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James Huddleston Slater, Henny J.A. Meijer

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

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For Peer Review

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

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**running title:** Systematic review of short dental implants.

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

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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 & 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) was analysed. Increase of 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 per year, comparing to 0.003 of the studies in the mandible. For studies which also included smokers the failure rate was 0.008 comparing to 0.004 of studies which excluded smokers. Surface topography and augmentation procedure were no source of heterogeneity.

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2  
3 **Conclusion:** There is fair evidence that short (<10 mm) implants can be successfully placed  
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5 in the partially edentulous patient, though with a tendency of an increasing survival rate per  
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8 implant length and the prognosis may be better in the mandible of non smoking patients.  
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### 10 11 12 13 14 15 **Clinical relevance**

16  
17  
18 **Scientific rationale for study:** Short implants (<10 mm) are increasingly used in the  
19  
20 posterior zone of partially edentulous patients. Many studies on the implant survival rates of  
21  
22 short implants have been published, a systematic review including meta-analyses of possible  
23  
24 confounders was lacking.  
25  
26

27  
28  
29 **Principal findings:** Implant length plays a major role in the survival rate of short implants,  
30  
31 while location and smoking status play some role and surface topography and bone  
32  
33 augmentation do not.  
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37  
38 **Practical implications:** Short (<10 mm) implants can be successfully placed in the partially  
39  
40 edentulous patients. Length should be considered in the treatment planning and the role of  
41  
42 location and smoking status may be associated with a less favourable outcome.  
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### 49 **Acknowledgements**

50  
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53 We gratefully acknowledge the assistance of Ms. S. van der Werf from the Groningen  
54  
55 university medical library for her assistance in the elaboration of the search strategy.  
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## Introduction

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, so 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 given an overview of the literature of short implants in a narrative or structured review. Hagi et al. (2004) showed that, when applying 6 and 7 mm implants, short implants with press-fit shape and a sintered porous surface geometry revealed the best performance. Das Neves et al. (2006) analyzed the treatment outcome of longitudinal studies using Brånemark and compatible implants of 7, 8.5 en 10 mm implants and concluded that short implants should be considered as a alternative treatment to advanced bone augmentation surgeries. Renouard & Nisand (2006) performed a structured review about the impact of implant length and diameter on survival rates in fully and partially edentulous patients and their review demonstrated a trend for an increase failure rate with short and wide-diameter implants. Two recent reviews have been published in which short implants were compared to conventional implants. Kotsovilis et al. (2009) concluded from their systematic review that the placement of short ( $\leq 8$  mm or  $< 10$  mm) rough-surface implants is not a less efficacious treatment modality compared to the placement of conventional ( $\geq 10$  mm) rough-surface implants. Romeo et al. (2010) concluded that the recent literature have demonstrated a similar survival rate for short and standard implants. But some important confounders need to be

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2  
3 studied in future studies as they might be a key factor for the success in the use of short  
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5 implants.  
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8  
9 In the past short implants have been associated with lower survival rates (Lee et al. 2005,  
10  
11 Romeo et al. 2010). There are several presumed reasons for a lower survival rate of short  
12  
13 implants in the posterior maxilla or mandible. First, compared to longer implants with a  
14  
15 comparable diameter there is less bone to implant contact when short implants are used,  
16  
17 simply because there is less implant surface. Secondly, short implants are mostly placed in the  
18  
19 posterior zone where the quality of the alveolar bone is relatively poor, especially in the  
20  
21 maxilla (type III or IV, Lekholm & Zarb 1985). Thirdly, often a very oversized crown has to be  
22  
23 made to reach occlusion, because of the extensive resorption in the posterior region, which  
24  
25 causes a higher (<1->2) crown to implant ratio. Crown to implant ratios between 0.5 and 1  
26  
27 were proposed to prevent peri-implant bone stress, crestal bone loss, and eventually implant  
28  
29 failure (Haas et al. 1995, Rangert et al. 1997, Glantz & Nilner 1998). But the most recent  
30  
31 systematic review on 2 studies on crown to implant ratios concluded that the ratio does not  
32  
33 influence the peri-implants crestal bone loss (Blanes 2009).  
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41 To avoid the use of short implants the extremely resorbed bone can be augmented using a  
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43 bone grafting technique. This modification in the patient's anatomy makes it possible to insert  
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45 a longer implant, but an extra surgical intervention also leads to greater patient's morbidity,  
46  
47 higher costs and a longer treatment period. Esposito et al. (2010) concluded from their  
48  
49 systematic review on augmentation procedures of the maxillary sinus: "Short implants (5-8  
50  
51 mm) may be as effective and cause fewer complications than longer implants placed using a  
52  
53 more complex technique." And from their systematic review on horizontal and vertical bone  
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55 augmentation techniques for dental implant treatment they concluded (Esposito et al. 2010):  
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3 “Short implants appear to be a better alternative to vertical bone grafting of resorbed  
4 mandibles. Complications, especially for vertical augmentation, are common.”  
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9 New developments of the different implant systems, especially regarding the surface micro-  
10 topography and chemistry, has resulted in higher survival rates of short implants (Romeo et  
11 al. 2010, Kotsovillis et al. 2009, Hagi et al. 2004, Renouard & Nisand 2006). The implant  
12 surface used to be a smooth turned surface, but nowadays different techniques, e.g., acid-  
13 etching, grit blasting and titanium plasma spraying, altered the micro-topography of the  
14 implant surface by making the surface rougher. Applying such these techniques results in a  
15 tremendously enlarged implant surface. Recent developments are on the level of nano-  
16 topography (Meirelles et al. 2008, Meirelles et al. 2008).  
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29 To our knowledge, no systematic review with meta-analyses to determine the role of possible  
30 predictors has been performed on short (<10 mm) endosseous implants in the partially  
31 edentulous patients. Hence, the objective of this article was to systematically assess the  
32 clinical outcome of short implants (<10 mm) in partially edentulous patients and to evaluate  
33 the sources of heterogeneity between studies by subgroup analyses (viz. length, surface  
34 topography, smoking, implant location (mandible versus maxilla) and bone augmentation  
35 procedure).  
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## 51 **Materials & methods**

