J Clin Periodontol 2011; 38: 856–863 doi: 10.1111/j.1600-051X.2011.01750.x

Journal of Clinical Periodontology

Impact of dental implant length on early failure rates: a meta-analysis of observational studies

Bernhard Pommer[1], Sophie Frantal[2], Jürgen Willer[3], Martin Posch[2], Georg Watzek[1] and Gabor Tepper[1]

[1]Department of Oral Surgery, Bernhard Gottlieb School of Dentistry, Medical University of Vienna, Vienna, Austria; [2]Core Unit of Medical Statistics and Informatics, Medical University of Vienna, Vienna, Austria; [3]Department for Interdisciplinary Dentistry and Technology, Donau-University, Krems, Austria

Pommer B, Frantal S, Willer J, Posch M, Watzek G, Tepper G. Impact of dental implant length on early failure rates: a meta-analysis of observational studies. J Clin Periodontol 2011; 38: 856–863. doi: 10.1111/j.1600-051X.2011.01750.x.

Abstract

Aim: To test the null hypothesis of no difference in failure rates of short (minimum length: 7 mm) and longer dental implants ($\geqslant$10 mm), a meta-analysis was performed on prospective observational trials.

Materials and Methods: A systematic electronic and hand search was performed to identify eligible studies. Having additional data supplied by the authors, 54 publications were included (19,083 implants).

Results: In case of mandibular implants, the null hypothesis of no impact of reduced implant length on failure within the first year of prosthetic loading could not be rejected. A significant impact of implant length could be substantiated for short machined implants in the anterior [odds ratio (OR) 5.4] and posterior maxilla (OR 3.4), while short rough-surfaced implants demonstrated increased failure rates in the anterior maxillary sites. No influence of implant diameter and denture type on the failure rate of short implants could be revealed.

Conclusion: In areas of reduced alveolar bone height the use of short dental implants may reduce the need for invasive bone augmentation procedures.

Key words: diameter; failure rate; length; short implants; success rate

Accepted for publication 21 May 2011

Endosseous dental implants to replace the natural tooth provide a reliable basis for fixed and removable dentures (Stellingsma et al. 2004). Reduced alveolar bone height due to post-extraction ridge resorption and maxillary sinus pneumatization represents a major limitation in the use of dental implants (Tawil & Younan 2003). Surgical treatment options to overcome this limitation comprise either supplementary bone augmentation procedures or the exclusive use of implants reduced in length (das Neves et al. 2006). The key advantage of placing short implants is the avoidance of invasive bone augmentation surgery associated with donor site morbidity, additional treatment duration and financial burden (Nedir et al. 2004). Further benefits include a reduced risk of sinus perforation and mandibular paraesthesia, as well as the possibility to obviate pre-surgical diagnostic radiography (Misch et al. 2006, Morand & Irinakis 2007). Positive clinical results have increased the interest in this promising technique (Romeo et al. 2006, Tawil et al. 2006, Maló et al. 2007). However, increased failure rates have been observed when placing dental implants under 10 mm in length (Bahat 2000, Attard & Zarb 2003, Weng et al. 2003), indicating a tendency of failures to occur either within the healing phase or the first year of prosthetic loading.

Current literature is still controversial in regard to the reliability and indications of short dental implants. Systematic reviews did not reveal a clear correlation between implant length and implant success rates and evidence from randomized controlled trials (RCTs) is still missing (Hagi et al. 2004, Stellingsma et al. 2004, das Neves et al. 2006, Renouard & Nisand 2006, Kotsovilis et al. 2009). Meta-analysis of RCTs is the gold standard for appraising evidence from clinical trials (Sterne et al. 2001); however, meta-analyses of non-randomized studies allow interventions to be evaluated that are not feasible to investigate by RCTs (Deeks et al. 2003, Reeves & Gaus 2004). As it seems unethical to investigate short implants in jaw regions of large bone volumes in RCTs, it was decided to perform a meta-analysis of prospective observational studies. The aim of the present investigation was to test the null hypothesis of no impact of reduced implant length on implant failure within the first year of loading.

Conflict of interest and source of funding statement

The authors declare that there are no conflicts of interests.
No external funding was obtained.

© 2011 John Wiley & Sons A/S

Materials and Methods

Literature search and selection

A search of English literature published from January, 1998, to January, 2008, was conducted involving an electronic MEDLINE, EMBASE, and CENTRAL search and hand searching of 29 journals (supporting information Table S1). Studies were considered if they met following inclusion criteria: (1) prospective clinical investigations, defined as observational studies where allocation occurs in the course of usual treatment decisions (Higgings & Green 2008), reporting implant failure rates within the first year of prosthetic loading based on established criteria (Albrektsson et al. 1986), (2) endosseous titanium implants placed in non-augmented, healed jawbone and loaded after a conventional healing period of 3–6 months (Degidi et al. 2006), and (3) implants shorter than 10 mm (minimum length: 7 mm) included. Trials investigating patients with general systemic illness or under 20 years of age were not considered. Two reviewers (B. P. and G. T.) independently screened the titles and abstracts of the search results. Full texts of all papers that were considered eligible for inclusion by one or both of the reviewers were obtained for further assessment against the stated inclusion criteria. Disagreements were resolved by consensus. When multiple reports on the same patients were identified, the most recent publication was included.

Data abstraction and collection

Out of 1363 articles screened, 119 publications were selected as preliminary candidates and underwent data abstraction in duplicate. The Newcastle–Ottawa scale (NOS) was used to assess study quality (Wells et al. 2001). Studies that received NOS ratings of $\geqslant 7$ stars (of nine possible stars) were judged as ''high quality'' (Chak et al. 2009). For each trial following information was recorded: implant system and surface texture, number of implants lost to follow-up, and type of prosthetic rehabilitation. The implant data was subdivided according to implant dimension and jaw position; however, the majority of studies did not detail individual failure scores for the various implant lengths and diameters. Owing to inappropriate presentation or limited information provided in the articles, breakdown of data corresponding to the first year of observation could rarely be achieved. Hence a total of 95 authors were contacted for clarification or missing data (119 articles). The corresponding authors received prepared data forms by postal mail, fax, and e-mail and were sent a reminder after 3 and 6 months. Studies were not considered if the required information was not obtained within an editing time of 8 months. After taking into account the additional data kindly provided by the authors, 54 trials constituted the final selection (Fig. 1).

