Success and Failure Rates of Osseointegrated Implants in Function in Regenerated Bone for 72 to 133 Months

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Purpose: *Guided bone regenerative therapy has become a significant component of clinical implant practice. Initial reports have demonstrated success rates of implants in regenerated bone under function comparable to the success rates of implants placed in native nonregenerated host bone. This report documents the success and failure rates of osseointegrated implants placed in regenerated bone for up to 133 months in function.* ***Materials and Methods:*** *A retrospective analysis of a group of 607 titanium plasma-sprayed cylindric implants placed in regenerated bone, the success and failure rates of which were previously reported at 6 to 51 months in function, were assessed.* ***Results:*** *The implants demonstrated cumulative success rates of 97.2% for the maxilla and 97.4% for the mandible, yielding an overall cumulative success rate of 97.4% for up to 133 months in function.* ***Discussion and Conclusions:*** *Titanium plasma-sprayed osseointegrated implants of various diameters, lengths, and designs, utilized in a variety of clinical scenarios, demonstrated functional cumulative success rates comparable to those of implants placed in nonregenerated host bone for extended periods of time in this patient population.* Int J Oral Maxillofacial Implants 2005;20:77–83

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The efficacy of guided bone regeneration (GBR) procedures in the treatment of a variety of clinical challenges is well established. Through the utilization of autogenous or nonautogenous materials beneath an array of appropriately selected membranes, lost hard tissues may be predictably regenerated in extraction socket areas, around immediately placed implants, buccolingually and apico-occlusally on atrophic ridges, and over implant dehiscences and fenestrations generated at the time of implant placement.[1–5]

However, while the short-term success of implants placed in the regenerated bone is well documented,[6–8] the long-term stability of implants in regenerated bone under function has not been extensively reported. The success and failure rates of the group of titanium plasma-sprayed (TPS) cylindric implants examined in this report have been documented previously for 6 to 51 months in function.[6] The stability of both the implants and the surrounding regenerated bone under function for significantly longer periods of time can now be examined.

MATERIALS AND METHODS

Following a thorough review of medical histories, patients were deemed unsuitable to receive implant therapy if they met any of the following criteria:

- Uncontrolled diabetes, immune diseases, or other contraindicating systemic conditions
- Radiation therapy in the head and neck region in the 12-month period prior to proposed therapy
- Chemotherapy in the 12-month period prior to proposed therapy
- Uncontrolled periodontal disease, or an unwillingness to undergo needed periodontal therapy, for remaining teeth
- Severe psychologic problems
- Unwillingness to commit to a long-term posttherapy maintenance program

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A complete physical examination of oral hard and soft tissues was carried out for each patient, and an overall dental treatment plan was formulated in conjunction with the treating restorative clinicians. Panoramic radiographs were taken of all patients; formatted computerized axial tomography scans were also taken when they were deemed clinically necessary. Diagnostic casts, waxups, and surgical guides were also used as needed. In preparation for this study, probing depth to the bone crest was measured, with local anesthetic as necessary, on the midbuccal, midlingual, midmesial, and middistal aspects of the implants in all patients. These measurements were more representative of the stability of the regenerated bone over time than were radiographic examinations, because the majority of the treated defects were on the buccal aspects of the implants and thus could not be well assessed radiographically.

Three hundred nineteen of the patients whose treatment was documented in a previous report[6] were followed continually through maintenance visits until the time of current statistical compilation. Of these patients, 181 were female and 138 were male. Patient age ranged from 24 to 86 years (mean age 49 years). All surgical therapy and preoperative and postoperative assessments of success or failure were recorded by the author. All radiographs were taken by 1 of 3 dental assistants and were exposed utilizing a Rinn kit (Dentsply/Rinn, Elgin, IL) to standardize the radiographs as much as possible in a clinical practice setting.

