Review

Are Short Dental Implants (<10 mm) Effective? A Meta-Analysis on Prospective Clinical Trials

Alberto Monje,* Hsun-Liang Chan,* Jia-Hui Fu,† Fernando Suarez,* Pablo Galindo-Moreno,‡ and Hom-Lay Wang*

Background: This study aims to compare the survival rate of short (<10 mm) and standard (≥10 mm) rough-surface dental implants under functional loading.

Methods: An electronic literature search using PubMed and Medline databases was conducted. Prospective clinical human trials, published in English from January 1997 to July 2011, that examined dental implants of <10 mm with a 12-month follow-up were included in this meta-analysis. The following data were retrieved from the included articles: the number of implants, implant dimensions, implant locations, types of prostheses, follow-up periods, and implant survival rates. Kaplan-Meier survival estimates and the hazard rates were analyzed and compared between short and standard implants.

Results: Thirteen studies were selected, examining 1,955 dental implants, of which 914 were short implants. Short dental implants had an estimated survival rate of 88.1% at 168 months, when standard dental implants had a similar estimated survival rate of 86.7% ($P = 0.254$). The peak failure rate of short dental implants was found to occur between 4 and 6 years of function. This occurred at an earlier time point compared with standard dental implants, where the peak failure rate occurred between 6 and 8 years of function.

Conclusions: This study shows that in the long term, implants of <10 mm are as predictable as longer implants. However, they fail at an earlier stage compared with standard implants. *J Periodontol 2013;84:895-904.*

KEY WORDS

Alveolar bone loss; dental implants; evidence-based dentistry; longitudinal studies; survival rate.

* Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI.
† Department of Periodontics, Faculty of Dentistry, National University of Singapore, Singapore.
‡ Department of Oral Surgery, University of Granada, Granada, Spain.

Respective centripetal and centrifugal bone resorption of the maxilla and mandible often result in a residual ridge that is inadequate for ideal implant placement.[1] Numerous techniques, such as guided bone regeneration (GBR), block grafts, sinus augmentation, distraction osteogenesis, and transposition of the inferior alveolar nerve, have been used successfully to increase residual ridge dimensions to facilitate ideal three-dimensional (3D) placement of a dental implant.[2] GBR, for example, enjoys positive treatment outcomes,[3,4] but its success is compromised when there is wound exposure.[5] Therefore, bone augmentation procedures are not without limitations. In addition, patients may not accept these procedures for a variety of reasons, such as donor site morbidity, additional treatment duration, and increased cost.[6,7] Consequently, treatment alternatives such as placing angled[8,9] or short[10] implants are proposed. The all-on-4 protocol involves placing implants at an inclination of 30°[8,9] in an attempt to reduce surgical trauma, implant number, and cantilever length.[11] Placement of short implants, on the other hand, avoids violations of neighboring vital structures, reduces surgical complications, and increases patient satisfaction.[6,12] At present, there is no consensus on the definition of a short implant.[13] Some authors defined short

doi: 10.1902/jop.2012.120328

implants as ≤7 mm,[14] ≤8 mm,[15] or ≤10 mm[16] long. In this study, a short implant is defined as a dental implant that is <10 mm long whereas a standard length dental implant is ≥10 mm.

Emerging evidence demonstrated that dental implants <10 mm in length could be used successfully to restore edentulous spans.[17-19] However, it is important to know that the formation and preservation of osseointegration is dependent on multiple factors, such as biologic or prosthetic factors. Biologic factors, for example, bone density and smoking habits, were found to influence the success of short implants.[13] The cumulative estimated failure rate of maxillary short implants was approximately triple that of mandibular short implants and smoking doubled it.[13] In addition, the cluster effect due to the presence of several implants in individual patients appeared to be a possible influencing factor.[20] Prosthetic factors, for example, crown-to-implant ratio, splinting, occlusal table, cantilever length, implant system, opposing dentition, and bruxism, on the other hand, did not influence short implant failure.[21-23] Therefore, as supported by several systematic reviews,[17-19] the use of short dental implants has grown in popularity over recent years. However, the effectiveness of short dental implants compared with standard ones was not investigated. This meta-analysis sets out to compare the efficacy of short and standard implants, in terms of hazard ratio and peak failure rate, over a long-term follow-up period of ≥36 months.

MATERIALS AND METHODS

An electronic search of the PubMed and Medline databases for relevant studies published in English from January 1997 to July 2011 was performed by one examiner (AM). The key words used in the search included a combination of "prospective studies," "survival rate," "survival analysis," "dental implantation," "dental implants," "endosseous implants," "oral implants," "short implants," and "short length." A manual search of implant-related journals, including *Clinical Implant Dentistry and Related Research*, *International Journal of Oral and Maxillofacial Implants*, *Clinical Oral Implants Research*, *Implant Dentistry*, *European Journal of Oral Implantology*, *Journal of Oral Implantology*, *International Journal of Oral and Maxillofacial Surgery*, *Journal of Oral and Maxillofacial Surgery*, *Journal of Dental Research*, *International Journal of Prosthodontics*, *Journal of Prosthetic Dentistry*, *Journal of Clinical Periodontology*, *Journal of Periodontology*, and *International Journal of Periodontics & Restorative Dentistry*, from January 1997 to July 2011, was also performed.

Inclusion criteria were randomized clinical trials, human clinical trials, or prospective trials with a clear aim of investigating the success or survival rate of short (<10 mm) implants. Studies had to have a minimum sample size of 10 healthy patients with 10 short implants that were in function for ≥1 year.