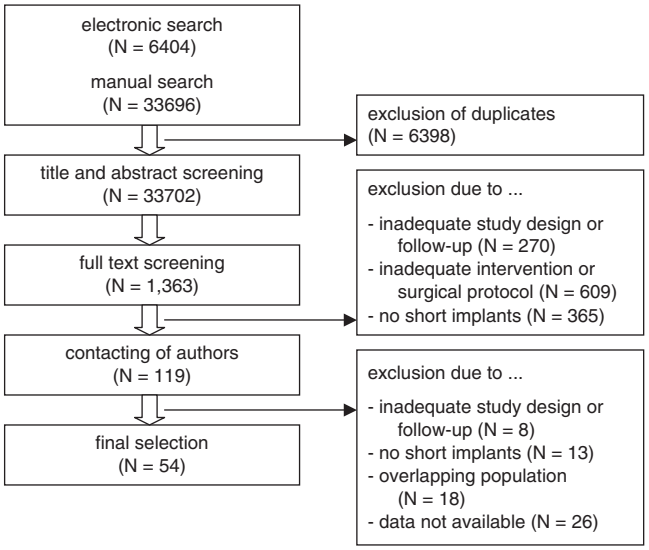

Fig. 1. Flow chart for the search process indicating numbers (*N*) of excluded studies, stages of exclusion, and reasons for exclusion.

Quantitative data synthesis

Outcome measure was implant failure within the first year of prosthetic loading defined as implant mobility, infection, pain, peri-implant radiolucency, or progressive marginal bone loss (Albrektsson et al. 1986). Implants in patients lost to follow-up were not analysed. Two types of analyses were performed: (1) within-study comparison: To estimate the effect of implant length, diameter, and surface texture on failure rates, Mantel–Haenszel tests for the overall odds-ratios, Fischer-exact-tests for the odds-ratios in each study (including 95% confidence intervals), and Woolf's tests for statistical heterogeneity were performed. To correct for multiple testing (for the three overall Mantel–Haenszel tests) a Bonferroni corrected two-side significance level of $0.05/3 = 0.0167$ was applied. The impact of implant length was separately tested for machined- as well as rough-surfaced implants for following subgroups: anterior maxilla, posterior maxilla, anterior mandible, and posterior mandible. In each of the above analyses, only studies with at least 10 implants in each group were included. (2) Descriptive analyses: From the data pooled across all 54 studies failure rates and 95% confidence intervals (based on the binomial test) were computed according to implant diameter and type of denture. All analyses were performed using R 2.4.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

The mean NOS score of the 54 included trials was 7.2 ± 0.5 and ranged between 7 and 9 (supporting information Table S2) indicating high methodological quality throughout the included studies (Table 1). A total of 19,563 implants were placed, of which 480 implants could not be analysed due to patient dropout within the first year (mean drop-out rate: 2.0%). Of the 19,083 implants included, 40.1% were placed in the maxilla and 59.9% were placed in the mandible. 49.3% of the implants were inserted in incisor and canine regions (anterior positions), the other half in pre-molar and molar regions (posterior positions). According to their surface texture, the implants were grouped into 8686 machined and 10,397 rough implants (Khang et al. 2001). 1880 implants supported fixed restorations (single crowns or fixed partial dentures), and 6865 implants supported removable dentures. The mean implant

© 2011 John Wiley & Sons A/S

Table 1. Descriptive information on the 54 included studies

Study	Total number of implants	Number of implant failures	Number of implants lost to follow-up	Implant manufacturer	Implant surface	Type of denture
Arvidson et al. (1998)	618	7	9	Astra Tech	Machined	Fixed
Astrand et al. (2000)	167	12	0	Straumann	Rough	Fixed
Astrand et al. (2004a)	371	9	0	Various	Both	Fixed
Astrand et al. (2004b)	150	3	0	Various	Both	Fixed
Attard and Zarb (2003)	398	18	5	Nobel Biocare	Machined	Fixed
Bahat (2000)	652	25	35	Nobel Biocare	Machined	Fixed
Bakke et al. (2002)	24	0	0	Astra Tech	Machined	Removable
Balleri et al. (2002)	45	0	0	Nobel Biocare	Machined	Fixed
Behneke et al. (2000)	114	0	0	Straumann	Rough	Fixed
Behneke et al. (2002)	340	4	7	Straumann	Rough	Removable
Bergkvist et al. (2004)	144	5	0	Straumann	Rough	Fixed
Bischof et al. (2004)	43	1	0	Straumann	Rough	Fixed
Bischof et al. (2006)	259	2	4	Straumann	Rough	Fixed
Brocard et al. (2000)	830	11	0	Straumann	Rough	Both
Degidi et al. (2006)	521	3	0	Friatec	Rough	Fixed
Deporter et al. (1998)	20	0	0	Endopore	Rough	Fixed
Deporter et al. (1999)	156	6	0	Endopore	Rough	Removable
Deporter et al. (2001a)	48	0	0	Endopore	Rough	Fixed
Deporter et al. (2001b)	149	4	0	Endopore	Rough	Fixed
Eliasson et al. (2000)	476	2	0	Nobel Biocare	Machined	Fixed
Ferrigno et al. (2002)	1044	4	0	Straumann	Rough	Both
Friberg et al. (2000)	247	6	4	Nobel Biocare	Machined	Both
Friberg et al. (2003)	88	8	0	Nobel Biocare	Machined	Fixed
Friberg et al. (2005)	451	5	60	Nobel Biocare	Rough	Both
Gaucher et al. (2001)	688	5	3	Implant Innovations	Rough	Both
Gotfredsen and Karlsson (2001)	128	2	18	Astra Tech	Both	Fixed
Grunder et al. (1999)	219	3	14	Implant Innovations	Rough	Both
Hallman (2001)	182	1	1	Straumann	Rough	Both
Jemt and Johansson (2006)	450	9	20	Nobel Biocare	Machined	Fixed
Khang et al. (2001)	432	36	20	Implant Innovations	Both	Both
Künzel et al. (2002)	432	1	12	Straumann	Rough	Both
Mattsson et al. (1999)	86	1	0	Nobel Biocare	Machined	Fixed
Moheng and Feryn (2005)	266	9	0	Various	Rough	Both
Nedir et al. (2006)	522	2	25	Straumann	Rough	Both
Ortorp and Jemt (2004)	367	0	11	Nobel Biocare	Machined	Removable
Palmer et al. (2005)	21	0	2	Astra Tech	Rough	Fixed
Preiskel and Tsolka (2004)	269	5	2	Nobel Biocare	Machined	Fixed
Renouard et al. (1999)	59	4	0	Nobel Biocare	Machined	Fixed
Romeo et al. (2002)	187	0	4	Straumann	Rough	Fixed
Romeo et al. (2003)	100	2	0	Various	Both	Fixed
Romeo et al. (2004)	759	2	0	Straumann	Rough	Both
Romeo et al. (2006)	265	0	0	Straumann	Rough	Both
Sethi et al. (2000)	2261	33	141	Various	Both	Both
Tangerud et al. (2002)	85	5	0	Nobel Biocare	Machined	Fixed
Tawil and Younan (2003)	253	4	9	Nobel Biocare	Machined	Fixed
Tawil et al. (2006)	244	0	0	Nobel Biocare	Machined	Fixed
Testori et al. (2001)	485	6	34	Implant Innovations	Rough	Fixed
Visser et al. (2006)	196	8	0	Various	Both	Removable
Weng et al. (2003)	874	41	9	Implant Innovations	Machined	Fixed
Wennerberg et al. (2001)	538	1	4	Nobel Biocare	Machined	Removable
Widmark et al. (2001)	117	5	9	Nobel Biocare	Machined	Both
Widmark et al. (2003)	194	3	16	Nobel Biocare	Machined	Both
Willer et al. (2003)	1250	11	2	Friatec	Rough	Both
Wismeijer et al. (1999)	281	4	0	Straumann	Rough	Removable

