A Targeted Review of Study Outcomes With Short (≤7 mm) Endosseous Dental Implants Placed in Partially Edentulous Patients

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Background: Generally, threaded root-form endosseous dental implants are thought to perform poorly in short lengths (i.e., <10 mm). However, whether modifications in implant surface geometry will improve performance of short threaded implants is less clear.

Methods: The relationship between dental implant failure rates and their surface geometry, length, and location (maxilla versus mandible) was explored in the published literature. Using a MEDLINE search (1985 through 2001), studies were sought with the following criteria: 1) data suitable to calculate failure rates of implant lengths ≤7 mm versus >7 mm; 2) data separable into maxillary versus mandibular results; 3) criteria for "failure" clearly defined; and 4) minimal functional period of 2 years.

Results: Twelve papers were identified as follows: eight with machined threaded implants, two with acid-treated threaded implants, and two with sintered porous-surfaced press-fit implants. The following results were found: 1) machined surface implants experienced greater failure rates than textured surface implants; 2) with the exception of sintered porous-surfaced implants, 7 mm long dental implants appear to have higher failure rates than those >7 mm length; and 3) with textured surface implants, higher failure rates were more likely in the maxilla than in the mandible, but with machined surface implants there were no differences in failure rates between maxilla and mandible.

Conclusions: Dental implant surface geometry is a major determinant in how well these implants perform in short lengths, defined here as lengths of ≤7 mm. While threaded implants show higher failure rates in short versus longer lengths, sintered porous-surfaced implants perform well in the defined "short" lengths. More studies are needed to better assess the performance of short, acid-washed threaded implants. *J Periodontol 2004;75: 798-804.*

KEY WORDS

Dental implants, failure; dental prosthesis design.

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A major limitation in the use of most endosseous dental implant designs currently in clinical use is that, in order to ensure success, adequate bone height needs to be available to receive implant lengths of at least 10 mm in the mandible or 13 mm in the maxilla.[1] While implants of 7 mm (or even less) have been provided by various manufacturers, these are generally thought to have a poor prognosis, although to our knowledge no comprehensive review of studies using such short implants has been published. This review and analysis of published literature aims at providing such information.

MATERIALS AND METHODS

A literature search was conducted using the OVID computerized database MEDLINE for the years 1985 through 2001 to identify articles dealing with 7 mm long dental implants for the management of partial edentulism. The search terms used included: dental implants, partial edentulism, failure, 7 mm length, and fixed partial dentures. The reference lists in each of the retrieved articles were further scrutinized in the hopes of identifying any literature missed with this database. Only studies published in English and involving human subjects were considered.

A total of 21 articles were found dealing with both 7 mm implants and partial edentulism in the defined time frame and these were reviewed for inclusion. The following inclusion criteria were applied:

1) the reported data needed to be specific enough to allow calculation of the failure rates of any 7 mm long (or shorter) implants used and of the standard deviations of these failure rates; 2) the data provided could clearly be separated into maxillary and mandibular experiences; 3) the criteria for implant failure had been clearly defined; and 4) all implants had been in function for a minimum of 24 months. If more than one publication referred to the same data, the most recent report was used.

Twelve of the 21 identified studies satisfied these criteria and are summarized in Table 1. Eight reports[1-8] dealt with machined threaded implants,‡ two[9,10] with acid-washed threaded implants,§ and two[11,12] with tapered, press-fit, sintered porous-surfaced implants.‖

Statistical Methods

The data were obtained and separated according to jaw (i.e., location), implant type (machined threaded, textured threaded, or press-fit sintered porous-surfaced implants) and implant lengths used, i.e., ≤7 mm in length versus >7 mm lengths. A weighted repeated measures logistic regression was performed in order to assess whether these three factors as well as all two-way interactions between these three variables had any effect on failure rates between the two types of threaded implants. Pair-wise comparisons also were made using Bonferroni-adjusted pair-wise tests.

Since both studies[11,12] on sintered porous-surfaced implants were done by the same investigators, it was not possible to distinguish between author/paper effects, and the effect of this implant type relative to the other two implant types. Consequently, these two papers were excluded from the main part of the analysis, and examined separately through a weighted logistic regression.

Table 1.