Exclusion criteria were animal studies, retrospective human trials with insufficient information, and studies involving smooth-surface implants or immediate implant placement and/or loading.

Several factors, namely, implant dimensions, implant features, total number of implants placed, healing time, location, type of prosthesis, follow-up periods, implant survival and failure rates, or the number of failed implants, were extracted from the selected studies. A spreadsheet was formulated in which the number of implants from each included article was added. The number of failed implants was calculated from the survival/failure rate, if not provided in the original study. The dependent variable (implant survival) was dichotomic and coded as 0 or 1, when the implant had survived or failed at the end of the observation period, respectively. Independent variables included implant length (0 and 1 represented short and standard implants) and follow-up periods. Multivariate analyses could not be performed due to inadequate information about the features of the implants, for example, their diameters and locations and the types of prostheses they supported. Therefore, statistical software[§] was used to compute the weighted mean implant survival rate, estimated cumulative implant survival rate, and hazard rate for short and standard implants, without considering other possible variables. The weighted mean survival rates were represented as forest plots for both groups. The Kaplan-Meier estimator, including the estimated standard deviation along with the 95% confidence interval (CI) was used to plot the cumulative survival rate. The log-rank test was applied to compare the survival rates (from 0 to 1, with 1 being no failures) between short and standard implants. The significance value was set at 0.05. The hazard rate was defined as the number of events per unit of time divided by the number at risk. It represented the number of failures within a short period of time and demonstrated failure rates in different time frames of the observation period.

RESULTS

An initial screening yielded a total of 381 articles, of which 39 potentially relevant articles were selected after an evaluation of their titles and abstracts. Full text was obtained, with only 13 of the articles[24-36] fulfilling the inclusion criteria and subsequently analyzed in this meta-analysis. Figure 1

§ R Software, The R Foundation for Statistical Computing, Vienna, Austria.

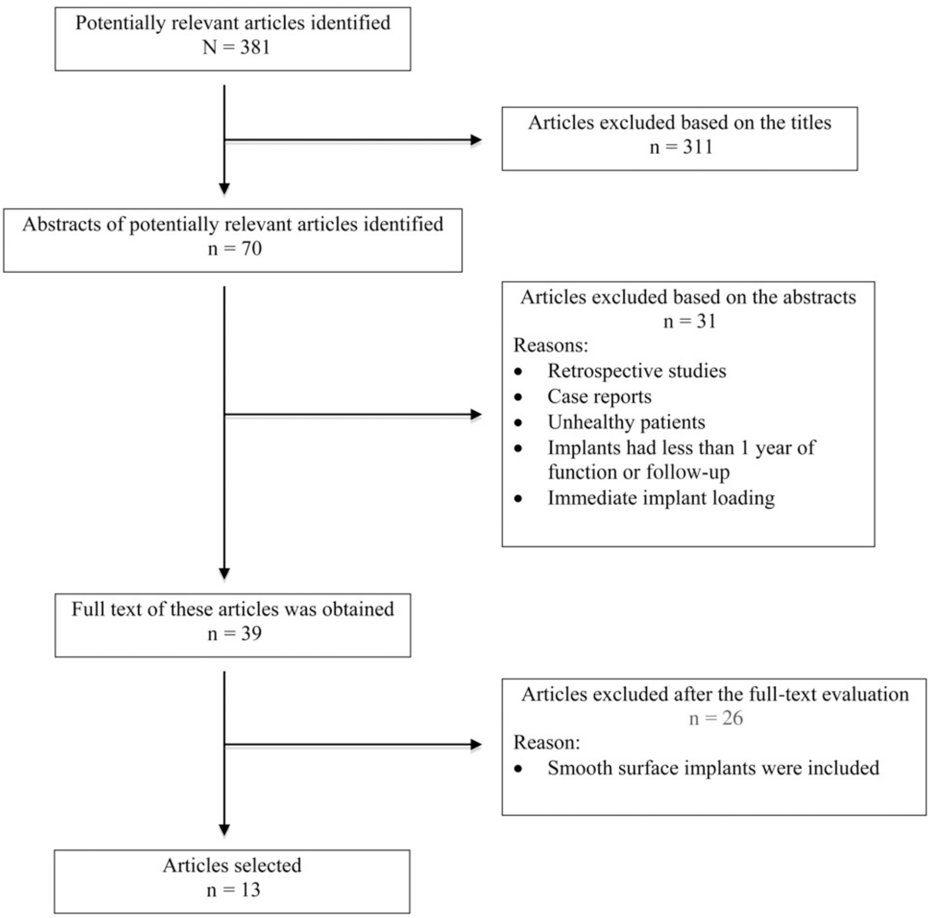


Figure 1.
Study selection process.

illustrates the selection process, and Table 1 summarizes the details of each study.

A total of 1,955 dental implants of ≥10 mm were analyzed. There were 914 short dental implants, of which 377 were 6-mm implants (377 of 1,955, or 19.28%), five were 7-mm implants (five of 1,955, or 0.26%), 349 were 8-mm implants (349 of 1,955, or 17.85%), and 183 were 8.5-mm implants (183 of 1,955, or 9.36%). Comparatively, there were 1,041 standard dental implants (1,041 of 1,955, or 53.24%) included and analyzed in this meta-analysis (Fig. 2). The short and standard implants had a follow-up period of 12 to 168 months and 18 to 168 months, respectively.