Astra Tech AB (Mölndal, Sweden), Straumann AG (Waldenburg, Switzerland), Nobel Biocare (Gothenburg, Sweden), Friatech (Mannheim, Germany), Implant Innovations (West Palm Beach, FL, USA), Endopore (Innova Corporation, Toronto, ON, Canada).

diameter accounted 4.0 mm (range: 2.75–6.5 mm): 2568 implants were classified as narrow-diameter implants (<3.75 mm), and 16,515 implants as regular-diameter implants ($\geqslant 3.75$ mm). Implant length ranged between 7 and 20 mm: 2581 implants were shorter than 10 mm in length (short implants), while 16,502 implants were as least 10 mm long.

Within-study comparison of short and long implants was possible in 40 trials and is illustrated as a forest plot (Fig. 2). Short implants demonstrated a significantly higher overall failure rate compared with longer implants [odds ratio (OR) 1.8] with significant differences observed in the anterior (OR 6.1) and posterior (OR 3.6) maxilla, while no effect could be seen in the mandible (Table 2). Rough-surfaced implants

© 2011 John Wiley & Sons A/S

showed significantly lower failure rates than machined ones (OR 3.6) and were therefore tested separately: While machined implants still demonstrated a significant impact of implant length overall as well as in the anterior and posterior maxilla (OR 2.2, 5.4, and 3.4, respectively), no significant overall effect could be substantiated for rough-surfaced implants (OR 1.1). In the anterior maxilla, short rough-surfaced implants demonstrated significantly increased failure rate (1.4% *versus* 0.0%), yet, no OR could be calculated due to the absence of long implant failures. In conclusion, the null hypothesis of no impact of reduced implant length on implant failure within the first year of loading could not be rejected with the exception of machined maxillary implants and rough-surfaced implants in the anterior maxilla.

There was no significant difference between narrow- and regular-diameter implants, neither for machined (OR 1.1) nor for rough surfaces (OR 1.0). Significant heterogeneity across studies was observed only in implant diameter comparison ($p = 0.01$). The symmetry of the funnel plot (Fig. 3) does not suggest the presence of publication bias (Sterne & Egger 2001). Descriptive analyses yielded no increased failure rates of short narrow-diameter implants compared with short regular-diameter implants in both maxillary and mandibular sites (Table 3). Failure rates of short implants supporting fixed dentures were not found to be higher than those supporting removable dentures, yet direct comparison was only possible for implants placed in the anterior mandible.

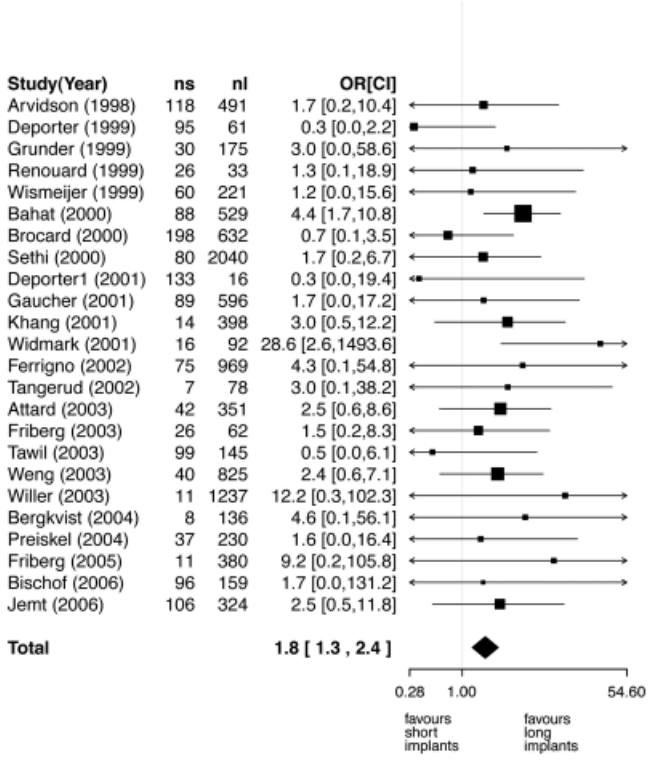

Fig. 2. Forest plot: number of short (ns) and long implants (nl) in each study and odds ratios (OR) with 95% confidence intervals (CI). Studies with <10 implants in each group or OR = 0, OR = ∞, and OR not estimable were excluded.

