Short Implants—An Analysis of Longitudinal Studies

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Purpose: *The purpose of this study was to consider the therapeutic decision whether to use advanced surgery or short implants based on data concerning the use of these implants found in follow-up studies.* ***Materials and Methods:*** *The MEDLINE database was consulted for follow-up studies published between the years 1980 and 2004. For those studies that met the inclusion and exclusion criteria, data concerning the number of implants 7, 8.5, or 10 mm long placed and lost, the time at which the failure occurred, and related risk factors were gathered for 33 studies arranged in tables and subjected to analysis. The studies included 16,344 implant placements with 786 failures (4.8%). Implants were analyzed according to the time of failure (ie, before or after prosthesis seating) and risk factors implicated in the failures.* ***Results:*** *The total rate of failures was 4.8%. Implants 3.75 mm wide and 7 mm long failed at a rate of 9.7%, compared to 6.3% for 3.75 × 10-mm implants. It was found that 54.9% of failures occurred before the prosthesis connection. Finally, 66.7% of all failures were attributed to poor bone quality, 45.4% to the location (maxilla or mandible), 27.2% to occlusal overload, 24.2% to location within the jaw, and 15.1% to infections (an implant could be associated with multiple risk factors).* ***Discussion:*** *The analysis revealed that among the risk factors, poor bone quality in association with short implants seemed to be relevant to failure. The use of implants 4 mm in diameter appeared to minimize failure in these situations. The 3.75 × 7-mm implant presented the highest failure rate (9.7%) of 1,894 implants analyzed (excluding implant designs with higher failure rates but few total implants).* ***Conclusion:*** *Short implants should be considered as an alternative to advanced bone augmentation surgeries, since surgeries can involve higher morbidity, require extended clinical periods, and involve higher costs to the patient.* Int J Oral Maxillofac Implants 2006;21:86–93

Key words: *bone quality, risk factors, short implants*

Severely resorbed jaws are quite common. Extremely atrophic residual ridges are often very difficult or impossible to properly fit with conventional complete dentures.[1] Implant treatment can be an effective alternative in such situations. Follow-up studies have revealed high success rates for implant usage associated with different kinds of prosthetic rehabilitation, confirming the advantages of this treatment.[2–30] However, reduced alveolar bone height can limit implant placement anatomically, especially in the posterior regions of the maxilla and mandible. Thus, success in the treatment of patients with inadequate bone quantity can be compromised, and inadequate bone height can be considered a risk factor for dental implant failure.[1,3,7,10,15,16,18,22,25,31] In situations of extremely reduced bone volume, the surgeon may employ bone augmentation procedures, which result in higher costs, greater morbidity, and longer treatment times.

Another possibility for addressing such borderline situations involves the use of short implants. However, short implants have been associated with lower predictability.[5,6,12,14–16,18,19,22,25,29,31,32] The bone

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Table 1 Inclusion and Exclusion Criteria of the Longitudinal Studies

Inclusion criteria	Exclusion criteria
• Appeared in an English language journal • Reported on Brånemark System–compatible implants • Presented a study with a follow-up period of at least 1 year	• Was a follow-up study of advanced surgical techniques • A clinical follow-up emphasizing peri-implant tissues • An immediate loading follow-up study • Re-state prosthetic or orthodontic studies • A follow-up with a focus on surgical techniques of fixation

found in posterior regions of the jaws is usually of poor quality, especially in the maxilla, where physical access and higher occlusal forces of the oral cavity can render a lower success rate than the anterior region.[10,28] Some authors have suggested the use of implants with roughened surfaces as a viable way to reduce the failure rate of short implants.[27,28,31] Another possibility for addressing such borderline situations involves the use of short implants. However, short implants have been associated with lower predictability.[5,6,12,14–16,18,19,22,25,29,31,32]

The term "short implant" is somewhat subjective. Some authors[10,18,32] have defined "short implants" as "implants no longer than 7 mm." Others[26,27,30] have considered "short implants" to be implants up to 10 mm long. In spite of the aforementioned research demonstrating the low predictability of short implants, it is possible to achieve high success rates for short implants. However, there is hesitancy concerning their employment in clinical practice. Unanswered questions surrounding the use of short implants include, "What is considered practical longevity for these implants?" "At what point in time could failures be expected to occur?" and "What are the factors related to the short length which could lead to failure?" Medical treatment based on evidence is the conscious utilization of scientific reports to make an individual decision.[33] In light of these considerations, the present study was undertaken to evaluate and gather data from published articles on the use of short implants and their clinical success.