Forest plots showed the mean implant survival rate was 0.92 (95% CI: 0.88 to 0.94) and 0.93 (95% CI: 0.89 to 0.96) for the short and standard implant groups, respectively (Fig. 3). The cumulative survival rates and hazard rates were calculated for 781 short and 1,017 standard implants, which had a follow-up period of ≥36 months (Table 2). At 168 months, the estimated survival rate for the short and standard implants was 0.881 (95% CI: 0.825 to 0.912) and 0.867 (95% CI: 0.849 to 0.914), respectively. It was not significantly different between the two groups ($P = 0.254$; Fig. 4).

The hazard rate was used to evaluate the risk of implant failure over time. Short implants experienced a 10-fold increase in hazard rate (3.3E–04 to 3.4E–03) between 48 and 66 months, after which the implant failure rate decreased. A similar surge in hazard rate (6.04E–05 to 2.87E–03) was also observed among standard implants; however, it occurred between 72 and 96 months. The results suggested that short implants tend to fail after 4 to 6 years of function, whereas standard implants failed at a later time (6 to 8 years; Fig. 5).

DISCUSSION

It is undeniable that short dental implants have a role in the rehabilitation of edentulous spans. This is especially true in the posterior mandibular region, where significant horizontal and vertical bone loss,[37] coupled with anatomic limitations such as proximity to the inferior dental nerve and presence of lingual concavities,[38] pose as surgical and restorative challenges to both clinicians and patients. It was demonstrated that advanced bone grafting, for example, mandibular bone blocks or lateral window sinus augmentations with simultaneous implant placement, had significantly more intra- and postoperative complications.[6,12] Hence, patient satisfaction toward the surgical procedure and the treatment outcomes was generally better when short implants were used.[6,12]

Recent evidence has demonstrated that short implants have a reasonable survival rate.[13,17-19] The cumulative survival rate for short implants, <10 mm, was 99.1% after a follow-up period of 3.2 ± 1.7 years.[18] Even 5-mm implants had an estimated survival rate of 93.1% after 2 years.[17] The biologic and biomechanical success rates were 98.8% and 99.9%, respectively,[18] with 57.9% of failures of short implants occurring before the prosthetic connection.[19] In addition, implants placed in the maxilla

Table 1.

Descriptive Information of the Selected 13 Studies

Article	Total Number of Implants	Number of Implants in Each Group	Length (mm)	Width (mm)	Healing Time (months)	Follow-Up (months)	Location	Type of Prostheses	Implant Survival Rate (%)	Implant Failure Rate (%)
ten Bruggenkate et al.[24]	253‖	253	6	3.5	4	72	UP/LM	ST/FPD/FFA	94	6
Deporter et al.[25]	156¶	156	8.5	NA	2.5	72	LM	OD	93.4	6.6
Polizzi et al.[26]	25#	2	7	5.1	6	36	UP/LM	ST	100	0
		8	8.5	5.1	6	36	UP/LM	ST	87.5	12.5
		15	10	5.1	6	36	UP/LM	ST	83.4	6.6
Hallman[27]	33‖	7	8	3.3	3 to 6	18	UP/LM	ST/FPD	85.8	14.2
		26	10	3.3	3 to 6	18	UP/LM	ST/FPD	100	0
Testori et al.[28]	158**	3	7	3.75	2	36	UP/LM	ST/FPD/FFA	100	0
		19	8.5	3.75-5	2	36	UP/LM	ST/FPD/FFA	98	2
		136	10	3.75-5	2	36	UP/LM	ST/FPD/FFA	98.6	1.4
McGlumphy et al.[29]	80††	20	8	4	3 to 6	60	UP/LM	FPD	80	20
		60	10	4	3 to 6	60	UP/LM	FPD	88.3	11.7
Willer et al.[30]	125‡‡	11	8	3.3-4	3 to 6	60	UP/LM	ST/FPD/OD	86.2	13.8
		114	10	3.3-4	3 to 6	60	UP/LM	ST/FPD/OD	86.2	13.8
Nedir et al.[31]	291‖	97	8	4.8-4.1-3.3	2.3 to 4.5	84	UP/LM	NA	100	0
		194	10	4.8-4.1-3.3	2.3 to 4.5	84	UP/LM	ST/FPD/FFA	99.5	0.5
Ferrigno et al.[32]	445‖	103	8	NA	6	108	UP	OD	88.9	11.1
		342	10	NA	6	108	UP	ST/FPD/FFA	90.5	9.5

Table 1. (continued)

Descriptive Information of the Selected 13 Studies

Article	Total Number of Implants	Number of Implants in Each Group	Length (mm)	Width (mm)	Healing Time (months)	Follow-Up (months)	Location	Type of Prostheses	Implant Survival Rate (%)	Implant Failure Rate (%)
Romeo et al.[33]	265	111∥§§	8	3.75-4.1-4.8	3 to 6	168	UP/LM	ST/FPD/FFA	86.4	3.6
		154∥,∥∥	10	3.75-4.1-4.8	3 to 6	168	UP/LM	ST/FPD/FFA	97.5	2.5
Rossi et al.[34]	40∥	19	6	4.1	1 to 2	24	LM	ST	89.5	10.5
		21	6	4.8	1 to 2	24	LM	ST	100	0
Guljé et al.[35]	60¶¶	60	6	4	3	12	LM	OD	96.7	3.3
Van Assche et al.[36]	24∥	24	6	4.1	6	24	UP	OD	97.9	2.1

UP = maxilla; LM = mandible; ST = single tooth; FPD = fixed partial denture; FFA = full fixed arch; OD = overdenture; NA = not available.

and/or machine-surfaced implants had higher failure rates.[18,19]