### 52 *Data identification and selection*

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54 A MEDLINE and EMBASE search from January 1980 to October 2009 was conducted to  
55 identify studies on short endosseous implants in partially edentulous patients. In the present  
56 study an implant of length <10 mm was defined as a short implant, regardless the level of  
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3 placement. A search strategy was set up in duplicate and independently by the first author and  
4  
5 by an expert in searching literature databases. The electronic search was carried out by  
6  
7 applying the following free text words and the applied thesaurus (MeSH): # 1 Search dental  
8  
9 implant OR dental implants OR dental implantation OR endosseous dental implantation OR  
10  
11 endosseous implant OR endosseous implants OR endosseous implantation, # 2 Search short\*  
12  
13 OR short-length OR short OR short length OR length, # 3 Search # 1 AND # 2 NOT (case-  
14  
15 report OR case report OR case reports) NOT review NOT animal. To complete the search, we  
16  
17 checked the reference lists in the obtained literature for additional relevant articles. No  
18  
19 language restrictions were applied.  
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26 Two reviewers (GT and LDH) evaluated the relevance of studies by a first selection based on  
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28 title and abstract. Disagreement about whether a study should be included for full inspection  
29  
30 was resolved by a consensus discussion. Full-text documents were obtained for all possibly  
31  
32 relevant articles. One reviewer (GT) read the full-text documents of all relevant articles and  
33  
34 selected the articles for further methodological appraisal using the in- and exclusion criteria  
35  
36 described below. To test the quality of the data extraction, a second reviewer (LDH) who was  
37  
38 blinded to data extraction of the first reviewer, again extracted the data of a random subset of  
39  
40 25% of the included articles to see whether there was a consensus in extracting data. There  
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42 was an excellent agreement between the two reviewers (kappa >0.95) for the extraction of the  
43  
44 data.  
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50  
51 Inclusion criteria:

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54 - Study design: randomized controlled trial (RCT) or prospective cohort study  
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58 - Patients: partially edentulous  
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- Follow-up: >1 year

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3 - Implant length: <10 mm  
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7 - Minimum total number of short implants (<10 mm) placed in the assessed implant cohort of  
8  
9 a particular study: 5 (When 2 implants of length 6 mm and 3 implants of length 7 mm were  
10  
11 placed the study was also included)  
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17 Exclusion criteria:  
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21 - Study design: retrospective study, case report, review, non-clinical studies, explanation of  
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23 technique or manual  
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25

26  
27 - Implants: (alumina)-zirconium implants or mini-implants for orthodontic anchorage  
28  
29

30  
31 - Suprastructures: cantilever constructions  
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33

34  
35 - Subjects: animals  
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41 *Validity assessment*  
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45 Two reviewers (GT and LDH) assessed the methodological quality using the forms 'quality  
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47 assessment of a cohort study' and 'quality assessment of a randomized clinical trial'  
48  
49 developed by the Dutch Cochrane Centre, a centre of the Cochrane Collaboration (tables 3 &  
50  
51 4). These two validity tools consist of 8 and 9 items, which have to be scored with a plus,  
52  
53 minus or a question mark. It was decided that studies scoring four or more plusses were  
54  
55 considered methodological acceptable. The two observers independently generated a score for  
56  
57 the included articles. No blinding for author, institute or journal was performed.  
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### *Missing data*

When not all needed data was given 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 (GT and LDH) regarding eligible studies was expressed as a percentage of agreement of Cohen's unweighted kappa.

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, paresthesia 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 whole 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 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.