MATERIALS AND METHODS

The MEDLINE database of the National Library of Medicine was searched for longitudinal articles which evaluated implants in relation to their length and were published between the years 1980 and 2004. The search was undertaken with the words "dental implants and length and clinical" (or longitudinal or retrospective or follow-up) and yielded 101 studies.

This analysis was conducted for Brånemark System–compatible implants, since they share the same fixation technique and design, characteristics which make comparison to other systems difficult. The material gathered was subject to inclusion and exclusion criteria (Table 1).

This analysis also included studies not listed in the initial MEDLINE search but cited by studies found. Other studies were obtained through manual search. Of the 101 articles initially found, 31 were found eligible after application of the inclusion/exclusion criteria.

The data of interest for this investigation were collected and grouped in tables. The total numbers of short implants (implants 7, 8.5, or 10 mm in length) placed and lost are presented in Table 2. Time of implant failure (ie, before or after prosthesis placement) is displayed in Table 3.

The main risk factors reported in each study, especially those most commonly related to implant failure, are shown in Table 4.

RESULTS

A total of 16,344 implants were placed in the studies examined; 786 of these implants (4.8%) failed and were removed. Relatively few implants 8.5 mm in length or 5 mm in diameter were placed, because these are relatively new designs; thus, analysis of these was difficult. Of the 1,894 implants placed that were 7 mm long and 3.75 mm wide, only 184 (9.7%) were lost; implants of the same length showed a failure rate of 7.5% when the diameter was 4 mm.

All of the implants in Table 3 (which displays information on failures before or after prosthesis connection and in the first year of function) were either Brånemark System implants (Nobel Biocare, Göte-

Table 2 Clinical Studies of Patients Rehabilitated with Brånemark-Compatible Implants

	Follow-up (y)	Total no. of implants placed/lost	3.75 mm			4.00 mm			5.00 mm		
			7	8.5	10	7	8.5	10	7	8.5	10
Friberg et al[32] (1991)	1	4641/69	793/44	-	-	-	-	-	-	-	-
Quirynen et al[25] (1991)	4	196/2	5/0	-	48/1	-	-	-	-	-	-
Triplett et al[1] (1991)	5.2	130/8	46/2	-	84/6	-	-	-	-	-	-
Naert et al[22] (1992)	6.5	509/29	65/9	-	281/18	-	-	-	-	-	-
Jemt and Lekholm[15] (1993)	5	259/7	54/5	-	-	-	-	-	-	-	-
Jemt and Pettersson[17] (1993)	3	70/1	1/0	-	11/0	-	-	-	-	-	-
Nevins and Langer[23] (1993)	1–6	1203/56	119/9	-	525/24	-	-	-	-	-	-
Bahat[5] (1993)	0.4–5.8	732/34	.../12	-	.../7	-	-	-	-	-	-
Ekfeldt et al[9] (1994)	3.8	93/1	2/0	-	16/1	-	-	-	-	-	-
Jemt and Lekholm[16] (1995)	5	801/113	298/72	-	291/...	-	-	-	-	-	-
Henry et al[13] (1995)	1	53/1	-	-	11/0	-	-	-	-	-	-
Becker et al[7] (1999)	6	282/30	-	16/0	110/10	1/0	4/0	29/6	5/3	4/0	11/0
van Steenberghe et al[29] (1990)	1	558/23	109/3	-	225/15	11/0	-	21/0	-	-	-
Henry et al[12] (1993)	3	/33	/7	-	/19	/1	-	/0	-	-	-
Higuchi et al[14] (1995)	3	/33	/7	-	/19	/1	-	/0	-	-	-
Lekholm et al[19] (1994)	5	/36	/7	-	/23	/1	-	/0	-	-	-
Lekholm et al[20] (1999)	10	461/34	92/6	-	193/23	9/0	-	14/0	-	-	-
Friberg et al[10] (2000)	1–14	260/17	247/17	-	-	-	-	-	-	-	-
Bahat[6] (2000)	10	660/35	49/10	3/0	118/5	35/2	-	66/3	-	-	11/1
Davarpanah et al[8] (2001)	3	614/42	-	43/...	57/...	-	62/...	91/...	-	-	23/...
Testori et al[27] (2001)	4	458/6	-	15/0	92/0	-	-	6/0	6/1	3/0	19/0
Naert et al[21] (2002)	16.5	1956/132	...	...	...	...	...	...	...	...	...
Testori et al[28] (2002)	3	405/9	...	...	...	...	...	...	...	...	.../1
Garlini et al[11] (2003)	6	555/8	...	...	...	...	...	...	...	...	...
Weng et al[30] (2003)	6	1179/104	7/...	11/...	275/...	-	1/...	10/...	11/...	47/...	144/...
Tawil and Younan[26] (2003)	1–7.7	269/12	14/3	26/0	69/1	10/2	12/0	28/0	3/0	8/2	55/3
Total		16344/786	1894 /184	60/0	1783 /112	66/5	16/0	164/9	14/4	15/2	96/3
%		4.8	9.7	0	6.3	7.5	0	5.4	28.6	13.3	3.2

