Efficacy and Predictability of Short Dental Implants (< 8 mm): A Critical Appraisal of the Recent Literature

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Purpose: *This review of literature was conducted to evaluate the predictability of treatment outcomes with short dental implants (SDI), ie, implants shorter than 8 mm.* ***Materials and Methods:*** *The review included studies, published between January 1990 and July 2011, that* (1) *involved SDI (< 8 mm) placed in human jaws,* (2) *had a minimum of 20 SDI in their analysis,* (3) *provided data on survival rates, and* (4) *reported a minimum observation period of at least 3 months after placement.* ***Results:*** *Forty-one studies fulfilled the above criteria; only 17 of these studies reported outcomes with microrough surface SDI. Six different lengths (4, 5, 6, 6.5, 7 and 7.5 mm) of microrough surface SDI with varying diameters (3.5 to 6 mm) were identified in the studies. A total of 1,828 microrough surface SDI were inserted and 45 failures were reported. Observation periods ranged from 3 months to 9 years. The reported survival rates for SDI ranged from 92.2% to 100%. From a total of 1,123 SDI inserted in specified jaw locations, failures were observed more often in the maxilla (n = 297, failed = 13) than in the mandible (n = 826, failed = 19). The review did not identify any correlation between implant diameter and survival for the microrough SDI.* ***Conclusions:*** *Microrough surface short implants (6 to 7.5 mm) appear to provide favorable survival rates and, therefore, can be predictably employed for simplification of implant therapy in situations of reduced alveolar heights in the posterior jaw segments.* Int J Oral Maxillofac Implants 2012;27:1429–1437

Key words: *dental implant, implant length (< 8 mm), literature review, short dental implants, treatment outcomes*

Short dental implants were introduced for simplified placement in compromised alveolar situations to avoid interference with vital anatomical structures, minimize surgical trauma and associated risks, and consequently reduce the morbidity of advanced surgical procedures.[1] Early descriptions in literature considered standard length implants as implants with intrabony lengths of 10 mm or more,[2] and short dental implants (SDI) as implants with less than 10 mm intrabony length.[3] The currently accepted definition for short dental implants is "a device with ≤ 8 mm intrabony length."[4,p47]

It has often been hypothesized that shorter implants have lower success rates than standard length fixtures. However, no distinct linear relationship between implant length and survival has been scientifically established.[5] Standard length implants (≥ 10 mm) are quoted to represent a minimum length for predictable success because, hypothetically, a better distribution of functional forces throughout the entire length of the implant was assumed.[6] However, these forces are demonstrated to be concentrated at the periimplant crestal bone.[7] There is evidence that implant length has minimal influence on the bone stress location, the intrabony implant displacement, and the implant component stress.[8,9] It has also been suggested that longer implants are more prone to mechanical

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complications because of their rigidity, while SDI allow flexure within the bone inducing a stress breaking effect.[10] Hence, it would appear that using SDI represents an overall prosthetic advantage in terms of long-term success in implant supported restorations.[9] However, this hypothesis needs to be challenged by randomized controlled trials. Bone quality, or bone density, in the region of installation has also been reported to play a role in SDI survival, and the posterior maxilla has been cited as a region for frequent failures.[11–15] Studies, however, do exist that demonstrate favorable success rates in this region.[2, 16, 17]

Current literature classifies implants of 8-mm length as short implants. These have been associated with favorable success rates and high predictability, with reported survival rates of 96% to 100% (over a 3- to 7-year observation period).[2,18–20] It is therefore natural to consider the use of 8-mm lengths as a routine treatment option and shift focus to lengths < 8 mm as "short implants." Few systematic reviews assessing the performance of SDI and their survival have been published to date.[21–24] These have, however, included implants up to an intrabony length of 10 mm.[21,23,24] Thus, the inclusion of longer implants in a short implant review may not effectively deliver a precise conclusion on predictability.

Therefore, the purpose of this review was to focus on evaluating the predictability of treatment outcomes with commercialized short implants of lengths < 8 mm by reviewing the available relevant publications. By excluding 8-mm implants from this analysis, the authors hypothesized to get a better insight on the clinically relevant predictability of SDI. Based on this assumption, a critical appraisal of the published data on such short implants (< 8 mm) placed in various edentulous segments of the jaws was undertaken to propose a well-defined rationale for the decision-making process when considering the installation of short implants in both compromised conditions or even routine situations.