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3 When the exposure time was not given separately for the short implants or the follow-up was  
4 not a closed period but had dispersal over years, a percentage (given by the number of short  
5 implants) of the total implant exposure time of all the implants was taken as the best available  
6 approximation. To exclude the studies just because their follow-up was not a closed period or  
7 also longer implants were studied was not preferred. For the calculation of the estimated  
8 survival rate after 2 years, the total number of events was considered to follow a Poisson  
9 distribution.  
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21 Summary estimates of the annual failure were calculated for different implant lengths in a  
22 stratified analysis. The different lengths of 5, 6, 7, 8, 8.5, 9 and 9.5 mm were studied. Sources  
23 of heterogeneity were explored using stratified analyses for the determinants surface  
24 topography, location (maxilla vs. mandible), smoking and bone augmentation procedures. The  
25 results of smooth turned surfaces were compared to roughened surfaces (i.e. dual acid-etched  
26 or titanium plasma sprayed) and the failures of short implants in the maxilla were compared to  
27 the mandible. Smokers were divided into two groups; 1) only non-smokers included in the  
28 study; 2) no restrictions about smoking habits; non-smokers, moderate and heavy smokers  
29 ( $\geq 15$  cigarettes per day) were included in the study. Whether an augmentation procedure was  
30 performed simultaneously with placing the implant was scored as; 1) no augmentation  
31 procedure; 2) augmentation performed which might be either local sinus floor elevation  
32 surgery, a local covering of a fenestration of the implant surface or a local covering of an  
33 dehiscence of the implant surface.  
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53 In order to assess the heterogeneity of the included studies the Cochran's Q statistic and  
54 associated *P*-value and the  $I^2$ -test were calculated.  $I^2$  quantified no heterogeneity by 0%, mild  
55 heterogeneity by  $<30\%$ , moderate heterogeneity by 30-60% and notable heterogeneity by  
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3 >60%. Standard errors were calculated to obtain 95% confidence intervals (CI's) of the  
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6 estimated of the failure rates.

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9 Two-year survival proportions were calculated via the relationship between estimated failure  
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11 rate and survival function  $S$ ,  $S(T) = \exp(-T \times \text{failure rate})$ , by assuming constant failure rates  
12  
13 (Kirkwood & Sterne 2003). The 95% CI's for the survival proportions were calculated using  
14  
15 the 95% confidence limits of the event rates.  
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20 Analyses were performed using the statistical software package 'Meta-analysis'  
21  
22 (Comprehensive Meta-analysis Version 2.2, Biostat, Englewood NJ (2005), www.meta-  
23  
24 analysis.com).  
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26

## 27 28 29 30 31 **Results**

### 32 33 34 *Data identification and selection*

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38 The MEDLINE and EMBASE search identified 960 and 393 publications, respectively. A  
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40 total of 164 publications was eligible for full text analysis. Checking references in the  
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42 obtained literature did yield 1 additional publication (Becker et al. 1999). Of the 165  
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44 publications, 61 publications fulfilled the inclusion criteria. Methodological assessment of  
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46 these 61 eligible publications revealed 39 methodologically acceptable publications. The  
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48 inter-reviewer agreement on the methodological appraisal was measured with an unweighted  
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50 kappa: 0.83. Disagreement was generally caused by slight differences in interpretation and  
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52 was easily resolved in a consensus discussion. Unfortunately eight eligible articles had to be  
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54 excluded from the meta-analysis because the contacted authors did not respond on either of  
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56 the attempts for obtaining more details about the study. Furthermore, one author did not want  
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3 to engage in a reanalyses of his data. In addition, the data of one study was published twice,  
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5 the data of the most recent publication was included (Glauser et al. 2003, Glauser et al. 2005).  
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8 Finally, a total of 29 publications was selected for data analysis. Figure 1 outlines the  
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10 algorithm of the study selection procedure.  
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14 The 29 eligible publications included a total of 28 prospective cohort and 1 randomized  
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16 controlled trial (RCT). The RCT included in this systematic review focused on submerged  
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18 versus non-submerged healing of endosseous implants and not on implant length. The mean  
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20 follow-up of the 29 publications was 3.7 years (range 1.6-8.1 year). The first study was  
21  
22 published in 1993, the latest in 2009. The median year of publication was 2003. The 29  
23  
24 studies included a total of 2611 short implants (lengths 5, 6, 7, 8, 8.5, 9 and 9.5 mm). An  
25  
26 overview of all studies included is given in table 1. This table is ranked by implant length  
27  
28 (from 5 to 9.5 mm). A study can be mentioned twice or more times in table 1 as a variety of  
29  
30 implant lengths can be used in a particular study, e.g. in the study of Corrente et al. 2009 10  
31  
32 implants of length 5 mm and 38 of length 7 mm were placed. The summary of the estimated  
33  
34 survival rate after 2 years for the different implant length was 93.1% (95% CI: 79.7%-100%)  
35  
36 for 5 mm, 97.4% (95% CI: 94.4%-100%) for 6 mm implants, 97.6% (95% CI: 96.3%-98.8%)  
37  
38 for 7 mm implants, 98.4% (95% CI: 97.8 %-99.0%) for 8 mm implants, 98.8% (95% CI:  
39  
40 98.2%-99.6%) for 8.5 mm implants, 98.0% (95% CI: 96.4%-99.%) for 9 mm implants and  
41  
42 98.6% (95% CI: 94.6%-100%) for 9.5 mm implants.  
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#### 54 *Sources of heterogeneity between included studies*