Summary of Studies Reviewed

Reference	Study Design	Total Number of Implants (N ≤7 mm)
van Steenberghe et al.[1] (1990)	Prospective	558 (120)
Friberg et al.[2] (1991)	Retrospective	470 (77)
Naert et al.[3] (1992)	Retrospective	490 (58)
Bahat[4] (1993)	Prospective	732 (116)
Jemt and Lekholm[5] (1993)	Prospective	259 (54)
de Bruyn et al.[10] (1999)	Prospective	85 (9)
Gunne et al.[6] (1999)	Prospective	69 (37)
Ivanoff et al.[7] (1999)	Retrospective	299 (109)
Lekholm et al.[8] (1999)	Prospective	461 (101)
Testori et al.[9] (2001)	Prospective	485 (7)
Deporter et al.[11,12] (2001)	Prospective	199 (76)

RESULTS

The data obtained from the 12 papers reviewed here are displayed in Tables 2 (maxillary sites) and 3 (mandibular sites) as failure rates for implants of lengths >7 mm or as lengths ≤7 mm. In all cases, implant failure was defined as actual implant loss. In the majority of these studies, relatively few short (≤7 mm) implants were used (Table 1). Only one study[7] involved the use of endosseous threaded dental implants with lengths <7 mm. These investigators assessed machined threaded implants of two short lengths (6 or 7 mm) and three different diameters (3.75, 4.0, and 5.0 mm). As discussed below, the shortest implants used in their study were 6 mm in length and 5.0 mm in diameter, but these performed rather poorly with, for example, mandibular failure rates of 33.3%.

For the other studies in which machined threaded implants were used in partially edentulous patients, the failure rates for 7 mm long implants varied considerably. Most of these short implants were of standard diameter (3.75 mm), were splinted to longer implants for extra support, and were used in the posterior segments of both jaws. In the maxilla, these 7 mm long implants showed failure rates of zero[2] (N = 11 implants) to 18.2%[8] (N = 22), with five of the relevant seven reports showing failure rates of around 10% or more. By comparison, rates of failure for similar implants of lengths >7 mm were 2.6%[2] (N = 189) to 8.0%[8] (N = 163) (Table 2). All but one[2] of the eight studies showed higher failure rates in the maxilla with lengths of 7 mm than with those of >7 mm.

In the mandible, 7 mm long machined threaded implants with diameters of 3.75 or 4.0 mm showed failure rates ranging from 1.5%[2] (N = 66) to 11%[6] (N = 37), compared with 1.1%[2] (N = 204) to 14%[6] (N = 32) for similar implants of lengths >7 mm (Table 3).

The other two studies reporting results on threaded implants were those of Testori et al.[9] and de Bruyn et al.[10] in which implants with an acid-treated surface finish were employed. Testori and his colleagues were assessing threaded implants with an acid-etched surface treatment¶ in both maxillary and mandibular sites in a prospective, private practice multi-center trial. They defined "short" implants as ≤10 mm in length, and in fact very few 7 mm long implants (7 of 485) were used.

‡ Nobelpharma Inc., Goteborg, Sweden.
§ 3I Corp., West Palm Beach, FL or Core-Vent Corp., Encino, CA.
‖ Innova Corp., Toronto, ON.
¶ Osseotite, 3I Corp.

Table 2.
Maxillary Outcomes in Partial Edentulism

Reference	Implant	Failure Rates	
		>7 mm	≤7 mm
Bahat[4]	Machine threaded	3.8%	9.5% (N = ?)
de Bruyn et al.[10]	Acid washed	8.9%	33% (N = 6)
Deporter et al.[11]	Porous surface	3.8%	0.0% (N = 46)
Friberg et al.[2]	Machine threaded	2.6%	0.0% (N = 11)
Ivanoff et al.[7]	Machine threaded	6.1%	4.0%* (N = 25) 9.8%† (N = 41)
Jemt and Lekholm[5]	Machine threaded	2.3%	13.3% (N = 15)
Lekholm et al.[8]	Machine threaded	8.0%	18.2% (N = 22)
Naert et al.[3]	Machine threaded	3.2%	10% (N = 30)
van Steenberghe et al.[1]	Machine threaded	4.2%	10.7% (N = 28)
Testori et al.[9]	Acid washed	1.9%	33.3% (N = 3)

* Diameters 3.75 or 4.0 mm.
† Diameter 5 mm and length 6 mm.

