecchinato et al.	2004	65	9	Rough	Both arches	Included	Unknown	2	1	1452	0.008	98.4
Nedir et al.	2004	7	9	Rough	Maxilla	Included	Minor	4.4	0	264	0.022	95.7
Nedir et al.	2004	1	9	Rough	Mandible	Included	Minor	4.4	0	38	0.136	76.2
Deporter et al.	2001b	89	9	Rough	Maxilla	Excluded	Yes	2	3	3445	0.010	98.0
Deporter et al.	2001a	16	9	Rough	Mandible	Excluded	Unknown	2.7	0	544	0.011	97.8
Summary estimate (95% CI) of 9 mm implant											*0.010* (0.002–0.018)	*98.0* (96.4–99.6)
Degidi et al.	2006	68	9.5	Rough	Both arches	Moderate included	Unknown	2	0	816	0.007	98.6
Summary estimate (95% CI) of 9.5 mm implant											*0.007* (0–0.028)	*98.6* (94.6–100)

CI, confidence interval.

0.010) for rough implants and 0.010 (95% CI: 0.005–0.016) for the machined implants, respectively, a difference of 29% between the two different surface topographies compared with the summary of the estimated failure rate of all lengths of 0.007 (95% CI: 0.006–0.009). The estimated failure rate of implants placed in the maxilla was significantly higher [0.010 (95% CI: 0.005–0.016)] than that for implants in the mandible [0.003 (95% CI: 0.001–0.006)]; a significant difference of 100%. The estimated failure rates from studies in which smokers were strictly excluded were twice as low [0.004 (95% CI: 0.000–0.007)] compared with those in which heavy smokers ($\geqslant$15 cigarettes/day) were also included [0.008 (95% CI: 0.004–0.013)], a difference of 57%. The difference in the estimated failure rate in bone augmentation procedure simultaneously with placing the implants was not conspicuous. When no augmentation procedure was performed, the estimated failure rate was 0.010 (95% CI: 0.006–0.013) compared with when augmentation was performed 0.007 (95% CI: 0.004–0.010), a difference of 43%.

Heterogeneity was also calculated with Cochrane's *Q*-test per implant length *and* of all lengths together (see Table 4). All *p*-values were higher than the conventional cut point of 0.05, which indicated the homogeneity of the different studies with one implant length and of all the studies together. The I^2-test quantifies heterogeneity and for the implant lengths 5, 8.5, 9, 9.5 *and* of all lengths together, there seemed to be no heterogeneity, for implants length 6 and 8 mm, there was mild heterogeneity and for the group with implant length 7 mm, there seemed to be moderate heterogeneity.

Discussion

This systematic review of short implants ($<$10 mm) in partially edentulous patients shows a (negative) significant association between failure rate and implant length; the longer the implant, the higher the implant survival rate within the range of 5–8.5 mm length. The results for the shortest implants (5 mm, $n = 12$) have to be considered with some caution, however, as only two studies were available (Deporter et al. 2001b, Corrente et al. 2009). This increasing survival rate with implant length was not reported in the systematic review of Kotsovilis et al. (2009), who found no statistical difference between short ($\leqslant$8 or $<$10 mm) and conventional ($\geqslant$10 mm) implants, but they did not perform a meta-regression analysis per implant length. Romeo et al. (2010) also found a similar survival rate for short and standard implants.