To minimize short implant failure rates and compensate for the reduction in implant length, modifications to the micro and macro designs of dental implants, for example, increasing implant diameter, thread depth, surface treatment, and decreasing thread pitch, have been made.[28,32,39] These measures were made so that short implants can be used predictably, especially in non-ideal clinical situations, such as inadequate ridge height, proximity to vital structures,[36,40] and when the patient declined advanced bone grafting procedures because of the associated morbidity, increased cost, and treatment time.[41]

Increasing the implant diameter leads to a better engagement of the buccal and lingual cortical plates,[42] thus improving stress distribution within the surrounding bone.[43] Low stress levels were associated with wider implants, thus increasing the implant success or survival rates.[39,44] In a 3D finite element analysis, it was demonstrated that increasing the implant diameter resulted in a 3.5-fold reduction in crestal strain. On the contrary, increasing the implant length resulted in a 1.65-fold reduction in crestal strain.[45] However, other studies showed that increasing implant diameter did not compensate for the reduction in length.[23,46] A recent systematic review demonstrated that 5.0-mm-wide implants had less favorable results compared with narrower implants of lengths ≤8 mm.[2] The additional heat generated during the preparation of the wider osteotomies was speculated to have led to an increase in implant failure rate.[42] Therefore, although it seemed logical to place a wider implant to compensate for the shorter length, the expected treatment outcomes might not be as favorable as having narrower implants of shorter lengths.

Geometry and surface topography are crucial for the short- and long-term success of short dental implants. Surface composition, hydrophilicity, and roughness are parameters that may play a role in implant–bone interaction.[47] Short implants with a roughened surface have shown higher resistance to torque removal than those with other types of surface topography.[48] Numerous studies reported a high implant survival rate of ≥95% with sandblasted and acid-etched and titanium plasma-sprayed implants.[31,32,49]

∥ Straumann, Basel, Switzerland.
¶ Innova, Toronto, Ontario, Canada.
\# Nobel Biocare, Goteborg, Sweden.
** BIOMET 3i, Palm Beach Gardens, FL.
†† Omniloc, Centerpulse Dental, Carlsbad, CA.
‡‡ Friatec, Friadent, Mannheim, Germany.
§§ Zimmer Dental, Carlsbad, CA.
∥∥ Brånemark System, Nobel Biocare, Goteborg, Sweden.
¶¶ Astra Tech AB, Mölndal, Sweden.

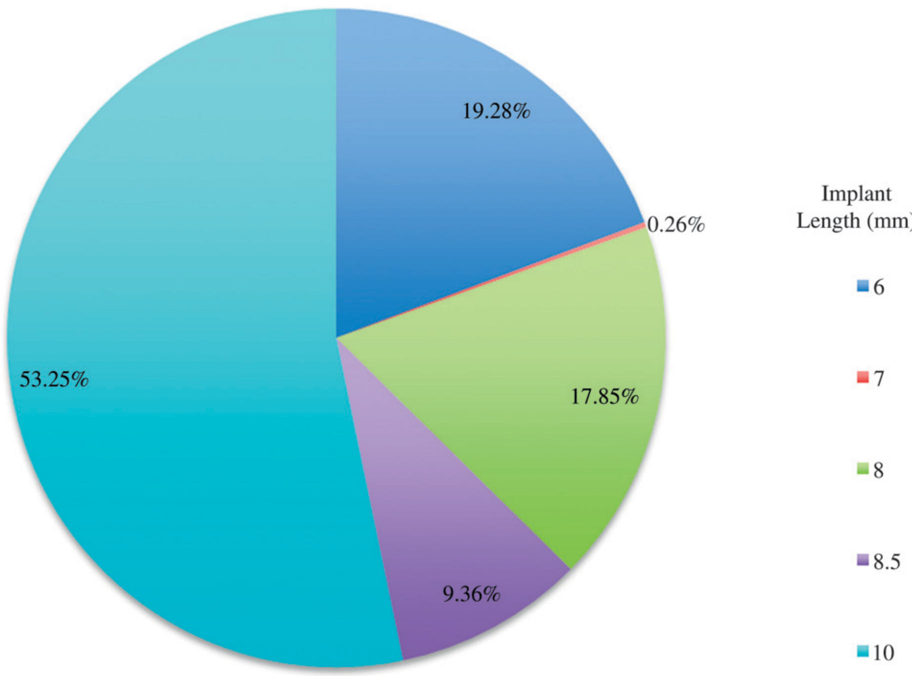
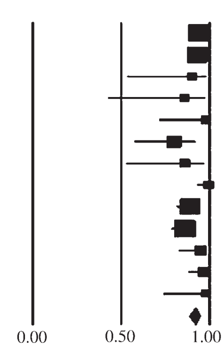


Figure 2.
Distribution of dental implants according to their lengths.