Table 3.
Mandibular Outcomes in Partial Edentulism

Reference	Implant	Failure Rates	
		>7 mm	≤7 mm
de Bruyn et al.[10]	Acid washed	0%	0% (N = 3)
Deporter et al.[12]	Porous surface	0%	0% (N = 32)
Friberg et al.[2]	Machine threaded	1.1%	1.5% (N = 66)
Gunne et al.[6]	Machine threaded	14.0%	11.0% (N = 37)
Ivanoff et al.[7]	Machine threaded	7.1%	9.1%* (N = 22) 33.3%† (N = 21)
Jemt and Lekholm[5]	Machine threaded	0%	7.7% (N = 39)
Lekholm et al.[8]	Machine threaded	7.6%	2.5% (N = 70)
Naert et al.[3]	Machine threaded	2.8%	3.6% (N = 28)
van Steenberghe et al.[1]	Machine threaded	8.1%	3.3% (N = 81)
Testori et al.[9]	Acid washed	0.9%	0% (N = 4)

* Diameters 3.75 or 4.0 mm.
† Diameter 5 mm and length 6 mm.

Six of these 7 mm long implants were 5 mm in diameter and the remaining one was 6 mm in diameter (i.e., no 3.75 or 4.0 mm diameter implants 7 mm long were placed). They reported that one of the three (33%) 7 mm long implants used in the maxilla failed, while all four placed in the mandible appeared successful. This was in comparison to failure rates in the maxilla of 1.9% and in the mandible of 0.9% for all implants of >7 mm length. de Bruyn et al.[10] reported a 33% failure rate in the posterior maxilla for 7 mm long acid-treated threaded implants,[#] compared to 8.9% with similar implants of lengths >7 mm.

The results of the logistic regression analysis (Table 4) for the threaded (machined and textured) implants reported in these 10 papers indicated that generally textured threaded implants performed better than machined threaded implants ($P < 0.0001$), at least in lengths of >7 mm. There were too few (and large standard deviations) threaded implants of lengths 7 mm or less used to allow comparison of textured versus machined threaded in these lengths only. Secondly, threaded implants generally performed significantly better in lengths of >7 mm than in lengths of ≤7 mm ($P < 0.0001$). Regarding implant location by jaw, generally threaded implants performed significantly better in the mandible than in the maxilla ($P < 0.0001$). However, there were significant interactions for implant type with both location ($P = 0.0001$) and implant length ($P < 0.0001$). The pair-wise comparisons provided more information regarding these interactions (Table 5). These comparisons indicated that while machined threaded implants performed similarly in the mandible and maxilla ($P = 1.00$), textured threaded implants performed significantly better in the mandible than in the maxilla ($P < 0.0006$). Regarding the interactions between implant type and implant length, there was a significant difference ($P < 0.0006$) in performance of short versus long textured (acid-etched) threaded implants. In contrast, there was no significant difference in the performance of machined threaded implants for the two implant length groupings ($P = 0.15$), probably because of the large variation of results among investigators and the small number of short implants used. There was, however, a noticeable trend suggesting that machined threaded implants did perform less well in lengths of 7 mm.

In the two papers of Deporter et al.,[11,12] 76 of the 199 sintered porous-surfaced implants placed were 7 mm or less in length. Implant lengths used in

[#] Screw Vent, Core-Vent Corp.

Table 4.

Logistic Regression Results (threaded implants only)

Implant	Parameter Estimate	*P* Value
Implant type (machined versus textured)	−1.66	<0.0001
Implant length (≤7 mm versus >7 mm)	−2.53	<0.0001
Location (maxilla versus mandible)	−2.56	<0.0001
Implant type × location interaction	2.51	0.0001
Implant type × length interaction	1.94	<0.0001

Table 5.

Pair-Wise Comparisons for Threaded Implant Types

Effect	Description of Comparison	*P* Value
Implant type	Machined versus textured	<0.0001
Implant length	≤7 mm versus >7 mm	<0.0001
Location	Maxilla versus mandible	<0.0001
Implant type × location	Machined maxilla versus machined mandible	1.00
Implant type × location	Textured maxilla versus textured mandible	<0.0006
Implant type × implant length	Machined, ≤7 mm versus >7 mm	0.15
Implant type × implant length	Textured, ≤7 mm versus >7 mm	<0.0006

Table 6.

Logistic Regression Results (porous surface only)

Implant	Parameter Estimate	*P* Value
Implant length (≤7 mm versus >7 mm)	2.67	0.98
Location (maxilla versus mandible)	2.67	0.98
Implant length × location interaction	−2.67	0.98

the maxillary patient group[11] included 5 mm (two implants only), 7 mm, 9 mm, and 12 mm. None of the 46 short (5 or 7 mm length) implants placed in maxillary sites failed. There were, however, one 12 mm long and three 9 mm long implant failures, a failure rate of 3.8% for porous-surfaced implants >7 mm long. In the posterior mandible, none of the 32 seven-mm long or 16 nine-mm long implants had failed at the time of publication.[12] The results of the logistic regression analysis of these outcomes are shown in Table 6. There were no significant effects of implant length or implant location on the performance in these two studies. Clearly, implant length was not a major cause for failure with this type of dental implant.

