Shorter Implants in Clinical Practice: Rationale and Treatment Results

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Introduction: *The use of shorter implants offers a number of potential advantages if such utilization yields the same level of treatment success as the use of longer implants. The purpose of this retrospective study was to assess the survival of short implants in various clinical situations in function over time.* ***Materials and Methods:*** *A retrospective study was conducted of all patients treated between May 2000 and May 2007 who received endosseous implants that were less than 10 mm in length. Patient age, gender, location of implants, type of prosthesis, time in function, and stability of peri-implant crestal bone were assessed.* ***Results:*** *The retrospective analysis identified 2,073 implants of 6 mm, 7 mm, 8 mm, or 9 mm in length placed in a variety of clinical situations in 1,774 patients. Cumulative implant survival rates for implants in function in various areas of the mouth supporting single crowns or short-span fixed prostheses ranged from 98.1% to 99.7%. Each indication was examined with regard to individual success and failure rates and mean time in function.* ***Conclusions:*** *When utilized appropriately, implants of 6 to 9 mm in length demonstrate cumulative survival rates under function comparable to those reported for longer implants.* INT J ORAL MAXILLOFAC IMPLANTS 2008;23:487–496

Key words: *osseointegrated implants, short implants, treatment planning*

In the natural dentition, crown-to-root ratio is often seen as an indicator of loss of supporting bone around tooth roots. As periodontal disease progresses, normally proportioned teeth exhibit greater crown-to-root ratios. It has been postulated that the lever arms of functional and parafunctional forces are increased in such situations, resulting in poorer prognoses for the teeth in question.

An assumption was made at the time of introduction of dental implants that longer implants would prove more advantageous in clinical use than their shorter counterparts, due to both an improved crown-to-implant ratio and the greater implant surface area available for osseointegration. This concept appeared to be supported by the data from early publications documenting use of machined, hex-headed, screw-type implants.[1–3]

The ability to place shorter implants and achieve the same level of clinical success observed with longer counterparts would afford a number of potential advantages to the clinician and the patient. Vital structures such as the inferior alveolar canal and the floor of the sinus could be more easily avoided through the use of shorter implants. The need for augmentation therapy in an apico-crestal dimension would also be significantly lessened. Furthermore, in cases where augmentation therapy would still be required, the extent of augmentation necessary would theoretically be decreased.

Although the use of shorter implants is tempting, it should only be undertaken if adequate evidence is available to support the hypothesis that shorter implant use will yield treatment results at least equal to those achieved with longer implants. The purpose of this paper is to examine the relevant *(1)* finite element analyses available, *(2)* published clinical data, and *(3)* treatment results of a private clinical practice.

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Fig 1 A radiograph obtained 5 years following the restoration of a standard-diameter 8-mm-long implant in a mandibular molar position demonstrates stability of the peri-implant crestal bone.

Fig 2 After 4 years in function, standard-diameter implants 6 and 8 mm long supporting a 3-unit mandibular splinted prosthesis demonstrate continued crestal bone stability.

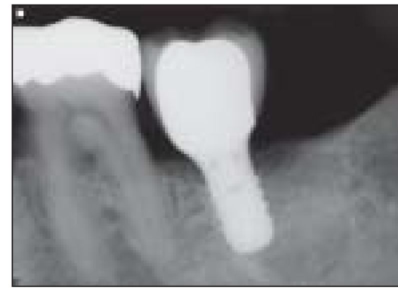

Fig 3 A radiograph of an 8-mm-long wide-platform implant supporting a molar crown obtained 72 months postrestoration.

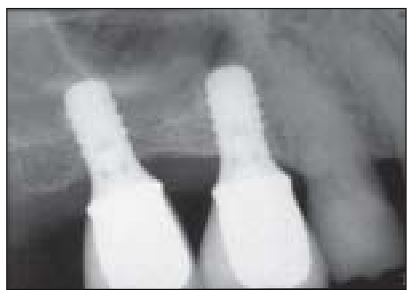

Fig 4 *(Left)* Two 8-mm-long and one 10-mm-long standard-diameter implants were placed in the posterior maxilla 6 months after augmentation had been achieved through the use of trephines and osteotomes. A 74-month postrestoration radiograph demonstrates stability of the crestal bone around the implants.

Fig 5 *(Right)* A radiograph obtained more than 6 years after restoration of two 8-mm-long implants with 6.5-mm-wide platforms restored with single crowns in the maxillary first and second molar positions. This radiograph demonstrates the stability of the crestal peri-implant bone.