Short implant group

Study	N	Survival rate	Lower limit	Upper limit	Relative weight
ten Bruggenkate et al. (1998)[24]	253	0.94	0.90	0.96	17.07
Deporter et al. (1999)[25]	156	0.93	0.88	0.96	15.25
Polizzi et al. (2000)[26]	10	0.90	0.53	0.99	3.19
Hallman (2001)[27]	7	0.86	0.42	0.98	3.01
Testori et al. (2002)[28]	22	0.98	0.71	0.99	1.64
McGlumphy et al. (2003)[29]	20	0.80	0.57	0.92	8.47
Willer et al. (2003)[30]	11	0.86	0.53	0.97	4.41
Nedir et al. (2004)[31]	97	0.99	0.92	1.00	1.87
Ferrigno et al. (2006)[32]	103	0.89	0.81	0.94	15.21
Romeo et al. (2006)[33]	111	0.86	0.78	0.91	16.73
Rossi et al. (2010)[34]	40	0.82	0.82	0.98	5.87
Guljé et al. (2011)[35]	60	0.88	0.88	0.99	5.50
Van Assche et al. (2011)[36]	24	0.98	0.74	0.99	1.78
Total	914	0.92	0.88	0.94	100.00

Survival rate and 95% CI



Standard implant group

Study	N	Survival rate	Lower limit	Upper limit	Relative weight
Polizzi et al. (2000)[26]	15	0.83	0.59	0.95	11.65
Hallman (2001)[27]	26	0.98	0.76	0.99	4.61
Testori et al. (2002)[28]	136	0.99	0.95	0.99	9.22
McGlumphy et al. (2003)[29]	60	0.88	0.77	0.94	16.82
Willer et al. (2003)[30]	114	0.86	0.78	0.91	19.10
Nedir et al. (2004)[31]	194	0.99	0.96	1.00	4.67
Ferrigno et al. (2006)[32]	342	0.90	0.86	0.93	20.42
Romeo et al. (2006)[33]	154	0.98	0.94	0.99	13.51
Total	1,041	0.93	0.89	0.96	100.00

Survival rate and 95% CI

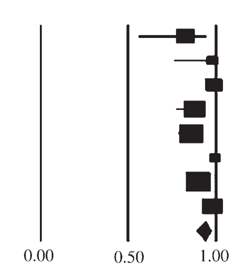


Figure 3.
The forest plots of the short and standard implant groups, summarizing the implant survival rates from each article.

Short implants with a roughened surface demonstrated significantly lower failure rate compared with machined-surface ones (odds ratio of 3.6).[46] However, a systematic review did not find that any particular implant surface demonstrated superiority in implant survival rate.[50] Nonetheless, inasmuch as smooth surface implants are currently scarcely available, only implants with roughened surfaces were analyzed, showing no significant difference in the estimated cumulative survival rate between short and standard implants (P = 0.254), therefore concurring with a systematic review that there was no significant difference in the failure rates of short and standard implants.[19]

As short implants demonstrated lower implant survival rates in the maxilla,[2,19,46] bone quality was thought to be a strong predictor of treatment outcome.[51,52] Most studies with short implants placed in the mandibles had a higher survival rate[53,54] than those placed in the maxilla.[32,55] This phenomenon could be attributed to an increase in bone density, improved mechanical properties of the implant–bone interface, and reduced stress concentration in bone,[56-58] therefore facilitating primary stability and early osseointegration, which compensated for the reduction in implant lengths.[54] In this analysis, it is not possible to evaluate separately the efficacy of short implants in either the maxillary or mandibular arches because of the lack of studies reporting success of implants placed only in one arch. Overall, five studies reported short and long implants placed at the same location, whereas three studies[1-3] and another two studies[4,5] reported data on implants

Table 2.

Survival Analysis for Short and Standard Implants From 36 to 168 Months

Time (months)	Number at Risk	Number of Events	Survival		
			Mean	Lower 95% CI	Upper 95% CI
Short implant group					
36	781	3	0.990	0.984	0.997
60	751	6	0.983	0.974	0.992
72	720	25	0.948	0.933	0.964
108	214	11	0.900	0.868	0.932
168	111	4	0.881	0.825	0.912
Standard implant group					
36	1,017	2	0.998	0.995	1.00
60	864	24	0.970	0.959	0.982
84	690	1	0.969	0.957	0.981
108	496	33	0.904	0.881	0.929
168	154	4	0.867	0.849	0.914

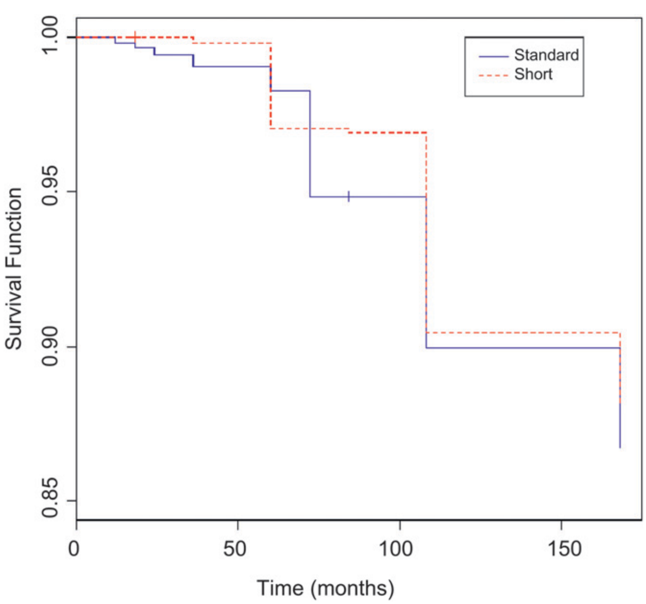


Figure 4.
Survival curves for short and standard (long) implants, illustrating their similar estimated cumulative survival rates at 168 months (P = 0.254).