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57 Sources of heterogeneity were explored in a sensitivity analysis with post hoc subgroups  
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59 analyses. The main question behind these analyses was not to see if there were subgroups to  
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3 be found, but merely to check whether results would change between these subgroups. These  
4  
5 so called stratified analyses were run for implant surface topography (rough vs. machined),  
6  
7 location (mandible vs. maxilla), smoking status (smokers were excluded vs. smokers were  
8  
9 included) and augmentation procedure (not performed simultaneously with placing the  
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11 implants vs. performed simultaneously with placing the implants). The overall results of all  
12  
13 implant lengths showed a similar estimated failure rate for the different surface topographies  
14  
15 0.008 (95% CI: 0-0.010) for rough implants and 0.010 (95% CI: 0.005-0.016) for the  
16  
17 machined implants, respectively. A difference of 29% between the two different surface  
18  
19 topographies comparing to the summary of the estimated failure rate of all lengths of 0.007  
20  
21 (95% CI: 0.006-0.009). The estimated failure rate of implants placed in the maxilla was  
22  
23 significant higher (0.010 (95% CI: 0.005-0.016)) as for implants in the mandible (0.003 (95%  
24  
25 CI: 0.001-0.006)); a significant difference of 100%. The estimated failure rate from studies in  
26  
27 which smokers were strictly excluded were twice as low (0.004 (95% CI: 0.000-0.007))  
28  
29 comparing in which heavy smokers ( $\geq 15$  cigarettes per day) were also included (0.008 (95%  
30  
31 CI: 0.004-0.013)); a difference of 57%. The difference in estimated failure rate in bone  
32  
33 augmentation procedure simultaneously with placing the implants was not conspicuous. When  
34  
35 there was not an augmentation procedure performed the estimated failure rate was 0.010 (95%  
36  
37 CI: 0.006-0.013) comparing to when augmentation was performed 0.007 (95% CI: 0.004-  
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39 0.010); a difference of 43%.

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49 Heterogeneity was also calculated with the Cochrane's Q-test per implant length *and* of all  
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51 lengths together (see table 2). All P-values were higher than the conventional cut point of  
52  
53 0.05, which indicated homogeneity of the different studies with one implant length and of all  
54  
55 the studies together. The  $I^2$ -test quantifies heterogeneity and for the implant lengths 5, 8.5, 9,  
56  
57 9.5 *and* of all lengths together there seems no heterogeneity, for implants length 6 and 8 mm  
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3 there was mild heterogeneity and for the group with implant length 7 mm there seems  
4  
5 moderate heterogeneity.  
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## 8 9 **Discussion**

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12 This systematic review about short implants (<10 mm) in partially edentulous patients shows  
13  
14 a (negative) significant association between failure rate and implant length; the longer the  
15  
16 implant the higher the implant survival rate within the range of 5 to 8.5 mm length. The  
17  
18 results for the shortest implants (5 mm, n=12) has to be considered with some caution,  
19  
20 however, as only two studies were available (Corrente et al. 2009, Deporter et al. 2001). This  
21  
22 increasing survival rate with implant length was not reported in the systematic review of  
23  
24 Kotsovilis et al. (2009) who found no statistical difference between short ( $\leq 8$  or <10 mm) and  
25  
26 conventional ( $\geq 10$  mm) implants, but they did not perform a meta-regression analysis per  
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28 implant length. Romeo et al. (2010) also found a similar survival rate for short and standard  
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30 implants.  
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38 This review also shows that the estimated failure rates of studies in which short implants were  
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40 placed in the mandible were lower than studies which placed short implants in the maxilla.  
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42 These results are in line with the treatment outcome of 'normal' length or standard implants,  
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44 i.e. implants with a length >10 mm (Friberg et al. 1991). Moreover, implant failures of  
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46 studies which excluded smokers were lower than the results of studies which included (heavy)  
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48 smokers ( $\geq 15$  cigarettes per day) patients. The association between smoking and implant  
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50 failure, as found in the current review, could not always be shown in other studies. In the  
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52 systematic review by Pjetursson et al. (2008) a difference in implant survival rate was found,  
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54 but could not reach statistical significance. Also in line with standard length implants no  
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56 difference in implant survival rate was observed between studies with and without (minor or  
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58 major) augmentation procedures. The latter findings are consistent with the findings of  
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3 Brocard et al. (2000), Buser et al. (2002), Hämmerle et al. (2002) and Pjetursson et al. (2008)  
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5 who also reported that the survival percentages are comparable for implants placed in  
6  
7 augmented bone or in non-augmented bone. In addition, in the current review also no  
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9 difference between the survival rates of implants with a rough surface and with a smooth  
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11 turned surface was noted. This is not consistent with the results of other studies specifically  
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13 addressing this topic. Pjetursson et al. (2008) reported in a systematic review significant  
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15 better results for implants with a rough surface simultaneously placed with a sinus floor  
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17 elevation. The systematic review on implant surface roughness and bone healing of Shalabi et  
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19 al. (2006) presented a positive relationship between bone-to-implant contact and surface  
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21 roughness. Wennerberg & Albrektsson (2009) concluded in their systematic review that  
22  
23 surface topography (or surface roughness) does influence bone response at the micrometer  
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25 level and might influence on a nanometer level. They also conclude that the majority of  
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27 published papers present an inadequate surface characterization. This might be the reason why  
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29 in the current study no difference in implant survival was found for the different surfaces.  
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31 Wennerberg & Albrektsson (2009) wrote “a surface termed ‘rough’ in one study was not  
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33 uncommonly referred as ‘smooth’ in another; many investigators falsely assumed that surface  
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35 preparation per se identified the roughness of the implant”.