MATERIALS AND METHODS

A retrospective analysis was carried out of all patients treated between May 2000 and May 2007 who received implants of 6, 7, 8, or 9 mm in length.

Prior to initiation of implant placement and subsequent restoration, thorough medical histories were obtained for all patients. Patients were excluded from consideration for implant therapy if at least 1 of the following criteria was applicable:

- A history of chemotherapy and/or head and neck radiation therapy within the 24 months prior to consultation
- A history of intravenous bisphosphonate therapy
- A history of uncontrolled diabetes
- A history of any other medical concerns that would render the patient a poor candidate for surgery in general
- A smoking habit of greater than 10 cigarettes per day
- An inability or unwillingness to make appropriate plaque control efforts
- An unwillingness to commit to an appropriate post-therapeutic maintenance regime

A thorough intraoral examination, including appropriate radiographs, was performed for all patients. This included periapical radiography, panoramic radiography, and computerized tomography.

Face-bow mountings of maxillary and mandibular casts were performed when necessary. Comprehensive treatment plans were developed by the author and all other treating clinicians and laboratory technicians prior to the initiation of therapy.

Internal attachment, titanium plasma-sprayed or sandblasted acid-etched rough-surface implants with a length of 6, 7, 8, or 9 mm and a standard neck of 6.5 mm (Straumann, Basel, Switzerland) were placed according to conventional protocols in the following clinical indications:

- Standard-diameter implants restored with single crowns in the posterior mandible (Fig 1)
- Two standard-diameter implants restored with a 3-unit fixed prosthesis in the posterior mandible (Fig 2)
- Implants with a 6.5-mm-wide neck restored with single crowns in the posterior mandible (Fig 3)
- Standard-diameter implants placed in the posterior maxilla and restored with single crowns (Fig 4)

Fig 6 An 8-mm-long wide-platform implant placed at the time of implosion of a bone core, utilizing previously described osteotome and trephine techniques.[25]

Fig 7 A radiograph obtained 6 months after core implosion and implant placement demonstrates consolidation of the displaced bone around the apex of the implant.

Fig 8 A radiographic view of an 8-mm-long wide-platform implant after more than 6 years in function. This radiograph demonstrates the stability of both the bone at the apex of the implant and the crestal bone around the implant.

Fig 9 A 3-unit fixed partial denture was removed in conjunction with the extraction of its 3 abutment teeth. The guide pin in place demonstrates the dimensions of bone crestal to the floor of the sinus.

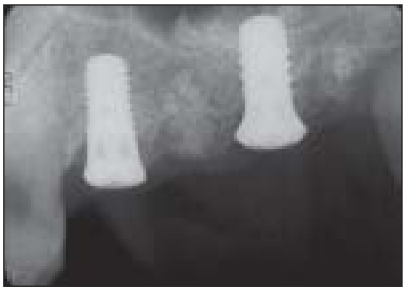

Fig 10 Following implosion of a bone core with a trephine and osteotome in the position of the first molar, a standard-diameter implant 8 mm long was placed in the position of the first premolar, and an 8-mm-long implant with a 6.5-mm-wide platform was placed in the first molar position. Graft materials were placed in the adjacent extraction sockets.

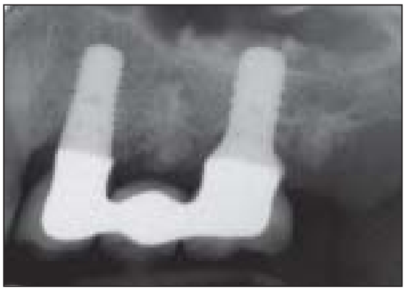

Fig 11 Radiograph obtained 49 months after restoration demonstrates stability of the crestal bone around both implants.

- Implants with a 6.5-mm-wide neck placed in the posterior maxilla and restored with single crowns (Fig 5)
- Implants with a 6.5-mm-wide neck placed in the posterior maxilla at the time of trephine and osteotome sinus augmentation, as described in a previous publication,[4] and restored with single crowns (Figs 6 to 8)
- One standard-diameter and 1 implant with a 6.5-mm neck supporting a 3-unit fixed partial denture in the posterior maxillary (Figs 9 to 11)

With the exception of regenerative therapy performed around the implants placed at the time of mandibular molar extraction, no regenerative treatment was performed around any of the other implants at the time of insertion.