DISCUSSION

The role of implant surface geometry in the development and maintenance of osseointegration has been discussed previously.[13] With all currently available dental implant designs, "osseointegration" under normal functional loading is dependent on the establishment of some sort of mechanical interlock between implant and host bone. Machined threaded implants achieve functional osseointegration by virtue of macroscopic bone interlock with the implant threads. The addition of a roughened surface texture (e.g., acid-etching) to the machined threads is known to add increased effectiveness to this interlock with associated improvements in overall clinical performance.[14,15] Machined threaded implants do not perform well in short lengths. Naert et al.[16] have reported failure rates of 7 mm long implants to be over 18%, while Weng et al.[17] found a 26% failure rate for another commercially available machined threaded device. Whether the addition of a roughened surface texture to threaded implants improves their performance in lengths of 7 mm or less is not clear. The data reviewed here would suggest that the addition of an acid-washed surface treatment does not improve the performance of such short lengths. However, the numbers of short acid-washed implants used in the studies reviewed were very small (seven of the 485 implants used by Testori et al.[9] and nine of the 85 implants used by de Bruyn et al.[10]) making a definite conclusion impossible based on the limited data reported.

Failure of threaded implants is generally considered to be related to progressive crestal bone loss. A number of factors can account for this crestal bone loss including reestablishment of "biologic width," local trauma and interference with vascularity related to implant placement, peri-implant infection and biomechanical effects.[18-20] Biomechanical failure is the most common reason for failure of threaded implant designs since their weak mechanical interlocking with bone offers little resistance to tensile forces arising from off-axis loading encountered during normal function.[21] For this reason, excessive forces are likely to develop especially in bone regions in contact with implant compression surfaces (i.e., the side of implant away from the force vector)[22,23] and may lead to bone microfractures and resorption on these compression surfaces[24,25] because of fatigue.[26] It might be speculated that short threaded implants would be more likely to suffer ill effects from this situation because the compressive forces borne would be concentrated over a relatively small area next to the coronal region of the implant; a counter-acting force likely would also act at the apex of the implant (Fig. 1A). Increasing the length of the implant might be predicted to result in these compressive forces acting over a greater portion of the implant-bone interface (Fig. 1B) thereby reducing local stresses acting in the crestal bone and the probability of microfracture occurrence. This hypothesis is currently being investigated in our laboratories using finite element modeling methods and, if true, could explain the lower failure rates of longer threaded implants assuming all other factors remained constant (i.e., peri-implant bone density and compressive strength and magnitude and direction of occlusal forces). Higher failure rates also would be expected in maxillary sites that are characterized by weaker, more porous bone. In support of this argument, the 10 referenced papers on results with threaded implants reviewed here showed significantly higher failure rates for threaded implants in lengths of 7 mm or less compared to lengths greater than 7 mm, and greater overall failure rates for threaded implants placed in the maxilla compared to those placed in the mandible.

Like threaded dental implants, sintered porous-surfaced implants become osseointegrated through mechanical interlock of host bone and implant. However, the sintered porous surface region with its interconnected pore network[27,28] allows three-dimensional bone interdigitation resulting in an interface zone structure that is resistant not only to compressive and shear forces but also to interface tensile forces.[23,29] Thus, transverse force components are resisted by tethering of the implant against tensile forces along the tension aspect of the interface as well as resisting compression and shear around the remaining implant circumference. Force transfer between porous-surfaced implants and host bone is distributed more uniformly around the implant rather than being concentrated at sites of compressive and shear transfer only.[29] Localized bone microfracture and coronal bone loss due to overloading is, therefore, less likely. A consequence of this more efficient implant fixation resulting from three-dimensional peri-implant bone-implant interlocking is a reduced dependence (and sensitivity) on implant length for maintenance of osseointegration.[11,12,30,31] In the two published reports with sintered porous-surfaced implants reviewed here, there were no failures when the implant was used in lengths of 7 mm or less, with all of the reported failures being for longer lengths (9 mm or 12 mm). Increased success with the sintered porous-surfaced design in bone of lower density and strength