This review also shows that the estimated failure rates of studies in which short implants were placed in the mandible were lower than studies that placed short implants in the maxilla. These results are in line with the treatment outcome of ''normal'' length or standard implants, i.e. implants with a length $>$10 mm (Friberg et al. 1991). Moreover, implant failures of studies that excluded smokers were lower than the results of studies that included (heavy) smokers ($\geqslant$15 cigarettes/day) patients. The association between smoking and implant failure, as found in the current review, could not always be shown in other studies. In the systematic review by Pjetursson et al. (2008), a difference in implant survival rate was found, but could not reach statistical significance. Also in line with standard length implants, no difference in implant survival rate was observed between studies with and without (minor or major) augmentation procedures. The latter findings are consistent with the findings of Brocard et al. (2000), Buser et al. (2002), Hämmerle et al. (2002), Pjetursson et al. (2008), who also reported that the survival percentages are comparable for implants placed in augmented bone or in non-augmented bone. In addition, in the current review, also, no difference between the survival rates of implants with a rough surface and with a smooth turned surface was noted. This is not consistent with the results of other studies specifically addressing this topic. Pjetursson et al. (2008) reported in a systematic review significantly better results for implants with a rough surface simultaneously placed with a sinus floor elevation. The systematic review on implant surface roughness and bone healing of Shalabi et al. (2006) presented a positive relationship between bone-to-implant contact and surface roughness. Wennerberg and Albrektsson (2009) concluded in their systematic review that surface topography (or surface roughness) does influence bone response at the micrometre level and might influence bone response at the nanometre level. They also conclude that the majority of published papers present an inadequate surface characterization. This might be the reason why in the current study no difference in implant survival was found for the different surfaces. Wennerberg and Albrektsson (2009) wrote ''a surface termed ''rough'' in one study was not uncommonly referred as ''smooth'' in another; many investigators falsely assumed that surface preparation per se identified the roughness of the implant''.

The studies included were also checked for the outcome measure peri-implant bone loss, but unfortunately, only three of the 29 selected studies reported data on per-implant bone loss around short implants (Deporter et al. 2001a, b, Romeo et al. 2006). There were also not enough data in the publications included to assess the determinant implant diameter in a subgroup analysis.

Two studies, Polizzi et al. (2000) and Mericske-Stern et al. (2001), of the 29 included studies for this review were only about single tooth replacements. A total of 59 implants with different lengths were included with an event rate of 4. These were insufficient data to perform a meta-analysis. The rest of the studies used assessed in this review included single- and multiple (splinted)-tooth replacements. In the data presented in these studies, no distinction was made between the implant-supported prosthetic rehabilitation and the removed implants; short implants could even be splinted to longer implants. This is a weakness of this systematic review, but one can assume that if there is severe peri-implantitis or loss of integration at one of a couple of splinted implants, the best practice is to remove this implant; otherwise, the other implants might also be lost.

Our study is an implant-based analysis, while we would have preferred to perform a patient-based analysis, as events (implant loss) tend to cluster within the same patients. However, for this kind of analysis, the data were not exactly sufficiently described, which was partly due to the fact that most of the studies included in this review are not only about short implants. Among others, we found some heterogeneity between studies, mostly due to the fact that most of the studies included were aggregated data sets. Some studies allowed to include certain groups (viz., smoking) whereas others excluded smo-

Table 4. Sources of heterogeneity and their possible role as expressed in the estimated failure rate per year