MATERIALS AND METHODS

An electronic database search of the dental literature using PubMed was undertaken to identify all papers published in English between January 1990 and July 2011, using the following search terms individually and in different combinations: "short dental implants," "length," "studies on," "clinical studies," "prospective," "retrospective," "randomized," "survival and success rates," "dental implants," "treatment outcomes," "systematic review," "literature review," and "meta-analysis."

Selection of Studies

For inclusion in this review, the studies were required to *(1)* involve SDI (< 8 mm) placed in human arches, *(2)* have a minimum number of 20 implants of the specified lengths in their analysis, *(3)* provide data on survival rates, and *(4)* report a minimum observation period of at least 3 months after placement.

Studies were excluded, if *(1)* implant length was not specified, or *(2)* complex surgical interventions and bone augmentation procedures were performed prior to implant placement.

Since the available research on this topic is limited, it was decided to include, besides randomized clinical trials (RCTs) and systematic reviews of RCTs, case series studies, cohort studies, and case control studies. Publications were excluded if there was more than one study by the same researcher(s) conveying the same data. In such an instance, only the most recent study was included.

The database search strategy was devised and performed by the first author (MS). The abstracts of the searched articles were screened thoroughly by two reviewers (MS and PR). Full-text analyses were performed only on the short-listed articles based on the initial screening and on mutual agreement between the two reviewers. The data were extracted jointly by the two reviewers, and were subsequently rechecked and verified by a third reviewer (LV); any disagreement was solved by means of a consensus discussion presided over by a senior reviewer (UCB). The information was extracted from the selected publications, including name of author(s), journal, study type, implant length, surface characteristics, diameter of the implants, number of implants placed and failed, survival rates, and region of placement (if mentioned). A meta-analysis was planned for the extracted data.

RESULTS

The PubMed search yielded a total of 842 articles for the various combinations of the search terms mentioned in the methods section. The procedural aspects of the literature search and selection process are presented in Fig 1. From the screened titles and abstracts (n = 842), full-text analysis (n = 58), and reference crosschecks (n = 3), 41 publications qualified to be included in this study.[1,17,19,25–61] However, studies reporting on machined surface implants were excluded from this review,[1,17,25–35,39–44,47,48,52,62] and, finally, 17 quality studies reporting on microrough surface SDI were included for data extraction and interpretation (Table 1). Six lengths of implants < 8 mm (4, 5, 6, 6.5, 7, and 7.5 mm) were identified in this review. Different implant brands (eg, 3i, Astra-Tech, Bicon, BTI, Endopore, Nobel, RBM, Straumann) with varying diameters (3.5 to 6 mm) and surface characteristics (coated, porous, and microrough) were used in the selected studies.

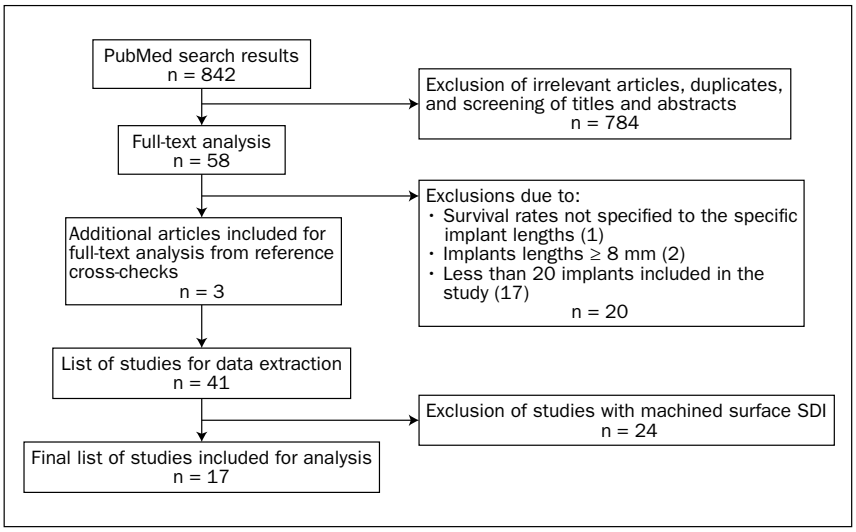

Fig 1 Procedural flow of the literature search and selection process. SDI = short dental implants.