Discussion

It has been an axiom in implant dentistry that longer implants guarantee lower failure rates, although a linear relationship between implant length and success has never been proven (Lee et al. 2005). Clinical strategies to increase the surface area of short implants include the use of rough-surfaced implants as well as wider implant diameters (Tawil

Table 2. Impact of implant length on implant failure rate (within-study comparison): odds ratios (OR) with 95% confidence intervals ($CI_{95\%}$), number of studies (*N*), test-statistics for Mantel–Haenszel tests (MH), estimated failure rates after 1 year of function and sample size (*n*) of short ($\geqslant 7$ mm, <10 mm) and long ($\geqslant 10$ mm) implants

	OR [$CI_{95\%}$]	*N*	MH (*p*)	Failure rate of short implants	Failure rate of long implants
All implants					
All positions	1.8 [1.3–2.5]	40	13.3 ($p<0.001$)	2.5% ($n = 2223$)	1.6% ($n = 14{,}158$)
Anterior maxilla	6.1 [2.2–17.3]	7	16.7 ($p<0.001$)	4.4% ($n = 203$)	0.6% ($n = 801$)
Posterior maxilla	3.6 [1.4–4.9]	13	12.0 ($p = 0.001$)	4.1% ($n = 464$)	2.3% ($n = 1579$)
Anterior mandible	0.8 [0.3–2.0]	10	0.4 ($p = 0.550$)	1.4% ($n = 420$)	1.1% ($n = 2241$)
Posterior mandible	0.9 [0.4–1.7]	22	0.2 ($p = 0.678$)	1.1% ($n = 934$)	1.7% ($n = 3669$)
Machined-surfaced implants					
All positions	2.2 [1.5–3.3]	17	16.2 ($p<0.001$)	4.1% ($n = 897$)	2.2% ($n = 6094$)
Anterior maxilla	5.4 [1.9–15.7]	3	12.8 ($p<0.001$)	6.0% ($n = 134$)	1.1% ($n = 440$)
Posterior maxilla	3.4 [1.7–6.6]	4	15.7 ($p<0.001$)	11.8% ($n = 136$)	3.7% ($n = 816$)
Anterior mandible	0.8 [0.2–3.6]	3	0.1 ($p = 0.760$)	1.0% ($n = 196$)	1.2% ($n = 1057$)
Posterior mandible	1.1 [0.5–2.3]	8	0.0 ($p = 0.856$)	2.2% ($n = 367$)	3.1% ($n = 1539$)
Rough-surfaced implants					
All positions	1.1 [0.6–2.1]	22	0.1 ($p = 0.733$)	1.2% ($n = 1298$)	0.7% ($n = 7544$)
Anterior maxilla	∞	4	7.9 ($p = 0.005$)	1.4% ($n = 69$)	0.0% ($n = 361$)
Posterior maxilla	0.9 [1.7–4.2]	9	0.0 ($p = 0.826$)	0.9% ($n = 328$)	0.8% ($n = 763$)
Anterior mandible	0.7 [0.2–2.4]	8	0.3 ($p = 0.575$)	1.8% ($n = 224$)	1.0% ($n = 1184$)
Posterior mandible	0.5 [0.1–2.3]	13	0.8 ($p = 0.365$)	0.4% ($n = 555$)	0.7% ($n = 2076$)

© 2011 John Wiley & Sons A/S

& Younan 2003). In the present analysis, however, short narrow-diameter implants did not demonstrate higher failure rates when compared with their regular-diameter counterparts. The present meta-analysis suggests that rough-surfaced implants with a minimum length of 7 mm represent no risk factor for implant failure if not placed in the anterior maxilla. The clinical use of short implants in this region may, however, be limited to edentulous patients (illustrated by the small sample size of only 1% of analysed implants), as single tooth replacement in the aesthetic zone generally calls for correct apico-coronal implant positioning in order to achieve long-term aesthetic results (Chen & Buser 2009).

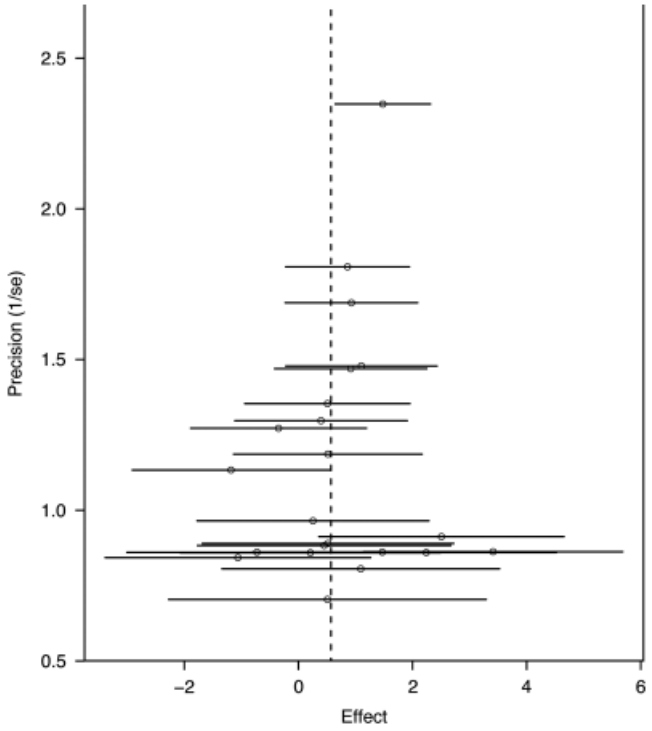

Fig. 3. Funnel plot for publication bias (1/standard error against log odds ratio). Only studies with finite standard error are included.

Identification of factors impairing dental implant success is the main goal of recent research in implant dentistry (Morand & Irinakis 2007). In assessing implant failure rates, it is important to consider multiple factors together because of their interactive effects on the establishment and maintainance of osseointegration (Romeo et al. 2006). In the present meta-analysis attempts were made to control the relevant confounding variables (implant location, diameter, surface texture, timing of implant placement, loading protocol, type of denture, success criteria, and duration of follow-up). Further prosthetic factors, such as crown-to-implant ratio, splinting, occlusal table, cantilever length, implant system, opposing dentition, and bruxism, did not prove to influence short implant failure in recent investigations (Nedir et al. 2004, Tawil et al. 2006, Maló et al. 2007). One potential confounding factor is the cluster effect due to the presence of multiple implants in individual patients (Chuang & Cai 2006). Another important issue that should be kept in mind when interpreting these results is that they come from observational studies. There is controversy over the validity of evidence from non-randomized studies, as

Table 3. Descriptive analysis (data pooled across all 54 studies) for implant diameter and type of denture: failure rates (%) after 1 year of function [$CI_{95\%}$] and sample size (n) of short ($\geqslant 7$ mm, < 10 mm) and long ($\geqslant 10$ mm) implants