Implant success was assessed by the clinical and radiographic criteria of Albrektsson et al.[1]

RESULTS

A total of 2,073 implants were placed in 1,774 patients (851 men and 923 women). Patient age ranged from 21 to 83 years.

Distribution of implant placement was as follows: 315 standard-neck implants were placed in the posterior mandible and restored with single crowns. Five implants were mobile at the time of abutment connection. The cumulative success rate after 73 to 84 months in function, with a mean time in function of 36.2 months, was 98.4% (Tables 1 and 2).

Table 1 Implants in the Posterior Mandible Restored with Single Crowns: Distribution and Time in Function

Implant length (mm)	Months in function							
	0–12	13–24	25–36	37–48	49–60	61–72	73–84	Total
6	30	11	0	0	0	0	0	41
7	0	14	37	27	0	0	0	78
8	10	10	20	43	30	10	13	136
9	0	0	18	21	21	0	0	60
Total	40	35	75	91	51	10	13	315

Table 2 Implants in the Posterior Mandible Restored with Single Crowns: Cumulative Survival Rates

Months in function	Implants at beginning of interval	Implants lost during interval	Interval failure rate	Cumulative success rate (%)
0–12	315	5*	1.6	98.4
13–24	275	0	0	98.4
25–36	240	0	0	98.4
37–48	165	0	0	98.4
40–60	74	0	0	98.4
61–72	23	0	0	98.4
73–84	13	0	0	98.4

*Five implants (two 6 mm long; one 7 mm long; two 8 mm long) were mobile at abutment connection.

Table 3 Implants in the Posterior Mandible Restored as Abutments: Distribution and Time in Function

Implant length (mm)	Months in function							
	0–12	13–24	25–36	37–48	49–60	61–72	73–84	Total
6	11	7	0	0	0	0	0	18
7	11	6	13	5	0	0	0	35
8	26	12	20	18	33	13	7	129
9	0	0	13	17	17	0	0	47
Total	48	25	46	40	50	13	7	229

Table 4 Implants in the Posterior Mandible Restored as Abutments: Cumulative Success Rate

Months in function	Implants at beginning of interval	Implants lost during interval	Interval failure rate	Cumulative success rate (%)
0–12	229	3*	1-3	98.7
13–24	161	0	0	98.7
26–36	136	1†	0.7	98.0
37–48	90	0	0	98.0
49–60	70	0	0	98.0
61–72	20	0	0	98.0
73–84	7	0	0	98.0

*3 implants (two 8 mm long; one 9 mm long) were mobile at abutment connection.
†1 implant of 7mm was lost.

Table 5 Wide-Platform Implants in the Posterior Mandible Restored with Single Crowns: Distribution and Time in Function

Implant length (mm)	Months in function						
	0–12	13–24	25–36	37–48	49–60	61–72	Total
6	34	0	0	0	0	0	34
8	110	162	170	153	73	20	688
Total	144	162	170	153	73	20	722

Table 6 Wide-Platform Implants in the Posterior Mandible Restored with Single Crowns: Cumulative Survival Rates

Months in function	Implants at beginning of interval	Implants lost during interval	Interval failure rate	Cumulative success rate (%)
0-12	722	2*	0.3	99.7
13-24	0	0	0	99.7
25-36	0	0	0	99.7
37-48	0	0	0	99.7
49-60	0	0	0	99.7
61-72	0	0	0	99.7

* Two 8-mm-long implants were mobile at abutment connection.

Table 7 Wide-Diameter Implants in the Posterior Maxilla Restored with Single Crowns: Distribution and Time in Function

Implant length (mm)	Months in function							
	0–12	13–24	25–36	37–48	49–60	61–72	73–84	Total
6	39	33	19	0	0	0	0	91
8	54	57	51	44	32	22	0	260
9	0	0	0	0	17	24	21	62
Total	93	90	70	44	49	46	21	413

Table 8 Wide-Diameter Implants in the Posterior Maxilla Restored with Single Crowns: Cumulative Success Rate

Months in function	Implants at beginning of interval	Implants lost during interval	Interval failure rate	Cumulative success rate (%)
0-12	413	2*	0.5	99.5
13-24	320	1†	0.3	99.2
25-36	230	0	0	99.2
37-48	160	0	0	99.2
49-60	116	0	0	99.2
61-72	67	0	0	99.2
73-84	21	0	0	99.2

*Two implants (one 6 mm long and one 8 mm long) were mobile at abutment connection.
†One 8-mm long implant was lost during function.