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45 The included studies were also checked for the outcome measure peri-implant bone loss, but  
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47 unfortunately only 3 of the 29 selected studies reported data on per-implant bone loss around  
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49 short implants (Deporter et al. (2001), Deporter et al. (2001), Romeo et al. (2006)). There was  
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51 also not enough data in the publications included to assess the determinant implant diameter  
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53 in a subgroup analysis.

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58 Two studies, Mericske-Stern et al. (2001) and Polizzi et al. (2000), of the 29 included studies  
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60 for this review were only about single tooth replacements. A total of 59 implants with

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3 different length were included with an event rate of 4. This was insufficient data to do a meta-  
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5 analysis. The rest of the used studies assessed in this review included single and multiple  
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7 (splinted) tooth replacements. In the data presented in these studies no distinction was made  
8  
9 between the implant-supported prosthetic rehabilitation and the removed implants, short  
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11 implants could even be splinted to longer implants. This is a weakness of this systematic  
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13 review, but one can assume that if there is severe peri-implantitis or loss of integration at one  
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15 of a couple of splinted implants, it is best practice to remove this implant, otherwise the other  
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17 implants might also be lost.  
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23 Our study is an implant based analysis, while we would have preferred to perform a patient  
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25 based analysis, as events (implant loss) tend to cluster within the same patients. However, for  
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27 this kind of analysis the data were not exactly enough described, which was partly due to the  
28  
29 fact that most of the studies included in this review are not only about short implants.  
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33 Amongst others, we found some heterogeneity between studies, mostly due to the fact that  
34  
35 most of the included studies were aggregated data sets. Some studies allowed to include  
36  
37 certain groups (viz. smoking) whereas others excluded smokers. To precisely estimate the  
38  
39 influence of such determinants (viz. smoking) one needs access to the original data sets in  
40  
41 order to do the analyses on an individual level. It was, however, impossible to obtain all  
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43 original datasets. To explore and to estimate the influence of the sources of heterogeneity we  
44  
45 did a subgroup analysis. Although, point estimates of the calculated failure rates per implant  
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47 length were different, the confidence intervals around these point estimates were comparable,  
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49 when correcting for the normal finding that these intervals were extended after subgroups  
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51 analyses. Latter observations point to the conclusion that the heterogeneity is not enough to  
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53 reject the results of the estimated failure rate per implant length.  
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3 Our main outcome measure was the estimated implant survival rate after 2 years. We have  
4 chosen for a two year survival rate, as we tend to believe that after more than 1 year in  
5 function the implant survival rate as a function of time after loading has become rather  
6 constant (Esposito et al. 1998). To check this constancy we looked at studies with a follow-up  
7 up to one year and we estimated the survival rates after two years. From this calculations  
8 appeared very outranged numbers as 0.3 -12.0% survival rates. For this reason only studies  
9 with a mean follow up longer than one year were selected. The shortest mean follow up,  
10 included in this review, was 1.6 year. Our findings are confirmed by the prospective study of  
11 Cochran et al. (2009), who found in their radiographic evaluation of crestal bone the least  
12 bone loss between 1-year post-loading and the last 5-year recall. The most bone loss was  
13 found 6 months after implant placement.  
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### 34 **Conclusion**

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36 The findings from this systematic review add to the growing evidence that short (<10 mm)  
37 implants can be successfully placed in the partially edentulous patients, though with a  
38 tendency of an increasing survival rate per implant length. Installation of short dental implants  
39 in the mandible has a better prognosis over installation in the maxilla. Furthermore the results  
40 of studies excluding smokers revealed higher implant survival rates than studies including  
41 heavy smokers ( $\geq 15$  cigarettes per day). Surface topography and an augmentation procedure  
42 preceding the implant installation apparently could not be shown to affect the failure rate of  
43 short implants.  
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Table 1: Overview of the included studies and annual failure and survival rates grouped by implant length.