	All positions	Anterior maxilla	Posterior maxilla	Anterior mandible	Posterior mandible
Narrow diameter (< 3.75 mm)					
Short	1.7 [0.6–3.9]	3.9 [0.5–13.5]	2.0 [0.0–10.4]	1.6 [0.2–5.5]	0.0 [0.0–5.8]
	$n = 293$	$n = 51$	$n = 51$	$n = 129$	$n = 62$
Long	1.3 [0.9–1.8]	1.5 [0.8–2.5]	2.0 [0.7–4.3]	0.9 [0.4–1.8]	0.7 [0.1–2.6]
	$n = 2275$	$n = 919$	$n = 297$	$n = 785$	$n = 274$
Regular diameter ($\geqslant 3.75$ mm)					
Short	2.6 [2.0–3.3]	5.0 [2.5–8.7]	4.7 [3.0–6.8]	1.9 [1.0–3.4]	1.2 [0.6–2.2]
	$n = 2288$	$n = 221$	$n = 536$	$n = 568$	$n = 963$
Long	1.7 [1.5–1.9]	2.1 [1.5–2.7]	2.1 [1.6–2.7]	1.1 [0.8–1.4]	1.9 [1.5–2.3]
	$n = 14{,}227$	$n = 2416$	$n = 3155$	$n = 4315$	$n = 4341$
Supporting removable dentures					
Short	1.2 [0.2–3.5]			1.2 [0.2–3.5]	
	$n = 250$	$n = 0$	$n = 0$	$n = 250$	$n = 0$
Long	1.2 [0.8–1.9]			1.2 [0.8–1.9]	
	$n = 1630$	$n = 0$	$n = 0$	$n = 1630$	$n = 0$
Supporting fixed dentures					
Short	3.2 [2.3–4.3]	4.0 [1.6–8.1]	5.7 [3.7–8.4]	1.6 [0.2–5.5]	1.2 [0.4–2.6]
	$n = 1200$	$n = 174$	$n = 403$	$n = 129$	$n = 494$
Long	2.3 [1.9–2.7]	2.7 [1.9–3.8]	2.8 [2.1–3.6]	0.9 [0.4–1.6]	2.4 [1.8–3.2]
	$n = 6153$	$n = 1238$	$n = 1808$	$n = 1231$	$n = 1876$
All implants	1.8 [1.6–2.0]	2.1 [1.7–2.7]	2.5 [2.0–3.0]	1.1 [0.9–1.4]	1.7 [1.4–2.1]
	$n = 19{,}083$	$n = 3607$	$n = 4039$	$n = 5797$	$n = 5640$

© 2011 John Wiley & Sons A/S

they are more susceptible to bias (Deeks et al. 2003). Dimensions of bias to be assessed include selection, performance, detection, attrition, and publication bias (MacLehose et al. 2000). Selection bias (concerning comparability of groups) may occur due to non-randomized treatment allocation, so particular care was given to the assessment of confounding (Higgings & Green 2008). By definition of strict inclusion criteria and quality assessment it was attempted to reduce performance bias (concerning the fidelity of the intervention), detection bias (concerning correct assessment of outcome), and attrition bias (concerning completeness of sample, follow-up and data). Quality of reporting was no issue due to the additional information provided by the authors. Performance bias may be minimized by the fact that only six studies focused on the topic of implant length. The authors attach importance to the fact that the pattern of early implant failure may not be extrapolated to long-term outcomes, although studies indicate that the first year is crucial for the success of short implants (Maló et al. 2007).

The present meta-analysis confirms the hypothesis of multicenter retrospective studies (Misch et al. 2006, Maló et al. 2007) that implant diameter increase can not compensate for length reduction. Further studies are needed in order to clearly define the limits of narrow-diameter implants with regards to clinical indications and long-term fate (Renouard & Nisand 2006). The present results are in accordance with systematic reviews that observed increased failure rates of implants shorter than 7 mm (Hagi et al. 2004, das Neves et al. 2006). A research question that still remains to be answered is from what minimal length the risk of implant failure actually increases. To compare failure rates of short implants placed in original jawbone with those of longer implants placed in the augmented bone, randomized controlled studies are needed (Graziani et al. 2004).

Acknowledgements

We would like to express special acknowledgement to all authors that contributed in this ambitious project and kindly provided additional data of their investigations: P. Åstrand, N. J. Attard, M. Bakke, P. Balleri, G. Brunel, M. Degidi, D. Deporter, A. Eliasson, N. Ferrigno, B. Friberg, A. G. Grønningsæter, T. Jemt, T. Kaus, J. T. Lambrecht, D. Lops, T. Mattsson, H. J. Meijer, P. Moheng, R. Nedir, N. Nurdin, A. Örtorp, R. Palmer, A. Piattelli, H. W. Preiskel, A. Rätzer, A. Sethi, G. Tawil, A. Visser, A. Wennerberg, D. Wismeijer.

References

Albrektsson, T., Zarb, G., Worthington, P. & Eriksson, A. R. (1986) The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *The International Journal of Oral & Maxillofacial Implants* **1**, 11–25.

Arvidson, K., Bystedt, H., Frykholm, A., von Konow, L. & Lothigius, E. (1998) Five-year prospective follow-up report of the Astra Tech Dental Implant System in the treatment of edentulous mandibles. *Clinical Oral Implants Research* **9**, 225–234.

Astrand, P., Anzén, B., Karlsson, U., Sahlholm, S., Svärdström, P. & Hellem, S. (2000) Nonsubmerged implants in the treatment of the edentulous upper jaw: a prospective clinical and radiographic study of ITI implants – results after 1 year. *Clinical Implant Dentistry and Related Research* **2**, 166–174.

Astrand, P., Engquist, B., Dahlgren, S., Gröndahl, K., Engquist, E. & Feldmann, H. (2004a) Astra Tech and Brånemark system implants: a prospective 5-year prospective study of marginal bone reactions. *Clinical Oral Implants Research* **15**, 413–420.

Astrand, P., Engquist, B., Anzén, B., Bergendal, T., Hallman, M., Karlsson, U., Kvint, S., Lysell, L. & Rundcranz, T. (2004b) A three-year follow-up report of a comparative study of ITI Dental Implants and Brånemark System implants in the treatment of the partially edentulous maxilla. *Clinical Implant Dentistry and Related Research* **6**, 130–141.

Attard, N. J. & Zarb, G. A. (2003) Implant prosthodontic management of partially edentulous patients missing posterior teeth: the Toronto experience. *The Journal of Prosthetic Dentistry* **89**, 352–359.

Bahat, O. (2000) Brånemark system implants in the posterior maxilla: clinical study of 660 implants followed for 5 to 12 years. *The International Journal of Oral & Maxillofacial Implants* **15**, 646–653.