...Data not available.
- No implant of this length was placed or lost.

borg, Sweden) or 3i implants (3i/Implant Innovations, West Palm Beach, FL). The designs of the implants and the placement techniques used were similar. It was found that 45.1% of the failures occurred after loading, but if the first year of loading was considered, the failure rate for this period increased to 63.2%. Some studies presented a considerable number of failures after prosthesis connection in relation to before,[1,6,8,10,16,20,21] but they related those losses to clinically observed conditions (occlusal overload,[1,6,8,10,20,21] jaw fracture,[1,20] and systemic conditions) rather than to the use of short implants.

In relation to Table 4, it was observed that the authors, who reported area of the jaw as being a risk factor, usually mentioned the maxillary posterior, where type 4 bone is predominantly found.[34] When jaw was mentioned as a risk factor, the maxilla was most frequently cited; however, it was the bone quality in the maxilla that was the main cause for concern (Table 4).

DISCUSSION

A common finding in the vast majority of longitudinal studies concerned losses to follow-up, with patient removal being as high as 18%.[23] Most of the studies did not detail the characteristics of implants lost to follow-up, limiting them to merely listing the causes of implant or patient loss. One study reported whether the implants were in function when last seen,[5] while another[19] analyzed patients lost to follow-up in relation to gender, age, number of implants placed, bone quality, and jaw type. Notwithstanding, the length of implants lost to follow-up, which could influence positively or negatively the success rate for a given period, was not reported by most studies; nor were individual success rates for the various implant lengths and diameters. It is recommended that such information be provided in future studies.

Based on the results, important factors which need to be reported are: definition of the term "short implant," the time at which failure occurred (ie, before

Table 3 Clinical Studies Reporting on Implant Failure Before or After Prosthesis Connection and in the First Year of Function

References	Failures before prosthesis connection	Failures after prosthesis connection	Failures during the first year of function	Type of implant
Friberg et al[32] (1991)	69	0	0	Brånemark System
Quirynen et al[25] (1991)	2	0	0	Brånemark System
Triplett et al[1] (1991)	0	8	2	Brånemark System
Johns et al[18] (1992)	16	16	16	Brånemark System
Quirynen et al[24] (1992)	23	6	4	Brånemark System
Jemt and Lekholm[15] (1993)	4	3	0	Brånemark System
Jemt and Pettersson[17] (1993)	0	1	1	Brånemark System
Nevins and Langer[23] (1993)	31	25	NA	Brånemark System
Lekholm et al[19] (1994)	20	16	3	Brånemark System
Ekfeldt et al[9] (1994)	0	1	1	Brånemark System
Henry et al[13] (1995)	1	0	0	Brånemark System
Jemt et al[16] (1995)	38	75	40	Brånemark System
Becker et al[7] (1999)	13	17	13	Brånemark System
Lekholm et al[20] (1999)	16	18	3	Brånemark System
Bahat[6] (2000)	13	22	12	Brånemark System
Friberg et al[10] (2000)	5	12	0	Brånemark System
Davarpanah et al[8] (2001)	14	28	20	3i
Testori et al[27] (2001)	6	0	0	3i Osseotite
Naert et al[21] (2002)	52	80	42	Brånemark System
Testori et al[28] (2002)	6	3	2	3i Osseotite
Garlini et al[11] (2003)	8	0	0	3i Osseotite
Weng et al[30] (2003)	87	17	NA	3i
Tawil and Younan[26] (2003)	6	6	NA	Brånemark System
Total (%)	430 (54.9)	354 (45.1)	159 (25.9)	784 (100)