Most articles reported only a cumulative or an overall survival rate for the different lengths of implants investigated, while others did the same for different diameters. Some studies did not specify the region of installation of the implants (maxilla or mandible).[37,42,44,46–49,51,52,56] The exact number of dropouts or the exact time of failure(s), specific to length, site, and observation time was not mentioned in many articles. Furthermore, the selected articles differed from each other in the following parameters: implant number, implant length, implant diameter, study design, statistical analysis, and observation time. Due to the heterogeneity amongst the studies, the originally planned meta-analysis was not possible and a comprehensively structured descriptive analysis was performed in this review.

Observed Time Period

The observed time periods, ranging from 3 months[55] to 9 years,[58] reported in the studies have been converted into years for convenience and uniformity.

Survival Rates with Respect to Implant Lengths

Survival rates reported for microrough surface SDI (placed = 1,828, failed = 45) ranged from 92.2% to 100% for an observation period of up to 9 years (Table 2).[19,37,38,45,49,50,53,55,56,63] Three studies[45,50,58] on 7-mm SDI and one study[56] on 6.5- and 7.5-mm SDI, reported 100% survival rates.

4-mm and 5-mm Lengths. A single study presented data on 4-mm-long SDI, that was a recent prospective multicenter study.[60] The study, based on 100 implants, reported an implant survival rate of 92.3% over a 2-year period. A pilot study of a RCT on 5-mm SDI reported a 98.3% survival rate after 1 year.[59] This study reported on 60 SDI (5 mm × Ø 6 mm) that were placed in atrophic posterior maxillae and mandibles, with one failure in the maxilla before loading. Two other studies on 5-mm SDI reported 100% survival rates in a 1 to 9 year follow-up[58,64]; but these were excluded from the review because of their small sample sizes.

6-mm Length. From all studies reviewed, a total of 639 microrough surface implants were inserted and from these only 18 failed, with overall survival rates of 92.2% to 98.5% (observed period of 1 to 8 years).[19,37,38,51,53,57,61] The majority of the 6-mm SDI used were Straumann dental implants, comprising a total of 594 implants placed with only 15 failures (SLA = 302 placed, failed = 7; TPS = 292 placed, failed = 8).[19,37,38,53,57,61]

7-mm Length. A total number of 758 microrough surface SDI of 7 mm length were placed in both arches and 19 implants failed. The survival rates reported in a total of nine studies ranged from 96.2% to 100% for an observed time of up to 9 years.[19,45,46,49,50,54–56,58] Deporter et al[45] in a 3-year prospective study, presented a 100% survival rate for 7-mm sintered porous SDI (n = 32). Sohn et al,[58] in their retrospective study, also reported a 100% survival rate for 7-mm SDI (n = 30) in a 9-year follow-up period.

6.5-mm and 7.5-mm Lengths. Only one study supplied data in this category and reported a 100% survival rate over an observation period of 1 to 8 years.[56] More specifically, a total of 37 SDI of 6.5-mm length and 234 implants of 7.5-mm length were inserted.

Table 1 Overview of the Extracted Data on Microrough Surface Short Dental Implants (< 8 mm) from the Reviewed Studies