Bakke, M., Holm, B. & Gotfredsen, K. (2002) Masticatory function and patient satisfaction with implant-supported mandibular overdentures: a prospective 5-year study. *The International Journal of Prosthodontics* **15**, 575–581.

Balleri, P., Cozzolino, A., Ghelli, L., Momicchioli, G. & Varriale, A. (2002) Stability measurements of osseointegrated implants using Osstell in partially edentulous jaws after 1 year of loading: a pilot study. *Clinical Implant Dentistry and Related Research* **4**, 128–132.

Behneke, A., Behneke, N. & d'Hoedt, B. (2000) The longitudinal clinical effectiveness of ITI solid-screw implants in partially edentulous patients: a 5-year follow-up report. *The International Journal of Oral & Maxillofacial Implants* **15**, 633–645.

Behneke, A., Behneke, N. & d'Hoedt, B. (2002) A 5-year longitudinal study of the clinical effectiveness of ITI solid-screw implants in the treatment of mandibular edentulism. *The International Journal of Oral & Maxillofacial Implants* **17**, 799–810.

Bergkvist, G., Sahlholm, S., Nilner, K. & Lindh, C. (2004) Implant-supported fixed prostheses in the edentulous maxilla. A 2-year clinical and radiological follow-up of treatment with non-submerged ITI implants. *Clinical Oral Implants Research* **15**, 351–359.

Bischof, M., Nedir, R., Abi Najm, S., Szmukler-Moncler, S. & Samson, J. (2006) A five-year life-table analysis on wide neck ITI implants with prosthetic evaluation and radiographic analysis: results from a private practice. *Clinical Oral Implants Research* **17**, 512–520.

Bischof, M., Nedir, R., Szmukler-Moncler, S., Bernard, J. P. & Samson, J. (2004) Implant stability measurement of delayed and immediately loaded implants during healing. *Clinical Oral Implants Research* **15**, 529–539.

Brocard, D., Barthet, P., Baysse, E., Duffort, J. F., Eller, P., Justumus, P., Marin, P., Oscaby, F., Simonet, T., Benqué, E. & Brunel, G. (2000) A multicenter report on 1,022 consecutively placed ITI implants: a 7-year longitudinal study. *The International Journal of Oral & Maxillofacial Implants* **15**, 691–700.

Chak, E., Rutherford, G. W. & Steinmaus, C. (2009) The role of breast-feeding in the prevention of *Helicobacter pylori* infection: a systematic review. *Clinical Infectious Diseases* **48**, 430–437.

Chen, S. T. & Buser, D. (2009) Clinical and esthetic outcomes of implants placed in postextraction sites. *The International Journal of Oral & Maxillofacial Implants* **24** (Suppl.), 186–217.

Chuang, S. K. & Cai, T. (2006) Predicting clustered dental implant survival using frailty methods. *Journal of Dental Research* **85**, 1147–1151.

das Neves, F. D., Fones, D., Bernardes, S. R., do Prado, C. J. & Neto, A. J. (2006) Short implants – an analysis of longitudinal studies. *The International Journal of Oral & Maxillofacial Implants* **21**, 86–93.

Deeks, J. J., Dinnes, J., D'Amico, R., Sowden, A. J., Sakarovitch, C., Song, F., Petticrew, M. & Altman, D. G. (2003) Evaluating non-randomised intervention studies. *Health Technology Assessment* **7**, 1–173.

Degidi, M., Piattelli, A. & Carinci, F. (2006) Parallel screw cylinder implants: comparative analysis between immediate loading and two-stage healing of 1,005 dental implants with a 2-year follow up. *Clinical Implant Dentistry and Related Research* **8**, 151–160.

Deporter, D., Pilliar, R. M., Todescan, R., Watson, P. & Pharoah, M. (2001a) Managing the posterior mandible of partially edentulous patients with short, porous-surfaced dental implants: early data from a clinical trial. *The International Journal of Oral & Maxillofacial Implants* **16**, 653–658.

Deporter, D. A., Todescan, R., Watson, P. A., Pharoah, M., Pilliar, R. M. & Tomlinson, G. (2001b) A prospective human clinical trial of Endopore dental implants in restoring the partially edentulous maxilla using fixed prostheses. *The International Journal of Oral & Maxillofacial Implants* **16**, 527–536.

Deporter, D., Watson, P., Pharoah, M., Levy, D. & Todescan, R. (1999) Five- to six-year results of a prospective clinical trial using the Endopore dental implant and a mandibular overdenture. *Clinical Oral Implants Research* **10**, 95–102.

Deporter, D. A., Todescan, R., Watson, P. A., Pharoah, M., Levy, D. & Nardini, K. (1998) Use of the Endopore dental implant to restore single teeth in the maxilla: protocol and early results. *The International Journal of Oral & Maxillofacial Implants* **13**, 263–272.

Eliasson, A., Palmqvist, S., Svenson, B. & Sondell, K. (2000) Five-year results with fixed complete-arch mandibular prostheses supported by 4 implants. *The International Journal of Oral & Maxillofacial Implants* **15**, 505–510.

Ferrigno, N., Laureti, M., Fanali, S. & Grippaudo, G. (2002) A long-term follow-up study of non-submerged ITI implants in the treatment of totally edentulous jaws. Part I: ten-year life table analysis of a prospective multicenter study with 1286

© 2011 John Wiley & Sons A/S

implants. *Clinical Oral Implants Research* **13**, 260–273.

Friberg, B., Dahlin, C., Widmark, G., Ostman, P. O. & Billström, C. (2005) One-year results of a prospective multicenter study on Brånemark System implants with a TiUnite surface. *Clinical Implant Dentistry and Related Research* **7** (Suppl. 1), 70–75.

Friberg, B., Gröndahl, K., Lekholm, U. & Brånemark, P. I. (2000) Long-term follow-up of severely atrophic edentulous mandibles reconstructed with short Brånemark implants. *Clinical Implant Dentistry and Related Research* **2**, 184–189.

Friberg, B., Jisander, S., Widmark, G., Lundgren, A., Ivanoff, C. J., Sennerby, L. & Thorén, C. (2003) One-year prospective three-center study comparing the outcome of a ''soft bone implant'' (prototype Mk IV) and the standard Brånemark implant. *Clinical Implant Dentistry and Related Research* **5**, 71–77.

Gaucher, H., Bentley, K., Roy, S., Head, T., Blomfield, J., Blondeau, F., Nicholson, L., Chehade, A., Tardif, N. & Emery, R. (2001) A multi-centre study of Osseotite implants supporting mandibular restorations: a 3-year report. *Journal of the Canadian Dental Association* **67**, 528–533.