NA = data not available.
*When articles that did not present failures during the first year of function were excluded, the number of failures was 612; 306 (50%) of these failures occurred before prosthesis connection and 306 (50%) occurred after prosthesis connection. Of the failures that occurred after prosthesis connection, 159 (25.9%) occurred during the first year of function.

or after loading) and the possible cause of failure, smoking, occlusal overload, gender, infection, diameter, jaw, area and bone quality. Two controversial aspects concerning atrophic jaws should be discussed: the indications for advanced surgery or rehabilitation with short implants; and a change or a suggestion of change in the implant placement protocol for short implants aiming to optimize its predictability.

The failure rates in Table 2 for the 3.75 × 7-mm implants reveal a figure 2 times greater than the failure average (4.8%). Based on this and the fact that the implants of other lengths had their rates close to the average, it is reasonable to consider short implants as a risk factor when they have a design shorter than or equal to 3.75 × 7 mm. However, surface treatment, screw type, and design may be able to optimize success rates.[8,11,27,28,30]

Implant failure can hardly be accounted for by a single factor. It has been associated with poor bone quality,[3,4,6–14,16,18,19,21,23,25,27–31], short length,[1,10,12,19,29,32] narrow diameter,[6,9,12,14,20,29] parafunction,[1,2,6,8,10,20,21,24,26] gender,[14,29] infection,[2–4,22,24,25] implantation area,[1,2,5,23,24,27] and implant diameter.[6,9,12,14,20] Some of these factors can be more important than others, but the greatest complication resides in the association of 2 or more. This may be why the great majority (90.3%) of the 3.75 × 7-mm implants remained stable after several years of loading; their short length, although a risk factor, may not compromise clinical success if not associated with other risk factors.

As for the time at which failure was detected (Table 3), there was a tendency toward failure before prosthesis placement (54.9%), as reported in another bibliographic survey conducted by Goodacre and coworkers.[31] This fact was most often associated with surgical technique, lack of primary stability, loading during the healing period, and excessive application of torque during abutment connection.[5,11,13–15,19,23–25,28–31] Other studies, however,

Table 4 Risk Factors Related to Implant Failure Reported in the Studies

References	Smoking	Occlusal overload	Gender	Age	Infection	Area	Jaws	Poor bone quality
Adell et al[2] (1981)		X			X		X	
Albrektsson et al[4] (1988)					X			X
Adell et al[3] (1990)						X	X	X
van Steenberghe et al[29] (1990)			X				X	X
Friberg et al[32] (1991)						X	X	X
Quirynen et al[25] (1991)					X			
Triplett et al[1] (1991)		X						X
Johns et al[18] (1992)							X	X
Naert et al[22] (1992)					X			X
Quirynen et al[24] (1992)		X			X	X		
Henry et al[12] (1993)							X	X
Jemt and Lekholm[15] (1993)								
Nevins and Langer[23] (1993)						X	X	X
Bahat[5] (1993)						X	X	
Ekfeldt et al[9] (1994)								X
Lekholm et al[19] (1994)							X	X
Henry et al[13] (1995)							X	X
Higuchi et al[14] (1995)			X	X			X	X
Jemt and Lekholm[16] (1995)								X
Becker et al[7] (1999)								X
Lekholm et al[20] (1999)		X						
Bahat[6] (2000)		X				X	X	X
Friberg et al[10] (2000)		X				X		
Davarpanah et al[8] (2001)	X	X					X	X
Testori et al[27] (2001)						X	X	X
Naert et al[21] (2002)		X					X	
Testori et al[28] (2002)								X
Garlini et al[11] (2003)								X
Weng et al[30] (2003)								X
Tawil and Younan[26] (2003)		X						X
Total (%)	1 (3.0)	9 (27.2)	2 (6.0)	1 (3.0)	5 (15.1)	8 (24.2)	15 (45.4)	22 (66.7)

reported a greater number of failures after prosthesis placement.[1,6,8,10,16,20,21] Even so, a common finding in all of these studies was the tendency of failures to occur in the first year of function. As we can see in Table 3, of 306 implant failures after prosthesis connection (100%), 159 (52%) were lost during the first year of function. Unfortunately the data presented in the most of the studies reviewed did not permit a long-term analysis of failure correlated to length.