Table 9 Implants in the Posterior Maxilla After Osteotome and Trephine Use, Restored with Single Crowns: Distribution and Time in Function

Implant length (mm)	Months in function							
	0–12	13–24	25–36	37–48	49–60	61–72	73–84	Total
6	26	14	8	8	0	0	0	56
7	0	0	0	0	5	4	3	12
8	57	51	48	25	1	2	1	185
9	0	0	0	14	16	19	4	53
Total	83	65	56	47	22	25	8	306
10	13	24	28	10	18	3	3	99
11	0	0	0	5	3	1	0	9
Total	13	24	28	15	21	4	3	108

Table 10 Implants in the Posterior Maxilla After Osteotome and Trephine Use, Restored with Single Crowns: Cumulative Success Rate

Months in function	Implants at beginning of interval	Implants lost during interval	Interval failure rate	Cumulative success rate (%)
Length of 6-9 mm				
0-12	306	2*	0.7	99.3
13-24	223	1†	0.4	98.9
25-36	158	0	0	98.9
37-48	102	0	0	98.9
49-60	55	0	0	98.9
61-72	33	0	0	98.9
73-84	8	0	0	98.9
Length of 10 or 11 mm				
0-12	108	2*	1.9	98.1
13-24	95	0	0	98.1
25-36	71	0	0	98.1
37-48	43	0	0	98.1
49-60	28	0	0	98.1
61-72	7	0	0	98.1
73-84	3	0	0	98.1

*Four implants (one 6 mm, one 8 mm long, and two 10 mm long) were mobile at abutment connection.
†One implant 6 mm long was lost in function.

Another common situation was 2 standard-neck implants placed in the posterior mandible and restored with a 3-unit fixed splint (229 implants). Three implants were mobile at the time of abutment connection. One implant demonstrated progressive bone loss and was classified as a failure at 30 months postrestoration. The cumulative success rate at 73 to 84 months with a mean time in function of 40.5 months was 98.0% (Tables 3 and 4).

Seven hundred twenty-two implants with a wide neck (6.5 mm) were placed in the posterior mandible and restored with single crowns. One implant was mobile at abutment connection, yielding a cumulative success rate at 61 to 73 months (mean time in function, 28.5 months) of 99.9% (Tables 5 and 6).

Wide-neck (6.5-mm diameter) implants were placed in the posterior maxilla and restored with single crowns in 413 cases (413 implants). Two implants were mobile at the time of abutment connection. One implant was lost at 13 to 24 months. The cumulative success rate at 73 to 84 months was 99.2%, with a mean time in function of 35.3 months (Tables 7 and 8).

Three hundred six implants of various diameters were placed in the posterior maxilla at the time of trephine and osteotome sinus augmentation and restored with single crowns. Two implants were mobile at the time of abutment connection. One implant was lost in function at the 13- to 24-month interval. The cumulative success rate at 73 to 84 months, with a mean time in function of 30.9

Table 11 One Standard-Diameter and One 6.5-mm Implant Placed in the Posterior Maxilla and Restored with 3-unit Fixed Partial Dentures

Implant length (mm)	Months in function						
	0–12	13–24	25–36	37–48	49–60	61–72	Total
6	4	12	3	0	0	0	19
8	4	11	13	20	12	9	69
Total	8	23	16	20	12	9	88

months, was 98.9%. The cumulative success rate for implants 10 or 11 mm long at 73 to 84 months in function, with a mean time in function of 32.3 months, was 98.1%. The difference in cumulative survival rates between the 2 implant length groups was not statistically significant (Tables 9 and 10).

In some cases, 1 standard-diameter and one 6.5-mm-wide implant supported 3-unit fixed partial denture in the posterior maxilla (n = 88 implants). No implants were mobile at abutment connection. No implants were lost in function up to 72 months after restoration. Cumulative success rate at 61 to 72 months, with a mean time in function of 36.8 months, was 100% (Table 11).