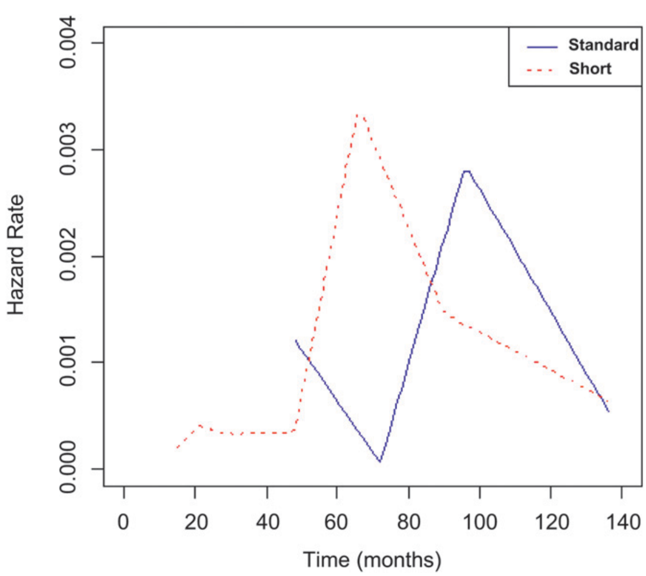


Figure 5.
Comparing the hazard rate between short and standard (long) implants indicating that peak failure rate of short implants occurred ≈2.5 years earlier than standard implants.

placed in the mandible and maxilla, respectively. Based on these studies, mean survival rate for short implants placed in the mandible and maxilla was 94.9% and 92.7%, respectively. Therefore, the higher survival rate of short implants placed in the mandible could be attributed to the increase in bone density and, hence, better primary stability. The enhanced primary stability can be speculated as compensating for the reduced implant length, although no significant differences were observed (P >0.05).

Nonetheless, in this meta-analysis, the short implants have an earlier peak failure rate, as indicated by the hazard rate. The reduced length could be speculated as resulting in less total bone-to-implant contact around short implants. As such, in sites where bone density is low, the increase in peri-implant strains might lead to the earlier loss of these implants.[45] As a result, implants of length >9 mm and diameter >4 mm would have a better success rate in type IV bone.[59]

Other prosthetic measures have also been implemented to boost the survival rates of short implants. For example, increasing the number of implants improved their collective biomechanical behavior because of changes in force transmission and stress distribution compared with single implants.[60] Splinting of implant crowns, too, led to less stress transmitted to each bone–implant interface compared with individual implant crowns.[61] In this meta-analysis, two studies[2,6] assessed the efficacy of short implants supporting single crowns, four studies[1,3-5] reported on short implants supporting overdentures, and one study[7] looked at short implants supporting fixed partial dentures. In view of the limited data available for analysis, the trend seemed to suggest that there were no observed differences in terms of implant survival rates between single or splinted prostheses. Therefore, it is important to note that it was impossible to derive any conclusion on the effect of prosthetic reconstructions on the survival rates of short dental implants.

CONCLUSIONS

This study shows that in the long term, implants <10 mm are as predictable as longer implants. However, if failures do occur, short implants generally fail 2.5 years earlier compared with standard implants.

ACKNOWLEDGMENTS

This work was partially supported by the University of Michigan Periodontal Graduate Student Research Fund. The authors acknowledge Professor Kerby A. Shedden and Yanming Li, a student from the Department of Statistics at the University of Michigan, for their guidance in conducting meta-analyses. The authors report no conflicts of interest related to this study.

REFERENCES

1. Pietrokovski J, Massler M. Alveolar ridge resorption following tooth extraction. *J Prosthet Dent* 1967;17:21-27.
2. Neldam CA, Pinholt EM. State of the art of short dental implants: A systematic review of the literature [published online ahead of print Oct 26, 2010]. *Clin Implant Dent Relat Res.* doi:10.1111/j.1708-8208.2010.00303.x.
3. Park SH, Lee KW, Oh TJ, Misch CE, Shotwell J, Wang HL. Effect of absorbable membranes on sandwich bone augmentation. *Clin Oral Implants Res* 2008;19:32-41.
4 Hammerle CH, Jung RE, Feloutzis A. A systematic review of the survival of implants in bone sites augmented with barrier membranes (guided bone regeneration) in partially edentulous patients. *J Clin Periodontol* 2002;29(Suppl. 3):226-231; discussion 232-233.
5. Oh TJ, Meraw SJ, Lee EJ, Giannobile WV, Wang HL. Comparative analysis of collagen membranes for the treatment of implant dehiscence defects. *Clin Oral Implants Res* 2003;14:80-90.
6. Esposito M, Cannizzaro G, Soardi E, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm-long, 4 mm-wide implants or by longer implants in augmented bone. Preliminary results from a pilot randomised controlled trial. *Eur J Oral Implantology* 2012;5:19-33.
7. Felice P, Soardi E, Pellegrino G, et al. Treatment of the atrophic edentulous maxilla: Short implants versus bone augmentation for placing longer implants. Five-month post-loading results of a pilot randomised controlled trial. *Eur J Oral Implantology* 2011;4:191-202.
8. Jensen OT, Adams MW. The maxillary M-4: A technical and biomechanical note for all-on-4 management of severe maxillary atrophy — Report of 3 cases. *J Oral Maxillofac Surg* 2009;67:1739-1744.
9. Jensen OT, Adams MW. All-on-4 treatment of highly atrophic mandible with mandibular V-4: Report of 2 cases. *J Oral Maxillofac Surg* 2009;67:1503-1509.
10. van Steenberghe D, Lekholm U, Bolender C, et al. Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: A prospective multicenter study on 558 fixtures. *Int J Oral Maxillofac Implants* 1990;5:272-281.
11. Takahashi T, Shimamura I, Sakurai K. Influence of number and inclination angle of implants on stress distribution in mandibular cortical bone with All-on-4 Concept. *J Prosthodont Res* 2010;54:179-184.
12. Pieri F, Aldini NN, Fini M, Marchetti C, Corinaldesi G. Rehabilitation of the atrophic posterior maxilla using short implants or sinus augmentation with simultaneous standard-length implant placement: A 3-year randomized clinical trial [published online ahead of print March 15, 2012]. *Clin Implant Dent Relat Res.* doi:10.1111/j.1708-8208.2012.00451.x.
13. Telleman G, Raghoebar GM, Vissink A, den Hartog L, Huddleston Slater JJ, Meijer HJ. A systematic review of the prognosis of short (<10 mm) dental implants placed in the partially edentulous patient. *J Clin Periodontol* 2011;38:667-676.
14. Friberg B, Gröndahl K, Lekholm U, Brånemark PI. Long-term follow-up of severely atrophic edentulous mandibles reconstructed with short Brånemark implants. *Clin Implant Dent Relat Res* 2000;2:184-189.
15. Renouard F, Nisand D. Impact of implant length and diameter on survival rates. *Clin Oral Implants Res* 2006;17(Suppl. 2):35-51.
16. das Neves FD, Fones D, Bernardes SR, do Prado CJ, Neto AJ. Short implants — An analysis of longitudinal studies. *Int J Oral Maxillofac Implants* 2006;21:86-93.
17. Jokstad A. The evidence for endorsing the use of short dental implants remains inconclusive. *Evid Based Dent* 2011;12:99-101.
18. Annibali S, Cristalli MP, Dell'Aquila D, Bignozzi I, La Monaca G, Pilloni A. Short dental implants: A systematic review. *J Dent Res* 2012;91:25-32.
19. Sun HL, Huang C, Wu YR, Shi B. Failure rates of short (≤ 10 mm) dental implants and factors influencing their failure: A systematic review. *Int J Oral Maxillofac Implants* 2011;26:816-825.
20. Chuang SK, Cai T. Predicting clustered dental implant survival using frailty methods. *J Dent Res* 2006;85:1147-1151.
21. Nedir R, Bischof M, Szmukler-Moncler S, Bernard JP, Samson J. Predicting osseointegration by means of