Many studies[1,2,6,8,10,20,21,24,26] found occlusal overload to be an important risk factor, even those that reported bruxism.[24,26] Lekholm and coworkers[19] did not observe any negative influence on the temporomandibular joint when the masticatory function was re-established with implant-supported restorations, even though implants do not have the same tactile sensibility as teeth.

Though individual muscular strength (biotype) was not reported in these follow-up studies as a possible risk factor, parafunction and overloading were.[1,2,6,8,10,20,21,24,26] The most distal position usually involves greater masticatory load than the anterior one. This load could be intensified by an individual with stronger muscular strength, as reported in some articles reporting greater failure rates.[1,6,10,31] Regarding gender, 2 studies[14,29] described a statistically greater occurrence of failures in men. It is generally accepted that men have a stronger individual muscular strength than women. Thus, the individual muscular strength in some subjects could be a determining factor in generating overload, which when associated with other risk factors could cause failures.

In relation to implant diameter, van Steenberghe and coworkers[29] believe that an implant with a 4-mm diameter should normally be used in situations in which bone resistance is so poor that the attainment of primary stability would be difficult to achieve. Statistical analyses reported in other studies[6,9,12,14,20] show that implant survival increases as implant diameter increases. However, Davarpanah and colleagues asso-

ciated 5-mm-diameter implants with higher failure rates and more frequent bone loss in the mandible.[8] These complications were attributed to overheating during surgical preparation of the implant receptor site, the placement of wide-diameter implants in residual ridges narrower than 8 mm in width, or the placement of 2 wide implants too close together. Such a situation could lead to secondary bone loss and the promotion of bone necrosis through diminished blood supply, which could explain the high failure rate found for the 5 × 7-mm implants in Table 2.

Considering these arguments and also the different bone qualities and thicknesses, it would seem more prudent to use 4- and 5-mm-diameter implants instead of 3.75 mm or narrower implants when planning to use short implants. As shown in Table 2, better results were obtained with 4-mm-wide implants than with 3.75-mm-wide implants.

As for the 5-mm-wide implants, they probably should be reserved for situations in which poor bone quality and good bone width are found.

Poor bone quality is likely the most significant factor associated with implant failure (Table 4). Bone quality was related to failure in most studies.[3,4,6–14,16,18,19,21,23,27–31] The losses were found predominantly in edentulous maxillae that presented poor bone quality and severe resorption. It was stressed that the combination of poor bone quality and short implant length would result in less mechanical stability when placing the implant and during its healing period.[5,6] In light of this, it would be tempting to correlate implant length to higher failure rates, but the importance of tissue status and bone quality cannot be overemphasized.[12] Concomitantly, the surgical handling of the receptor tissues is a factor known to be critical in achieving osseointegration. Accordingly, it seems appropriate to respect each of the multifactorial requirements for osseointegration and not overemphasize isolated variables such as implant length.[12]

In 2 studies,[5,6] Bahat did not find a significantly different success rate between type 4 bone and bone of types 2 and 3. Conversely, Goodacre and coworkers[32] found that 4% of the implants placed in bone of types 1, 2, and 3 were lost, while 16% of those placed in type 4 bone failed.