DISCUSSION

Numerous finite element analyses have been performed to assess force distribution following load application to implants of various dimensions. Lum[5] found that occlusal forces applied to implants were distributed primarily to the crestal bone, regardless of implant length. Lum and Osier also stated that masticatory forces were well tolerated by the crestal bone but that parafunctional forces were not well tolerated by the crestal bone and should be attenuated.[6,7]

Pierrisnard et al[8] performed a finite element analysis of 3.75-mm-wide hex-headed screw-type implants of 6 to 12 mm in length and reported that the magnitude and distribution of stress to the bone was constant and independent of implant length. These findings were contradicted by Petrie and Williams, who performed a finite element analysis of implants with diameters of 3.5 to 6 mm and lengths of 5.75 to 23.5 mm, placed in molar regions, and reported a reduction in peak crestal stress following force application with implants of increasing diameter and/or length.[9]

In contrast, Holmgren et al[10] and Himmlova et al[11] demonstrated that force application resulted in greatest force concentration at the bone crest and that implant length had no effect on either the magnitude of peak stress or stress distribution to the supporting bone.

The preponderance of finite element analyses demonstrates that implant length has no effect on the magnitude of stress experienced by the supporting alveolar bone crest around implants, which would seem to support the use of shorter implants if they offer specific advantages in given clinical situations.

Assessment of Clinical Studies

Early clinical studies documented that the use of machine-surfaced, externally hexed, screw-type implants appeared to support the use of longer implants.[1–3] Such an implant surface is seldom employed currently in clinical practice.

Feldman et al[12] reported on the 5-year survival rates of 2,294 rough-surface implants and 2,597 machined-surface implants. While the difference in cumulative survival rates between shorter and longer implants in the rough-surface implant group of 0.7% was not statistically significant, the difference in cumulative survival rates between longer and shorter implants in the machined-surface implant group of 2.2% was statistically significant.

Das Neves et al[13] reviewed the results of 33 studies of 16,344 Brånemark-type implants, and assessed failure rates over time. Seven hundred eighty-six failures were reported, representing a failure rate of 4.8%. There was no correlation between implant length and implant success or failure, except in 1 instance. Machined-surface, hex-headed, countersunk implants 3.75 mm wide and 7 mm long demonstrated a failure rate of 67.7% when placed in poor-quality bone. Such a finding has been reported previously by Jaffin and Berman.[3] This scenario is not representative of current clinical practice and is a poor indicator of the applicability of shorter implant use. Upon abutment connection and the expected loss of crestal bone around these countersunk hex-headed implants, less than 6 mm of the machined-surface implant would be available for osseointegration. Coupled with the fact that these implants were placed in poor-quality bone, the high failure rate could be predicted from both clinical experience and examination of the literature.

Buser et al[14] reported upon 2,359 titanium plasma-sprayed internal-attachment implants. No differences in implant survival rates between longer and shorter implants were reported in an 8-year life table analysis. Deporter et al[15] reported a 93.4% success rate after 5 to 6 years in function for 46 mandibular overdentures supported by rough-surface implants with a mean implant length of 8.7 mm. Ten Bruggenkate et al[16] reported a 93.8% cumulative success rate for two hundred fifty-three 6-mm-long titanium plasma-sprayed, internal-attachment screw-type and hollow cylinder implants supporting mandibular prostheses for 1 to 7 years.

Arlin[17] evaluated 630 titanium plasma-sprayed implants with a length of 6 to 16 mm placed in 264 patients. No statistically significant differences were found in cumulative survival rates in function at 2 years between the 6- to 8-mm-long implant group and the 10- to 16-mm-long implant group. A publication assessing the clinical results of 5,526 rough-surface implants of different lengths utilized in a variety of clinical applications found that implant length had no influence on cumulative survival rates for up to 72+ months in function.[18]

Examination of published finite element analyses and clinical reports, in conjunction with the data presented in this paper, strongly supports the hypothesis that the use of shorter implants in appropriate clinical situations yields cumulative survival rates in function over time comparable to those reported for longer implant use.

However, it must be stated that all implants reported on in this retrospective study were placed under specific conditions. Patients underwent appropriate diagnosis and multidisciplinary case work-up to formulate the necessary treatment plan prior to initiation of therapy. Implant placement was performed in the context of comprehensive care, including restoration of lost tooth structure and reestablishment of appropriate maxillomandibular relationships, as determined through the use of diagnostic waxups and clinical examination of the patient.

All parafunctional forces were treated as necessary through the use of reconstructive therapy, selective occlusal equilibration, bite appliances, or a combination of these therapies. It was explained to patients that they might have to wear their parafunctional appliances indefinitely.