Gotfredsen, K. & Karlsson, U. (2001) A prospective 5-year study of fixed partial prostheses supported by implants with machined and TiO2-blasted surface. *Journal of Prosthodontics* **10**, 2–7.

Graziani, F., Donos, N., Needleman, I., Gabriele, M. & Tonetti, M. (2004) Comparison of implant survival following sinus floor augmentation procedures with implants placed in pristine posterior maxillary bone: a systematic review. *Clinical Oral Implants Research* **15**, 677–682.

Grunder, U., Gaberthuel, T., Boitel, N., Imoberdorf, M., Meyenberg, K., Andreoni, C. & Meier, T. (1999) Evaluating the clinical performance of the Osseotite implant: defining prosthetic predictability. *Compendium of Continuing Education in Dentistry* **20**, 628–633.

Hagi, D., Deporter, D. A., Pilliar, R. M. & Arenovich, T. (2004) A targeted review of study outcomes with short ($<$ or $=7$ mm) endosseous dental implants placed in partially edentulous patients. *Journal of Periodontology* **75**, 798–804.

Hallman, M. (2001) A prospective study of treatment of severely resorbed maxillae with narrow nonsubmerged implants: results after 1 year of loading. *The International Journal of Oral & Maxillofacial Implants* **16**, 731–736.

Higgings, J. P. T. & Green, S. (2008) *Cochrane Handbook for Systematic Reviews of Interventions. Version 5.0.1*. The Cochrane Collaboration. Available at http://www.cochrane-handbook.org. [Accessed 09 June 2011]

Jemt, T. & Johansson, J. (2006) Implant treatment in the edentulous maxillae: a 15-year follow-up study on 76 consecutive patients provided with fixed prostheses. *Clinical Implant Dentistry and Related Research* **8**, 61–69.

Khang, W., Feldman, S., Hawley, C. E. & Gunsolley, J. (2001) A multi-center study comparing dual acid-etched and machined-surfaced implants in various bone qualities. *Journal of Periodontology* **72**, 1384–1390.

Kotsovilis, S., Fourmousis, I., Karoussis, I. K. & Bamia, C. (2009) A systematic review and meta-analysis on the effect of implant length on the survival of rough-surface dental implants. *Journal of Periodontology* **80**, 1700–1718.

Künzel, A. R., Schiel, H. J. & Lambrecht, J. T. (2002) Long-time results of ITI full-screw implants. Analysis of 10-year effectiveness of 468 implants. *Schweizer Monatsschrift für Zahnmedizin* **112**, 20–35.

Lee, J. H., Frias, V., Lee, K. W. & Wright, R. F. (2005) Effect of implant size and shape on implant success rates: a literature review. *The Journal of Prosthetic Dentistry* **94**, 377–381.

MacLehose, R. R., Reeves, B. C., Harvey, I. M., Sheldon, T. A., Russell, I. T. & Black, A. M. (2000) A systematic review of comparisons of effect sizes derived from randomised and non-randomised studies. *Health Technology Assessment* **4**, 1–154.

Maló, P., de Araújo Nobre, M. & Rangert, B. (2007) Short implants placed one-stage in maxillae and mandibles: a retrospective clinical study with 1 to 9 years of follow-up. *Clinical Implant Dentistry and Related Research* **9**, 15–21.

Mattsson, T., Köndell, P. A., Gynther, G. W., Fredholm, U. & Bolin, A. (1999) Implant treatment without bone grafting in severely resorbed edentulous maxillae. *Journal of Oral and Maxillofacial Surgery* **57**, 281–287.

Misch, C. E., Steignga, J., Barboza, E., Misch-Dietsh, F., Cianciola, L. J. & Kazor, C. (2006) Short dental implants in posterior partial edentulism: a multicenter retrospective 6-year case series study. *Journal of Periodontology* **77**, 1340–1347.

Moheng, P. & Feryn, J. M. (2005) Clinical and biologic factors related to oral implant failure: a 2-year follow-up study. *Implant Dentistry* **14**, 281–288.

Morand, M. & Irinakis, T. (2007) The challenge of implant therapy in the posterior maxilla: providing a rationale for the use of short implants. *The Journal of Oral Implantology* **33**, 257–266.

Nedir, R., Bischof, M., Briaux, J. M., Beyer, S., Szmukler-Moncler, S. & Bernard, J. P. (2004) A 7-year life table analysis from a prospective study on ITI implants with special emphasis on the use of short implants. Results from a private practice. *Clinical Oral Implants Research* **15**, 150–157.

Nedir, R., Bischof, M., Szmukler-Moncler, S., Belser, U. C. & Samson, J. (2006) Prosthetic complications with dental implants: from an up-to-8-year experience in private practice. *The International Journal of Oral & Maxillofacial Implants* **21**, 919–928.

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

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

Preiskel, H. W. & Tsolka, P. (2004) Cement- and screw-retained implant-supported prostheses: up to 10 years of follow-up of a new design. *The International Journal of Oral & Maxillofacial Implants* **19**, 87–91.

Reeves, B. C. & Gaus, W. (2004) Guidelines for reporting non-randomised studies. *Research in Complementary and Natural Classical Medicine* **11** (Suppl. 1), 46–52.

Renouard, F., Arnoux, J. P. & Sarment, D. P. (1999) Five-mm-diameter implants without a smooth surface collar: report on 98 consecutive placements. *The International Journal of Oral & Maxillofacial Implants* **14**, 101–107.

Renouard, F. & Nisand, D. (2006) Impact of implant length and diameter on survival rates. *Clinical Oral Implants Research* **17** (Suppl. 2), 35–51.

Romeo, E., Chiapasco, M., Ghisolfi, M. & Vogel, G. (2002) Long-term clinical effectiveness of oral implants in the treatment of partial edentulism. Seven-year life table analysis of a prospective study with ITI dental implants system used for single-tooth restorations. *Clinical Oral Implants Research* **13**, 133–143.

Romeo, E., Ghisolfi, M., Rozza, R., Chiapasco, M. & Lops, D. (2006) Short (8-mm) dental implants in the rehabilitation of partial and complete edentulism: a 3- to 14-year longitudinal study. *The International Journal of Prosthodontics* **19**, 586–592.