implant primary stability. *Clin Oral Implants Res* 2004;15:520-528.
22. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. *Int J Oral Maxillofac Implants* 2006;21:275-282.
23. Maló P, de Araújo Nobre M, Rangert B. Short implants placed one-stage in maxillae and mandibles: A retrospective clinical study with 1 to 9 years of follow-up. *Clin Implant Dent Relat Res* 2007;9:15-21.
24. ten Bruggenkate CM, Asikainen P, Foitzik C, Krekeler G, Sutter F. Short (6-mm) nonsubmerged dental implants: Results of a multicenter clinical trial of 1 to 7 years. *Int J Oral Maxillofac Implants* 1998;13:791-798.
25. Deporter D, Watson P, Pharoah M, Levy D, Todescan R. Five- to six-year results of a prospective clinical trial using the ENDOPORE dental implant and a mandibular overdenture. *Clin Oral Implants Res* 1999;10:95-102.
26. Polizzi G, Rangert B, Lekholm U, Gualini F, Lindström H. Brånemark System Wide Platform implants for single molar replacement: Clinical evaluation of prospective and retrospective materials. *Clin Implant Dent Relat Res* 2000;2:61-69.
27. Hallman M. A prospective study of treatment of severely resorbed maxillae with narrow nonsubmerged implants: Results after 1 year of loading. *Int J Oral Maxillofac Implants* 2001;16:731-736.
28. Testori T, Del Fabbro M, Feldman S, et al. A multicenter prospective evaluation of 2-months loaded Osseotite implants placed in the posterior jaws: 3-year follow-up results. *Clin Oral Implants Res* 2002;13:154-161.
29. McGlumphy EA, Peterson LJ, Larsen PE, Jeffcoat MK. Prospective study of 429 hydroxyapatite-coated cylindric omniloc implants placed in 121 patients. *Int J Oral Maxillofac Implants* 2003;18:82-92.
30. Willer J, Noack N, Hoffmann J. Survival rate of IMZ implants: A prospective 10-year analysis. *J Oral Maxillofac Surg* 2003;61:691-695.
31. Nedir R, Bischof M, Briaux JM, Beyer S, Szmukler-Moncler S, Bernard JP. 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. *Clin Oral Implants Res* 2004;15:150-157.
32. Ferrigno N, Laureti M, Fanali S. Dental implants placement in conjunction with osteotome sinus floor elevation: A 12-year life-table analysis from a prospective study on 588 ITI implants. *Clin Oral Implants Res* 2006;17:194-205.
33. Romeo E, Ghisolfi M, Rozza R, Chiapasco M, Lops D. Short (8-mm) dental implants in the rehabilitation of partial and complete edentulism: A 3- to 14-year longitudinal study. *Int J Prosthodont* 2006;19:586-592.
34. Rossi F, Ricci E, Marchetti C, Lang NP, Botticelli D. Early loading of single crowns supported by 6-mm-long implants with a moderately rough surface: A prospective 2-year follow-up cohort study. *Clin Oral Implants Res* 2010;21:937-943.
35. Guljé F, Raghoebar GM, Ter Meulen JW, Vissink A, Meijer HJ. Mandibular overdentures supported by 6-mm dental implants: A 1-year prospective cohort study. *Clin Implant Dent Relat Res* 2012;14(Suppl. 1):e59-e66.
36. Van Assche N, Michels S, Quirynen M, Naert I. Extra short dental implants supporting an overdenture in the edentulous maxilla: A proof of concept. *Clin Oral Implants Res* 2012;23:567-576.
37. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: A clinical and radiographic 12-month prospective study. *Int J Periodontics Restorative Dent* 2003;23:313-323.
38. Chan HL, Brooks SL, Fu JH, Yeh CY, Rudek I, Wang HL. Cross-sectional analysis of the mandibular lingual concavity using cone beam computed tomography. *Clin Oral Implants Res* 2011;22:201-206.
39. Vandeweghe S, De Ferrerre R, Tschakaloff A, De Bruyn H. A wide-body implant as an alternative for sinus lift or bone grafting. *J Oral Maxillofac Surg* 2011;69:e67-e74.
40. Winkler S, Morris HF, Ochi S. Implant survival to 36 months as related to length and diameter. *Ann Periodontol* 2000;5:22-31.
41. Nkenke E, Weisbach V, Winckler E, et al. Morbidity of harvesting of bone grafts from the iliac crest for preprosthetic augmentation procedures: A prospective study. *Int J Oral Maxillofac Surg* 2004;33:157-163.
42. Lee JH, Frias V, Lee KW, Wright RF. Effect of implant size and shape on implant success rates: A literature review. *J Prosthet Dent* 2005;94:377-381.
43. Ivanoff CJ, Sennerby L, Johansson C, Rangert B, Lekholm U. Influence of implant diameters on the integration of screw implants. An experimental study in rabbits. *Int J Oral Maxillofac Surg* 1997;26:141-148.
44. Meijer HJ, Kuiper JH, Starmans FJ, Bosman F. Stress distribution around dental implants: Influence of superstructure, length of implants, and height of mandible. *J Prosthet Dent* 1992;68:96-102.
45. Petrie CS, Williams JL. Comparative evaluation of implant designs: Influence of diameter, length, and taper on strains in the alveolar crest. A three-dimensional finite-element analysis. *Clin Oral Implants Res* 2005;16:486-494.
46. 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.
47. Le Guéhennec L, Soueidan A, Layrolle P, Amouriq Y. Surface treatments of titanium dental implants for rapid osseointegration. *Dent Mater* 2007;23:844-854.
48. Wennerberg A, Hallgren C, Johansson C, Danelli S. A histomorphometric evaluation of screw-shaped implants each prepared with two surface roughnesses. *Clin Oral Implants Res* 1998;9:11-19.
49. Ferrigno N, Laureti M, Fanali S. Inferior alveolar nerve transposition in conjunction with implant placement. *Int J Oral Maxillofac Implants* 2005;20:610-620.
50. Esposito M, Coulthard P, Thomsen P, Worthington HV. The role of implant surface modifications, shape and material on the success of osseointegrated dental implants. A Cochrane systematic review. *Eur J Prosthodont Restor Dent* 2005;13:15-31.
51. Misch CE, Dietsh-Misch F, Hoar J, Beck G, Hazen R, Misch CM. A bone quality-based implant system: First year of prosthetic loading. *J Oral Implantol* 1999;25:185-197.
52. Tada S, Stegaroiu R, Kitamura E, Miyakawa O, Kusakari H. Influence of implant design and bone quality on stress/strain distribution in bone around