Finally, regenerative therapy prior to implant placement was performed as necessary to reestablish ideal ridge form and prepathologic alveolar bone morphologies. Implants of less-than-ideal dimensions were not placed in cases where there was a lack of available bone. Rather, regenerative therapy was carried out to allow ideal positioning of implants of the desired dimensions. In addition to providing greater surface area for potential osseointegration with a given length implant, implant placement in an ideally constructed ridge affords the opportunity to better direct functional and parafunctional forces along the long axis of the implant. Finite element analyses have demonstrated that off-axis force application results in greater stress to the crestal bone surrounding the implant than axial force application.[19,20]

Implant design utilization was also strictly controlled in the treatment of the documented patients. Only rough-surface implants were employed. Numerous authors have documented the advantages of rough-surface implants over their machined-surface counterparts, including the greater surface area available for potential osseointegration and higher pull-out and back torque strengths at various time intervals.[21–23]

Examination of success and failure rates following implant placement in the posterior maxilla underscores the predictability of shorter implant use. Fugazzotto et al[24] reported on 987 implants that were 6, 7, 8, or 9 mm in length placed in maxillary molar positions and restored with single crowns. A cumulative success rate of 95.1% was reported after up to 84 months in function, with a mean time of 29.3 months in function.

A paper documenting the success and failure rates of 116 implants placed at the time of osteotome and trephine use reported a cumulative success rate of 98.3% for up to 4 years in function, with a mean time in function of 19.8 months.[25] As already discussed, the implants in the paper were included in the data reported upon for implants placed at the time of osteotome and trephine use in the posterior maxilla. If the longer implants of the initial study were followed to the present day, the implant cumulative success rate in function would be 98.1%. There is no statistical difference between the shorter and longer implant groups with regard to cumulative survival rates in function.

When discussing cumulative survival rates, it is important to differentiate between preloading implant failure and postloading implant failure. Implants mobile at uncovering are not mobile because they are shorter than other implants. An argument can be made that, when assessing postloading implant survival rates in function, and the influence of implant length on these postloading survival rates, only implants which were not mobile at the time of abutment connection should be considered. When the data is assessed in such a manner as to consider only postloading implant survival rates, the already favorable reported cumulative survival rates for shorter implants improves even further.

Despite this consideration, there is the implied potential for a higher percentage of implant mobility at the time of abutment connection with shorter implants as compared to longer counterparts. Shorter implants are almost always placed in sites with reduced bone height. As a result, any over-instrumentation of the osteotome site has the potential for greater impact in osteotomy sites of a lesser depth. Great care must be taken to avoid overheating or over-manipulation of a shallow osteotomy site. In addition, implant insertion must be accomplished as atraumatically as possible, with generation of a minimal amount of lateral pressure against the walls of the osteotomy to help prevent inadvertently widening the osteotomy site. It is for this reason that all implants in the present study were inserted utilizing handpiece attachments. No implants were placed with a manual torque wrench, as it is more difficult to control lateral pressure to the osteotomy walls with such a technique.

Proponents of longer implant use may contend that many of the published reports cited document implant placement in mutilated dentitions or otherwise advanced cases demonstrating significant bite collapse. In such scenarios, the crown-to-implant ratio would be significantly reduced and could very well mask potential problems with shorter implant placement and restoration. It is generally accepted that average crown-to-root ratios are 0.60 in the maxilla and 0.55 in the mandible in health.[25] If significant tooth wear and bite collapse had occurred, shorter implants could be employed while still attaining these "ideal" crown-to-implant ratios.

Rokni et al[26] examined 199 implants with lengths ranging from 5 to 12 mm that were restored with fixed prostheses. The mean crown-to-implant ratio was 1.5. The implants were in function for an average of 4 years. The authors reported that neither crown-to-implant ratio nor implant length had any effect on the supporting bone levels around the implants during this time period.

Tawil et al[27] found no relationship between crown-to-implant ratio and either peri-implant bone loss, implant success, or failure rates when assessing 262 machined-surfaced Brånemark implants in function for a mean time of 53 months.

CONCLUSIONS

Based upon this retrospective report of implants less than 10 mm in length, the following observations were made: 2,073 implants were placed and restored from May 2000 to May 2007. Implant success in support of single crowns ranged from 98.1% to 99.2% in various areas of the mouth. The success rate for implants used to support a fixed partial denture was 98.0%. These survival rates are similar to those reported in the literature, regardless of implant length.[28]

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