Study	Type of study	Restoration type	Follow-up period (y)	Implant surface (diameter in mm)	Number of 4 mm Max	Number of 4 mm Man	Number of 4 mm SR%
Buser et al[37]	Prospective	Fixed/removable	1–8	TPS (4.1)	–	–	–
ten Bruggenkate et al[38]	Prospective	Fixed/overdentures	1–7	SLA (3.5, 4.1)	–	–	–
Deporter et al[45]	Retrospective	Fixed	3.02	Sintered porous (4.1, 5)	–	–	–
Davarpanah et al[46]	Prospective	Fixed/overdentures	1–5	Rough (3.75, 4, 5, 6)	–	–	–
Feldman et al[49]	Prospective	Fixed	2–5	Osseotite (3.75, 4)	–	–	–
Fugazzotto et al[50]	Retrospective	Fixed	1–7	SLA (4.1, 4.8)	–	–	–
Gentile et al[51]	Retrospective	Fixed	1	Rough (5.7)	–	–	–
Arlin[53]	Retrospective	Fixed	1–5.4	SLA (4.1, 4.8)	–	–	–
Malo et al[54]	Retrospective	Fixed	1–5	TiUnite (3.75, 4)	–	–	–
Fugazzotto[19]	Retrospective	Fixed	3.01	SLA (4.1, 4.8, WN)	–	–	–
Felice et al[55]	Prospective	Fixed	0.25–1	Nanotite (4.0)	–	–	–
Anitua and Orive[56]	Retrospective	Fixed/overdentures	1–8	BTI (3.75, 4, 4.5, 5, 5.5, 6)	–	–	–
Sohn et al[58]	Retrospective	Fixed	1–9	Sintered porous (4.1, 5)	–	–	–
Rossi et al[57]	Prospective	Fixed	2	SLA (4.1, 4.8)	–	–	–
Esposito et al[59]	Pilot study (RCT)	Fixed	1	RBM (6)	–	–	–
Van Assche et al[61]	Prospective	Overdentures	2	SLActive (4.1)	–	–	–
Slotte et al[60]	Prospective	Fixed	2	SLActive (4.1)	0	100 (7)	92.3

Max = maxilla; Man = mandible; SR% = survival rate; WN = wide neck.

Table 2 Overview of Survival Rates of Microrough Surface Short Dental Implants in the Reviewed Studies

Implant length (mm)	No. of studies	Observation period (y)	Placed	Failed	Reported survival rate (%)
4	1	2	100	7	92.3
5	1	1	60	1	98.3
6	7	1–8	639	18	92.2–98.5
6.5	1	1–8	37	0	100
7	9	0.25–9	758	19	96.2–100
7.5	1	1–8	234	0	100
Total	17*	0.25–9	1,828	45	92.3–100

*Total number of reviewed studies.

Implant Diameter

Three of the 17 reviewed studies compared the impact of implant diameters and survival.[19,46,58] In a study by Davarpanah et al,[46] an increase in failures rates corresponded to increasing implant diameters, irrespective of implant length. The study reported the highest failure rates (25%) for 6-mm-diameter implants. Fugazzotto[19] reported survival rates of 99.2% for wide neck and 98.4% for standard neck configurations. Finally, Sohn et al[58] reported survival rates of 100% for both 5-mm and 4.1-mm diameters.

Location

Twelve studies specified the location of implant placement,[19,38,45,50,53–55,57–61] reporting a total number of 1,123 SDI placed in different segments of the maxilla

implants placed (failed) length- and arch-wise with the reported survival rates															
	5 mm			6 mm			6.5 mm			7 mm			7.5 mm		
	Max	Man	SR%	Max	Man	SR%	Max	Man	SR%	Max	Man	SR%	Max	Man	SR%
	–	–	–		39	96.7	–	–	–	–	–	–	–	–	
	–	–	–	45 (6)	208 (1)	97.0	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	0	32 (0)	100.0	–	–	–
	–	–	–	–	–	–	–	–	–		96 (4)	96.5	–	–	
	–	–	–	–	–	–	–	–	–		143 (5)	96.5	–	–	
	–	–	–	–	–	–	–	–	–	42 (0)	0	100.0	–	–	–
	–	–	–		45 (3)	92.2	–	–	–	–	–	–	–	–	
	–	–	–	0	35 (2)	94.2	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	27 (3)	104 (2)	96.2	–	–	–
	–	–	–	110 (1)	93 (2)	98.5	–	–	–	0	113 (2)	98.2	–	–	–
	–	–	–	–	–	–	–	–	–	–	60 (2)	96.7	–	–	–
	–	–	–	–	–	–		37 (0)	100		111 (1)	99.1		234 (0)	100.0
	–	–	–	–	–	–	–	–	–	0	30 (0)	100.0	–	–	–
	–	–	–	15	25 (2)	95.0	–	–	–	–	–	–	–	–	–
	34 (1)	26 (0)	98.3	–	–	–	–	–	–	–	–	–	–	–	–
	–	–	–	24 (1)	–	95.8	–	–	–	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 3 Overview of Jaw-Wise Distribution of the Short Dental Implants in the Reviewed Studies