Study	Year of publication	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	2009	10	5	rough	maxilla	moderate included	yes	1.7	0	193	0.030	94.2
Deporter	2001	2	5	rough	maxilla	excluded	yes	2	0	77	0.072	86.6
<b>Summary estimate (95% CI) of 5 mm implant</b>											<b>0.036</b> (0-0.114)	<b>93.1</b> (79.7-100)
Pjetursson	2009	7	6	rough	maxilla	included	unknown	3.2	3	234	0.134	76.5
Nedir	2004	5	6	rough	maxilla	included	yes	4.4	0	189	0.031	94.0
Nedir	2004	1	6	rough	mandible	included	yes	4.4	0	38	0.136	76.2
Tawil	2003	16	6	machined	mandible	unknown	unknown	2.5	0	1335	0.004	99.2
Mericske-Stern	2001	5	6	rough	both arches	moderate included	unknown	4.3	0	230	0.025	95.1
Brocard	2000	16	6	rough	both arches	included	yes	3.9	3	720	0.050	90.5
Becker	1999	2	6	machined	mandible	moderate included	unknown	1.6	0	68	0.081	85.0
Becker	1999	5	6	machined	maxilla	moderate included	unknown	1.6	1	171	0.070	86.9
<b>Summary estimate (95% CI) of 6 mm implant</b>											<b>0.013</b> (0-0.029)	<b>97.4</b> (94.4-100)
Corrente	2009	38	7	rough	maxilla	moderate included	yes	1.7	1	731	0.016	96.8
Glaser	2005	1	7	rough	both arches	included	yes	4	0	32	0.158	72.9
Beschnidt	2003	4	7	rough	both arches	included	yes	5.3	1	226	0.053	89.9
Tawil	2003	27	7	machined	mandible	unknown	unknown	2.5	5	2252	0.027	94.7
Davarpanah	2002	96	7	rough	both arches	moderate included	no	2.7	4	4243	0.011	97.8
Deporter	2001	44	7	rough	maxilla	excluded	yes	2	0	1703	0.004	99.2
Deporter	2001	32	7	rough	mandible	excluded	unknown	2.7	0	1088	0.005	99.0

1	Testori	2001	3	7	rough	maxilla	moderate included	no	3.6	1	147	0.082	84.9
2	Testori	2001	4	7	rough	mandible	moderate included	no	3.6	0	196	0.030	94.2
3	Polizzi	2000	2	7	rough	both arches	included	unknown	3	0	57	0.095	82.7
4	Becker	1999	1	7	machined	mandible	moderate included	unknown	1.6	0	34	0.150	74.1
5	Becker	1999	5	7	machined	maxilla	moderate included	unknown	1.6	3	171	0.211	65.6
6	Gunne	1999	37	7	machined	both arches	unknown	unknown	7.3	4	3601	0.013	97.4
7	Lekholm	1999	22	7	machined	maxilla	unknown	unknown	8.1	4	1999	0.024	95.3
8	Lekholm	1999	79	7	machined	mandible	unknown	unknown	8.1	2	7316	0.003	99.3
9	Bahat	1993	126	7	machined	maxilla	unknown	unknown	2.5	12	3818	0.038	92.7
10	<b>Summary estimate (95% CI) of 7 mm implant</b>											<b>0.012</b>	<b>97.6</b>
11												(0.006-0.019)	(96.3-98.8)
12	Pjetursson	2009	157	8	rough	maxilla	included	unknown	3.2	2	5238	0.004	99.0
13	Degidi	2006	10	8	rough	both arches	moderate included	unknown	2	0	120	0.111	80.1
14	Romeo	2006	111	8	rough	both arches	excluded	no	6.4	4	8525	0.006	98.8
15	Ferrigno	2005	103	8	rough	both arches	moderate included	yes	5	4	5784	0.008	98.4
16	Cecchinato	2004	33	8	rough	both arches	included	unknown	2	4	737	0.065	87.7
17	Nedir	2004	35	8	rough	maxilla	included	minor	4.4	0	1321	0.005	99.0
18	Nedir	2004	62	8	rough	mandible	included	minor	4.4	0	2340	0.003	99.4
19	Romeo	2004	72	8	rough	both arches	moderate included	no	3.9	6	5479	0.013	97.4
20	McGlumphy	2003	2	8	rough	maxilla	moderate included	unknown	5	0	104	0.055	89.6
21	McGlumphy	2003	18	8	rough	mandible	moderate included	unknown	5	2	985	0.024	95.2
22	Tawil	2003	7	8	machined	maxilla	unknown	unknown	2.5	1	584	0.021	95.9
23	Tawil	2003	20	8	machined	mandible	unknown	unknown	2.5	0	1668	0.004	99.2
24	Mericske-Stern	2001	44	8	rough	both arches	moderate included	unknown	4.3	3	2025	0.018	96.5
25	Brocard	2000	232	8	rough	both arches	included	yes	3.9	15	10440	0.017	96.6