Romeo, E., Lops, D., Margutti, E., Ghisolfi, M., Chiapasco, M. & Vogel, G. (2003) Implant-supported fixed cantilever prostheses in partially edentulous arches. A seven-year prospective study. *Clinical Oral Implants Research* **14**, 303–311.

Romeo, E., Lops, D., Margutti, E., Ghisolfi, M., Chiapasco, M. & Vogel, G. (2004) Long-term survival and success of oral implants in the treatment of full and partial arches: a 7-year prospective study with the ITI dental implant system. *The International Journal of Oral & Maxillofacial Implants* **19**, 247–259.

Sethi, A., Kaus, T. & Sochor, P. (2000) The use of angulated abutments in implant dentistry: five-year clinical results of an ongoing prospective study. *The International Journal of Oral & Maxillofacial Implants* **15**, 801–810.

Stellingsma, C., Vissink, A., Meijer, H. J., Kuiper, C. & Raghoebar, G. M. (2004) Implantology and the severely resorbed edentulous mandible. *Critical Reviews in Oral Biology and Medicine* **15**, 240–248.

Sterne, J. A. C. & Egger, M. (2001) Funnel plots for detecting bias in meta-analysis: guidelines on choice of axis. *Journal of Clinical Epidemiology* **54**, 1046–1055.

Sterne, J. A. C., Egger, M. & Davey-Smith, G. (2001) Investigating and dealing with publication and other biases in meta-analysis. *British Medical Journal* **323**, 101–105.

Tangerud, T., Grønningsaeter, A. G. & Taylor, A. (2002) Fixed partial dentures supported by natural teeth and Brånemark system implants: a 3-year report. *The International Journal of Oral & Maxillofacial Implants* **17**, 212–219.

Tawil, G., Aboujaoude, N. & Younan, R. (2006) Influence of prosthetic parameters on the survival and complication rates of short implants. *The International Journal of Oral and Maxillofacial Implants* **21**, 275–282.

Tawil, G. & Younan, R. (2003) Clinical evaluation of short, machined-surface implants followed for 12 to 92 months. *The International Journal of Oral & Maxillofacial Implants* **18**, 894–901.

Testori, T., Wiseman, L., Woolfe, S. & Porter, S. S. (2001) A prospective multicenter clinical study of the Osseotite implant: four-year interim report. *The International Journal of Oral & Maxillofacial Implants* **16**, 193–200.

Visser, A., Meijer, H. J., Raghoebar, G. M. & Vissink, A. (2006) Implant-retained mandibular overdentures versus conventional dentures: 10 years of care and aftercare. *International Journal of Prosthodontics* **19**, 271–278.

Wells, G., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M. & Tugwell, P. (2001) The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Available at http://www.ohri.ca/programs/clinical_epidemiology/oxford.htm (accessed January 2008).

Weng, D., Jacobson, Z., Tarnow, D., Hürzeler, M. B., Faehn, O., Sanavi, F., Barkvoll, P. & Stach, R. M. (2003) A prospective multicenter clinical trial of 3i machined-surface implants: results after 6 years of follow-up. *The International Journal of Oral & Maxillofacial Implants* **18**, 417–423.

Wennerberg, A., Carlsson, G. E. & Jemt, T. (2001) Influence of occlusal factors on treatment outcome: a study of 109 consecutive patients with mandibular implant-supported fixed prostheses opposing maxillary complete dentures. *International Journal of Prosthodontics* **14**, 550–555.

Widmark, G., Andersson, B., Carlsson, G. E., Lindvall, A. M. & Ivanoff, C. J. (2001) Rehabilitation of patients with severely resorbed maxillae by means of implants with or without bone grafts: a 3- to 5-year

© 2011 John Wiley & Sons A/S

follow-up clinical report. *The International Journal of Oral & Maxillofacial Implants* **16**, 73–79.
Widmark, G., Friberg, B., Johansson, B., Sindet-Pedersen, S. & Taylor, A. (2003) Mk III: a third generation of the self-tapping Brånemark System implant, including the new Stargrip internal grip design. A 1-year prospective four-center study. *Clinical Implant Dentistry and Related Research* **5**, 273–279.
Willer, J., Noack, N. & Hoffmann, J. (2003) Survival rate of IMZ implants: a prospective 10-year analysis. *Journal of Maxillofacial and Oral Surgery* **61**, 691–695.
Wismeijer, D., van Waas, M. A., Mulder, J., Vermeeren, J. I. & Kalk, W. (1999) Clinical and radiological results of patients treated with three treatment modalities for overdentures on implants of the ITI Dental Implant System. A randomized controlled clinical trial. *Clinical Oral Implants Research* **10**, 297–306.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Search strategy for electronic and manual searches. The number (N) of articles in the 29 screened journals are given.

Table S2. Quality assessment of the 54 included studies using the Newcastle Ottawa Scale (NOS). The NOS assesses nine criteria (category [A]–[E]): a maximum of 2 stars can be allotted in the category [E] while a maximum of 1 star can be given for all other categories. Description of star rating system: [A] studies are allotted one star in case the intervention cohort is truely or somewhat representative of the exposed individuals in the community; [B] studies are allotted one star in case the control cohort is drawn from the same community as the intervention cohort; [C] studies are allotted one star if secure records (e.g. health care records) or structured interviews are used; [D] demonstration that outcome of interest was not present at the start of the study earns one star; [E] study controls for sex and age groups earns one star, study controls for additional baseline factors earns another star; [F] studies are allotted one star in case of outcome assessment based on independent or blind assessment, reference to secure records (e.g. health records), or record linkage; [G] studies with a median duration of follow-up $\geqslant 6$ months are allotted one star; [H] studies with a follow-up rate $\leqslant 20\%$ are allotted one star.

Appendix S1. Studies included in the meta-analysis.

Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

Address:
Bernhard Pommer
Department of Oral Surgery
Bernhard Gottlieb School of Dentistry
Waehringerstr. 25a
A-1090 Vienna, Austria
E-mail: bernhard.pommer@meduniwien.ac.at

Clinical Relevance

Scientific rationale for the study: Short dental implants may provide a therapeutic alternative to supplementary bone augmentation surgery in patients with limited bone volume.

Principal findings: Rough-surfaced implants with a minimum length of 7 mm represent no risk factor for implant failure if not placed in the anterior maxilla.

Practical implications: Bone augmentation may be obviated by the use of short rough-surfaced implants; however, it may not be indicated to compensate length reduction by implant diameter increase.

© 2011 John Wiley & Sons A/S

This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy.
Users should refer to the original published version of the material.