			Maxilla		Mandible	
Implant length (mm)	No. of studies	Observation period (y)	Placed	Failed	Placed	Failed
4	1	2	NA	NA	100	7
5	1	1	34	1	26	0
6	5	1–8	194	9	361	6
6.5	1	1–8	NA	NA	NA	NA
7	6	0.25–9	69	3	339	6
7.5	1	1–8	NA	NA	NA	NA
Total	17*	0.25–9	297	13	826	19

NA = no data available from the reviewed studies; *total number of reviewed studies.

and mandible. From this total, 297 implants were placed in the maxilla (13 failures) and 826 were inserted in the mandible, revealing 19 failures (Table 3). Most studies reported a higher number of implant failures in the maxilla,[38,54,59,61] while Fugazzotto[19] demonstrated higher failures in the mandible.

DISCUSSION

This comprehensive structured review scrutinized the clinical studies published from January 1990 through July 2011, while corresponding to strict inclusion and exclusion criteria. It primarily drew focus to implants of lengths less than 8 mm. The data obtained in this review are exclusively from peer-reviewed scientific journals

in English. The studies exhibited a broad diversity in terms of observation time, implant length, implant diameter, implant surface, location of installation, study design, and surgical protocol. Furthermore, the studies showed variations related to the cited text and tables, unspecified dropouts, specific time of failure with respect to specific length, method of statistical analysis, and reporting. These factors deemed it impossible to systematically compare the reviewed publications with one another; which was a similar finding in an earlier published review.[22] Hence, the initially planned meta-analysis for the extracted data was not possible, and a descriptive, but nevertheless structured and methodologically sound, analysis was carried out in this review.

The authors observed that, although the studies were conducted with the focus of evaluating short length implants, the definition of "short length" varied in each study and ranged within a broad spectrum (4 to 11 mm). Although 8-mm length is considered short by the standards of current literature, its evaluation in this review was eliminated because the current-day survival rates for the 8-mm-length short implants are predictably high and comparable to those of standard implants.[2,18–20] Hence, the present review focused on lengths shorter than 8 mm and the authors suggest redefining the term "short dental implant" as a dental implant with an intrabony length between 6 and 7.5 mm; and define "ultra-short dental implant" as an implant with an intrabony length of less than 6 mm.

This review identified considerable heterogeneity in the observation periods and in the sample sizes of the reviewed studies. A significant number of quality studies[1,5,8,17,18,42,43,47,63–72] were excluded from this review because they had a sample size of less than 20 implants. An estimation of a proportion on small samples is unreliable and the chance of detecting a low or a high proportion is weak.[73] Hence, pooling studies with small sample sizes may underestimate the proportion of failures. It would also not be correct to pool all the studies analyzing implants with the same length and different surfaces because this may also further underestimate the failure rates. Therefore, studies with machined surface SDI were later decided to be excluded from this review, although they fulfilled the inclusion criteria and had adequate sample sizes.[1,17,25–36,39–44,47,48,52,62] Furthermore, machined surface implants are obsolete in modern day implant practice, hence, including them in the analysis would not have provided a clinically relevant comparison.

A total of 17 studies on SDI with structured microrough surfaces were reviewed and revealed survival rates of 92.2% to 100%.[19,37,38,45,46,49–51,53–61] The most recent study examined in this review was a 2-year prospective study on 4-mm long implants that reported a survival rate of 92.3% over a 2-year period in severely atrophied posterior mandibles.[60] The study, however, strongly hypothesized on the need for extreme care during the surgery and meticulous planning of the prosthetic superstructure in terms of occlusion, so as to prevent implant overload and eventual implant loss. The results were said to be comparable with other short implant lengths (6 to 8.5 mm), and the success was predominantly attributed to the excellent implant stability at placement.