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Buser	1997	389	8	rough	both arches			2	12	14532	0.010	98.0
<b>Summary estimate (95% CI) of 8 mm implant</b>											<b>0.008</b> (0.005-0.011)	<b>98.4</b> (97.8-99.0)
Glauser	2005	4	8.5	rough	both arches	included	yes	4	0	130	0.044	91.6
Sullivan	2005	21	8.5	rough	both arches	moderate included	no	3.6	1	1095	0.011	97.8
Farzad	2004	7	8.5	machined	both arches	unknown	unknown	3.9	0	328	0.018	96.5
Beschnidt	2003	12	8.5	rough	both arches	included	yes	5.3	1	678	0.018	96.5
Tawil	2003	2	8.5	machined	maxilla	unknown	unknown	2.5	0	167	0.035	93.2
Tawil	2003	44	8.5	machined	mandible	unknown	unknown	2.5	2	3670	0.002	99.6
Davarpanah	2002	189	8.5	rough	both arches	moderate included	no	2.7	11	8354	0.016	96.9
Davarpanah	2001	56	8.5	rough	both arches	unknown	no	3	2	1905	0.013	97.4
Testori	2001	8	8.5	rough	maxilla	moderate included	no	3.6	0	393	0.015	97.0
Testori	2001	14	8.5	rough	mandible	moderate included	no	3.6	0	687	0.009	98.2
Polizzi	2000	8	8.5	rough	both arches	included	unknown	3	1	226	0.053	89.9
Becker	1999	17	8.5	machined	mandible	moderate included	unknown	1.6	0	581	0.010	98.0
Becker	1999	7	8.5	machined	maxilla	moderate included	unknown	1.6	0	239	0.024	95.3
Grunder	1999	31	8.5	rough	both arches	included	no	2.4	0	884	0.007	98.6
<b>Summary estimate (95% CI) of 8.5 mm implant</b>											<b>0.006</b> (0.002-0.009)	<b>98.8</b> (98.2-99.6)
Degidi	2009	21	9	rough	both arches	moderate included	no	5	0	1260	0.008	98.4
Degidi	2006	39	9	rough	both arches	moderate included	unknown	2	0	468	0.012	97.6
Cecchinato	2004	65	9	rough	both arches	included	unknown	2	1	1452	0.008	98.4
Nedir	2004	7	9	rough	maxilla	included	minor	4.4	0	264	0.022	95.7
Nedir	2004	1	9	rough	mandible	included	minor	4.4	0	38	0.136	76.2
Deporter	2001	89	9	rough	maxilla	excluded	yes	2	3	3445	0.010	98.0
Deporter	2001	16	9	rough	mandible	excluded	unknown	2.7	0	544	0.011	97.8

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<b>Summary estimate (95% CI) of 9 mm implant</b>											<b>0.010</b> (0.002-0.018)	<b>98.0</b> (96.4-99.6)
Degidi	2006	68	9.5	rough	both arches	moderate included	unknown	2	0	816	0.007	98.6
<b>Summary estimate (95% CI) of 9.5 mm implant</b>											<b>0.007</b> (0-0.028)	<b>98.6</b> (94.6-100)

Table 2: Sources of heterogeneity and their possible role as expressed in 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							
			P-value	I <sup>2</sup>		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)	
						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 1 study included		only 1 study included		only 1 study included		only 1 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)