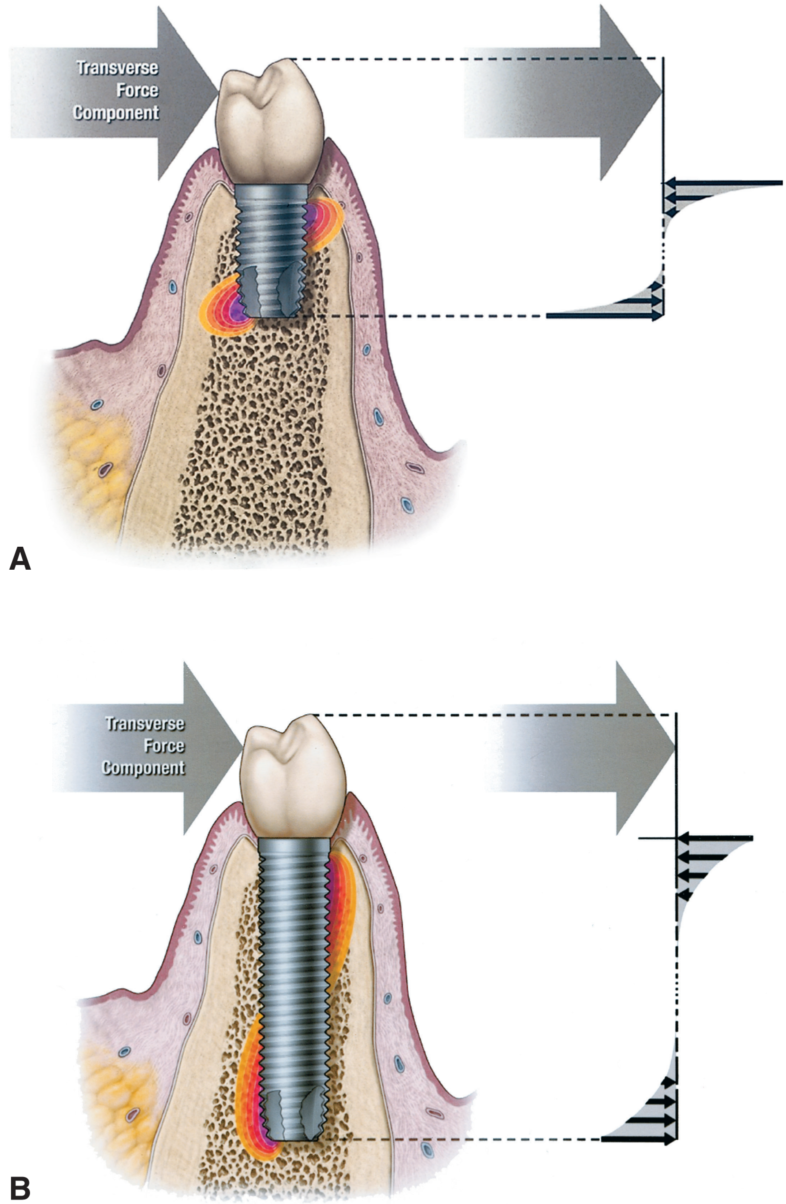

Figure 1.
*An artist's rendering of the expected stress distributions around threaded endosseous dental implants of **(A)** short length, compared to **(B)** longer length. The arrows represent the region of action and magnitude (represented by arrow lengths) of the expected compressive stresses due to a transverse force component acting in the direction shown. The shorter implant might be expected to develop a greater maximum compressive stress next to its coronal region that could, if these stresses were great enough, lead to bone microfracture and resorption. Distribution of the force over a greater implant length as in (B) would likely lower the maximum stresses that developed. Further work is in progress to test this hypothesis.*

is also suggested by this argument, and this corresponds to the clinical experience to date.

CONCLUSIONS

A targeted review of published papers (identified by the OVID computerized database MEDLINE for the years 1985 through 2001) reporting results with threaded endosseous dental implants was done to determine their performance in short versus longer lengths and with either machined or textured (acid-washed) surface features. The outcomes were contrasted to results with press-fit implants with a sintered porous surface geometry and similar length categories (i.e., 7 mm or less versus >7 mm). Ten papers for threaded implants and two for sintered porous-surfaced implants satisfied the defined criteria for inclusion in this review. It was observed that threaded implants in lengths of 7 mm or less had higher failure rates than longer ones, although the outcomes with short acid-washed implants need to be interpreted carefully because generally very few short implants were used. The best performance to date for short implants would appear to be those reported with a press-fit (i.e., non-threaded) shape and a sintered porous surface geometry. In the two published papers[11,12] with this implant design, all of the short implants used (38% of the total implants used in the study) were successful. Clearly, surface geometry (machined vs textured vs sintered porous) plays a major role in performance of endosseous dental implants of lengths 7 mm or less.

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