Implant length (mm)	Studies (*n*)	Implants (*n*)	Heterogeneity (Cochrane's *Q*-test)		Summary of estimated failure rate (95% CI)	Source of heterogeneity							
						Estimated failure rate by surface (95% CI)		Estimated failure rate by location (95% CI)		Estimated failure rate by smoking (95% CI)		Estimated failure rate by augmentation (95% CI)	
			p-value	I^2		rough	machined	mandible	maxilla	excluded	included	not performed	performed
5	2	12	>0.05	0.00	0.036 (0–0.114)	Only implants with rough surfaces		Only implants placed in the maxilla		0.072 (0–0.272)	No studies available	In all studies augmentation procedures were performed	
6	6	57	>0.05	3.29	0.013 (0–0.029)	0.045 (0.007–0.082)	0.005 (0–0.017)	0.096 (0–0.289)	0.058 (0–0.125)	No studies available	0.053 (0.008–0.098)	No studies available	0.046 (0–0.92)
7	13	521	>0.05	36.50	0.012 (0.006–0.019)	0.008 (0.001–0.014)	0.018 (0.005–0.031)	0.004 (0–0.008)	0.021 (0.002–0.040)	0.004 (0–0.012)	0.063 (0–0.160)	0.012 (0.001–0.023)	0.005 (0–0.014)
8	12	1295	>0.05	12.99	0.008 (0.005–0.011)	0.008 (0.006–0.011)	0.005 (0–0.016)	0.004 (0–0.009)	0.005 (0–0.011)	0.006 (0.000–0.011)	0.008 (0.001–0.015)	0.008 (0.003–0.013)	0.009 (0.005–0.013)
8.5	10	420	>0.05	0.00	0.006 (0.002–0.009)	0.014 (0.007–0.020)	0.007 (0–0.015)	0.002 (0–0.006)	0.020 (0–0.053)	No studies available	0.011 (0–0.027)	0.013 (0.006–0.020)	0.044 (0–0.166)
9	6	238	>0.05	0.00	0.010 (0.002–0.018)	Only implants with rough surfaces		0.011 (0–0.042)	0.002 (0–0.007)	0.002 (0–0.007)	0.009 (0–0.025)	0.008 (0–0.029)	0.002 (0.003–0.007)
9.5	1	68	>0.05	0.00	0.007 (0–0.028)	Only one study included		Only one study included		Only one study included		Only one study included	
All lengths	29	2611	>0.05	0.00	0.007 (0.006–0.009)	0.008 (0–0.010)	0.010 (0.005–0.016)	0.003 (0.001–0.006)	0.010 (0.005–0.016)	0.004 (0.000–0.007)	0.008 (0.004–0.013)	0.010 (0.006–0.013)	0.007 (0.004–0.010)

CI, confidence interval.

kers. To precisely estimate the influence of such determinants (viz., smoking), one needs access to the original data sets in order to perform the analyses on an individual level. It was, however, impossible to obtain all original datasets. To explore and to estimate the influence of the sources of heterogeneity, we carried out a subgroup analysis. Although point estimates of the calculated failure rates per implant length were different, the CIs around these point estimates were comparable, when correcting for the normal finding that theses intervals were extended after subgroup analyses. The latter observations lead to the conclusion that the heterogeneity is not enough to reject the results of the estimated failure rate per implant length.

Our main outcome measure was the estimated implant survival rate after 2 years. We have chosen a 2-year survival rate, as we believe that after >1 year in function, the implant survival rate as a function of time after loading has become rather constant (Esposito et al. 1998). To check this constancy, we looked at studies with a follow-up up to 1 year and we estimated the survival rates after 2 years. From these calculations, very outranged numbers such as 0.3–12.0% survival rates were obtained. For this reason, only studies with a mean follow-up longer than 1 year were selected. The shortest mean follow-up, included in this review, was 1.6 years. Our findings were confirmed by the prospective study of Cochran et al. (2009), who found, in their radiographic evaluation of crestal bone, the least bone loss between 1-year post-loading and the last 5-year recall. The most bone loss was found 6 months after implant placement.

Conclusion

The findings from this systematic review add to the growing evidence that short (<10 mm) implants can be placed successfully in the partially edentulous patients, although with a tendency towards an increasing survival rate per implant length. Installation of short dental implants in the mandible has a better prognosis over installation in the maxilla. Furthermore, the results of studies excluding smokers revealed higher implant survival rates than studies including heavy smokers (⩾15 cigarettes/day). Surface topogra-

phy and an augmentation procedure preceding the implant installation apparently did not affect the failure rate of short implants.

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Clinical Relevance

Scientific rationale for the study: Short implants (< 10 mm) are increasingly being used in the posterior zone of partially edentulous patients. Many studies on the implant survival rates of short implants have been published; a systematic review including meta-analyses of possible confounders was lacking.
Principal findings: Implant length plays a major role in the survival rate of short implants, while location and smoking status play some role and surface topography and bone augmentation do not.
Practical implications: Short (< 10 mm) implants can be placed successfully in the partially edentulous patients. Length should be considered in the treatment planning and the role of location and smoking status may be associated with a less favourable outcome.