implants: A 3-dimensional finite element analysis. *Int J Oral Maxillofac Implants* 2003;18:357-368.
53. Deporter D, Todescan R, Caudry S. Simplifying management of the posterior maxilla using short, porous-surfaced dental implants and simultaneous indirect sinus elevation. *Int J Periodontics Restorative Dent* 2000;20:476-485.
54. Renouard F, Nisand D. Short implants in the severely resorbed maxilla: A 2-year retrospective clinical study. *Clin Implant Dent Relat Res* 2005;7(Suppl. 1): S104-S110.
55. Widmark G, Andersson B, Carlsson GE, Lindvall AM, Ivanoff CJ. Rehabilitation of patients with severely resorbed maxillae by means of implants with or without bone grafts: A 3- to 5-year follow-up clinical report. *Int J Oral Maxillofac Implants* 2001;16:73-79.
56. Holmes DC, Loftus JT. Influence of bone quality on stress distribution for endosseous implants. *J Oral Implantol* 1997;23:104-111.
57. Hagi D, Deporter DA, Pilliar RM, Arenovich T. A targeted review of study outcomes with short (< or = 7 mm) endosseous dental implants placed in partially edentulous patients. *J Periodontol* 2004;75:798-804.
58. Bischof M, Nedir R, Abi Najm S, Szmukler-Moncler S, Samson J. A five-year life-table analysis on wide neck ITI implants with prosthetic evaluation and radiographic analysis: Results from a private practice. *Clin Oral Implants Res* 2006;17:512-520.
59. Li T, Kong L, Wang Y, et al. Selection of optimal dental implant diameter and length in type IV bone: A three-dimensional finite element analysis. *Int J Oral Maxillofac Surg* 2009;38:1077-1083.
60. Sahin S, Cehreli MC, Yalçin E. The influence of functional forces on the biomechanics of implant-supported prostheses — A review. *J Dent* 2002;30:271-282.
61. Misch CE, Steignga J, Barboza E, Misch-Dietsh F, Cianciola LJ, Kazor C. Short dental implants in posterior partial edentulism: A multicenter retrospective 6-year case series study. *J Periodontol* 2006;77: 1340-1347.

Correspondence: Dr. Hom-Lay Wang, 1011 North University Avenue, Ann Arbor, MI 48109-1078. Fax: 734/936-0374; e-mail: homlay@umich.edu.

Submitted May 29, 2012; accepted for publication August 7, 2012.