Since maxillary bone is usually poorer in quality than mandibular bone, it may have contributed to the increased failure rates in some studies.[2,3,5–7,12–14,18–20,22,23,27,31] However, Davarpanah and colleagues[8] and Testori and associates[28] reported that the use of special implants[8] with a treated surface[28] were the probable cause of higher success rates in maxillary bone in their studies. Prostheses supported by short implants seem to be an acceptable alternative for the completely or partially edentulous patient with minimal bone height, compared to conventional rehabilitation procedures and advanced surgery since at least 90% of the 7-mm-long implants studied became osseointegrated (Table 2). Friberg and colleagues[10] concluded that Brånemark System implant placement without the use of bone graft procedures in severely resorbed mandibles is a highly predictable procedure. They considered the technique employed in their study (implant placement in 5 to 6 mm of bone height) to be more advantageous than atrophic mandible reconstruction using autogenous grafts because of several factors: patient morbidity, duration of the treatment period, treatment simplicity and cost, continual bone graft resorption, and implant and prosthesis survival rates. On the other hand, some authors, such as Jemt and associates,[16] found advanced surgeries to be more advantageous; in Jemt and associates' study, the grafted patient group behaved statistically similarly to the group with intermediate bone resorption; both had higher success rates than the group with severe bone resorption treated with short implants.

In light of this analysis, the clinician, perceiving it to be inconclusive, is faced with a dilemma when deciding what treatment is indicated for a particular case. Since severe bone resorption conveys considerable risk when associated with poor bone quality and overload, bone grafting techniques could prevent failure in such associations. In patients with more favorable conditions, the probability of success with short implants rises, making it the best treatment option.

Some investigators who presented very high success rates[1,5,6,9,28] considered patient selection and treatment planning fundamental to their success. Some authors[1,5,28] attributed high success rates to careful surgical technique, seeking to engage or slightly penetrate the cortical plate of the inferior border in the mandible. Bahat[5] attributed the high success rate in his study to detailed surgical planning. This included occlusion planning and simulation of the steps necessary to reach the chosen goal; the correction of all pathoses before implant placement, including alignment of the teeth and leveling of the occlusal plane where appropriate; modification of the preparative sequence (protocol) to minimize the number of entries to create as tight a site as possible; and the placement of each implant exactly as planned. In his study, an implant was left in place only if it was firmly stabilized in the bone. Reaffirming his suggestions, Bahat[6] reported that site preparation was guided by the objective of minimizing ostectomy while maintaining an optimum implant direction.

Another important observation[10] has led other authors to confirm a dense bone texture in severely resorbed mandibles as a high risk factor for overheating of the bone tissue during site preparation, rendering future osseointegration difficult. Testori and associates[28] related their success to optimum primary stabilization; they were in agreeement with Tawil and Younan,[26] who reported that care was taken to alter the perforation sequence when poor bone quality was found so as to assure greater primary stability and better interface between implant and surrounding bone. In light of these statements, the results presented in Table 2, and the fact that most authors employed the conventional protocol "ad modum Brånemark," yielding an average failure rate of 9.8% for the 7-mm-long implants (1974 implants placed with 193 losses), it is reasonable to propose revision of the protocol for 7-mm implants, since the use of these implants could improve primary stability and, consequently, results. These implants may even be indicated for use with bone of poor quality.

Another important finding in the study of Bahat[6] was that 60% of the 7-mm-long implants which failed were the only implants in that segment of the arch. The survival of ≥ 7 mm implants probably depends on splinting (if possible, to longer implants). That is, long span cases with few unfavorable bone areas should not cause too much concern during planning. The number of implants placed in an edentulous area is relevant to success, since Lekholm and associates[19] found a higher failure rate for prostheses supported by 2 implants rather than 3. They suggested that fixed prostheses for edentulous patients be supported by 3 implants in a tripod alignment when possible. Thus, a greater number of implants with minimum distances between them should be sought in circumstances where bone height is low.[15,19]

CONCLUSIONS

According to the findings of this study it was possible to conclude that:

1. Short implants ≥ 7 mm long should be considered a risk factor during treatment planning.
2. Bone quality seemed to be a critical deciding factor in association with implants ≤ 7 mm long in determining the failure rate among the studies analyzed. An increase in diameter to 4 or 5 mm, as well as surface treatment, could minimize this problem.
3. In poor bone quality it is advisable to optimize primary stability; thus a protocol sequence should be sought which would satisfy this necessity.
4. The therapeutic success reported for the 3.75 × 7-mm implants (90.3%) provides support for the use of this implant design. Advanced surgical techniques which raise costs, morbidity, and treatment time may thus be circumvented.

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