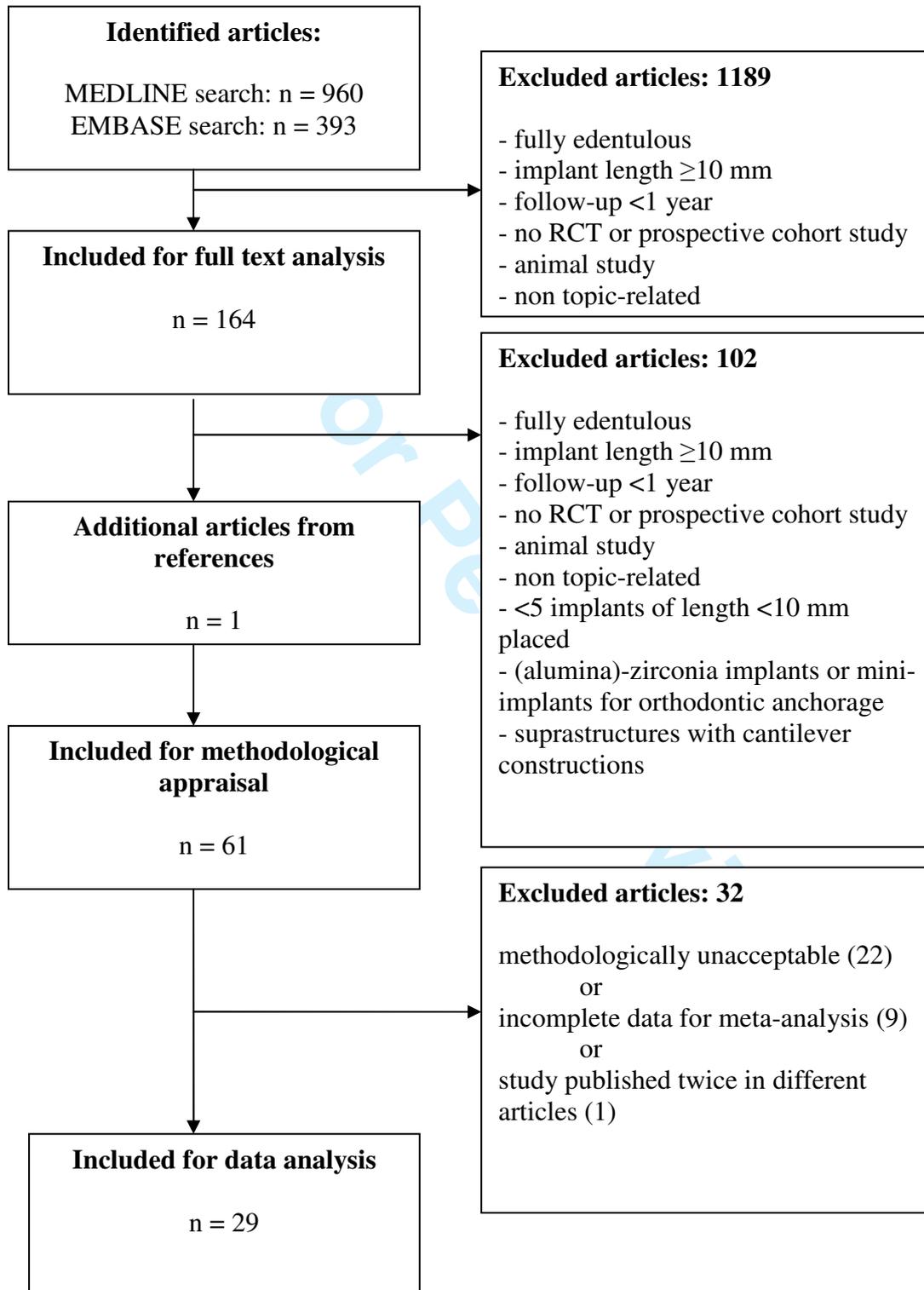
Table 3: Quality assessment of a cohort study

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?			
<b>Four or more pluses = methodologically acceptable</b>			

Table 4: 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?			
<b>Four or more plusses = methodologically acceptable</b>			

Figure 1: Algorithm of study selection procedure



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3 Dear professor Tonetti, editor-in-chief  
4 Journal of Clinical Periodontology  
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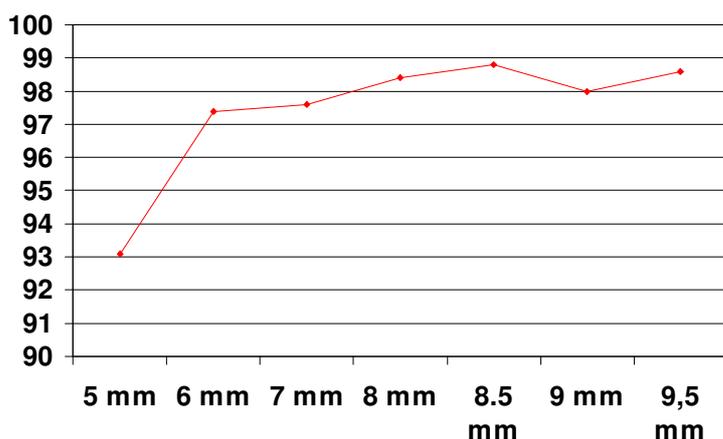
10 Groningen, February 18, 2010  
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13 Dear professor Tonetti,  
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16 We are very happy that our paper, when complying to the minor comments of the referees, is  
17 suitable for publication in Journal of Clinical Periodontology. We have changed the  
18 manuscript according to the comments of the referees. The changes are highlighted in the text.  
19 In detail:  
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### 22 **Referee 1**

23 The referee is right that our conclusion requires further refinement. It is indeed difficult to  
24 discern a true difference in % of the length as presented, although there is a tendency that  
25 survival increases with increasing implant length. See figure below.  
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44 Therefore, as requested, we have made the conclusion of our paper more in line with the data  
45 provided: *The findings from this systematic review add to the growing evidence that short*  
46 *(<10 mm) implants can be successfully placed in the partially edentulous patients, though*  
47 *with a tendency of an increasing survival rate per implant length.*  
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50 Furthermore, the referee asked us to indicate whether the RCT under consideration in our  
51 review was randomized relative to the question under consideration. This was not the case.  
52 Therefore, we have added the next sentence:

53 *The RCT included in this systematic review focused on submerged versus non-submerged*  
54 *healing of endosseous implants and not on implant length*  
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### 57 **Referee 2**

58 We have changed I2 into I<sup>2</sup> as was asked for.  
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We feel that our manuscript has improved further and hope that it now will be accepted for publication in Journal of Clinical Periodontology.

Best regards,  
Also on behalf of the co-authors

Gerdien Telleman

For Peer Review