The occurrence of peri-implantitis in 16% of patients treated with machined-surface implants 9 to 14 years after loading has been documented.[74] A systematic review reported that the incidence of peri-implantitis is likely to be higher in implants with roughened surfaces at 3 years of loading when compared with machined-surface implants (risk ratio = 0.80; 95% CI: 0.67 to 0.96).[75] Implants with turned surfaces had a 20% reduction in risk of being affected by peri-implantitis. This may in fact be critical for survival in microrough SDI, especially with very short lengths (4 mm and 5 mm). It has been documented that untreated peri-implant mucositis, which may lead to progressive destruction of the peri-implant tissues and subsequently to peri-implantitis, ultimately may lead to implant failure.[76] With longer implants, this situation may still be manageable as the increased implant length provides better chances of survival. Hence, extreme care should be emphasized in maintaining the peri-implant bone levels while employing SDI of lengths < 6 mm. Clinical common sense and concerns relative to dimensional manufacturing limitations, peri-implantitis, technical complications relating to implant components, and, importantly, a lack of sufficient research restrict the use of such SDI (< 6 mm) to extreme clinical situations only.

The majority of studies included in this review have used SDI of 6-mm and 7-mm lengths. These dimensions seem to be the preferred choice of clinicians. Interestingly, the most commonly used 6 mm SDI was that of the Straumann Dental Implant System (Straumann AG).[22] Studies on SLA surface 6-mm implants have been consistent with reported overall high survival rates between 94.2% and 100% for an observed period of 1 to 8 years.[19,37,38,50,53,57,60,61]

Former studies suggest that the implant diameter is of more significance to the survival outcome than its length.[77,78] Frequent failures were experienced with 5-mm diameter machined surface implants in comparison to the smaller diameters of 3.75 mm or 4.0 mm.[40] This increased failure rate may be attributed to the implant design, the bone quality at the site of placement, and the operator's learning curve. This review, however, did not identify such a correlation between implant diameters and implant survival in the microrough implants examined. In fact, this review identified

only three studies that had performed a comparison between implant diameters and failure rates.[19,46,58] Davarpanah et al[46] reported higher failure rates for large diameter implants, while Fugazzotto[19] reported better survival rates for wide neck configurations. Sohn et al[58] reported high survival rates for both standard (4.1 mm) and wide (5 mm) diameters of SDI. It should be underlined that data extracted from the studies on this topic were limited and inconclusive.

Bone quality and region of placement appear to play an important role in implant survival. In this review, the studies reported a marginally higher number of failures associated to SDI placed in the posterior maxilla.[38,54,59,61] In comparison, the number of failures in the mandible was less. This could be explained by the fact that the shape of the jaw and bone density are governing factors that play an important role in the survival of implants.[26] Traditionally, the emphasis has been primarily placed on bone morphology or bone density as important factors in predicting implant success and survival, and comparisons between short and standard length implants have been made in this light.[79] However, it is important to note that this is not an appropriate assessment of the outcomes associated with the use of SDI, since in most studies SDI were usually placed under compromised situations. Unless studies have evaluated outcomes of SDI under normal alveolar conditions, superficial comparisons should not be made with standard length and/or longer implants.

Finally, very few RCTs relevant to the current topic were identified by this review. Thus, prospective clinical trials with standardized protocols and well-defined study parameters are needed to further assess treatment outcomes and predictability of SDI, especially with regard to shorter implants (< 6 mm).

CONCLUSIONS

The survival rates and treatment outcomes associated with short implants are dependent on multifactorial parameters, and cannot be determined by mere comparisons between the existing studies, which differ from one another. This structured review, however, provides sufficient evidence of the predictability of treatment outcomes with microrough surface SDI (< 8-mm lengths) in the treatment of partially and fully edentulous arches. Microrough surface implants with lengths in the range of 6 to 7.5 mm appear to provide favorable survival rates, and this fact may significantly contribute to the simplification of implant therapy, namely in posterior segments of the arches.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Dr Christophe Combescure, biostatistician, for his most valuable advice for the statistical analyses. The authors reported no conflicts of interest related to this study.

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