IMZ TPS cylindrical implants (Biomet/Interpore International, Irvine, CA), 3.3, 4.0, or 4.25 mm in diameter and of various lengths; hex-headed, cylindrical TPS implants (Biomet/Interpore International), 4.0 mm in diameter and of various lengths; and TPS threaded Straumann implants (Straumann, Waldenburg, Switzerland) of various lengths and diameters were used for all patients. Resorbable tricalcium phosphate (TCP) (Miter, Warsaw, IN) or demineralized freeze-dried bone allograft (DFDBA) (Musculosekeletal Foundation, Holmoel, NJ) were employed as particulate grafting materials beneath expanded polytetrafluoroethylene (e-PTFE) membranes of various configurations (W.L. Gore, Newark, DE).

Following appropriate full thickness buccal and lingual and/or palatal flap reflection, therapy proceeded along 1 of the following courses (Table 1):

- Tooth extraction, debridement of the extraction socket, and immediate implant placement. The residual socket was filled with DFDBA, and the area was covered with an e-PTFE membrane.
- Implant placement with a resultant buccal fenestration. The fenestration was covered with a mixture of equal parts DFDBA and TCP, and an e-PTFE membrane was placed over the fenestrated area. Care was taken to ensure that the membrane overlay 2 to 3 mm of bone around the perimeter of the fenestration. Fenestrations ranged from less than 2 mm to more than 12 mm in length (Table 2). A fenestration denoted as "beyond apex" represented a situation where only the most coronal 2 to 3 mm of the implant were completely in bone, and the remainder of the implant body, including the apex, was devoid of a buccal plate of bone.
- Implant placement with a resultant buccal dehiscence. The dehiscence was covered with the aforementioned mixture of DFDBA and TCP, and an e-PTFE membrane. The membrane overlay 2 to 3 mm of bone around the perimeter of the dehiscence, covered the head of the implant, and overlay the palatal/lingual bone by 3 to 4 mm. The extent of the treated dehiscence ranged from less than 2 mm to 14 mm (Table 3). As a result, 4 dehisced implants that were treated demonstrated dehiscence of the buccal aspect of the implant to within 1 mm of the implant apex.
- Buccal ridge augmentation of an area deemed to be of insufficient buccolingual/palatal dimension to stabilize an implant in an acceptable position for subsequent restoration. The same mixture of DFDBA and TCP was placed. If deemed necessary, threaded stainless steel support screws (3i/Implant Innovations, Palm Beach Gardens, FL) were first positioned in the residual ridge to support an e-PTFE membrane, which was then placed. The e-PTFE membrane extended 4 to 5 mm beyond the augmented area buccally and 2 to 3 mm over the residual crest of the ridge lingually/palatally.
- Coronal ridge augmentation in a residual ridge deemed to be of sufficient dimension buccolingually, but inadequate apico-occlusally to accept implants of an adequate length to support the planned prosthesis long term. The situation was treated in the same manner as a buccal augmentation, except that the support screws were placed on the crest of the residual ridge. The support screws protruded from the crest of 2 of the ridges for 3 mm, from the crest of 6 of the ridges for 4 mm, and from the crest of 1 of the ridges for 5 mm.

All flaps were sutured with Gore-Tex sutures (W. L. Gore). Postoperative management, including chlorhexidine rinses, antibiotic coverage, anti-inflammatory use, and pain medication, have been described in detail in a previous publication.[5,6]

As has also been previously noted,[6] primary soft tissue closure was not attained over membranes in 64 sites, resulting in the removal of 34 of the aforementioned membranes 4 to 6 weeks postoperatively,

Table 1 Implant Distribution by Jaw and Indication

Defect type	Implants placed in maxilla	Implants placed in mandible	Total implants placed
Dehiscence	91	71	162
Fenestration	46	23	69
Immediate exraction	116	68	184
Buccolingual ridge augmentation	75	108	183
Apico-occlusal ridge augmentation	3	6	9
Total	331	276	607

Table 2 Dimensions of Implants and Treated Fenestrations

Length of fenestration (mm)	Implant dimensions (mm)		
	4 × 11	4 × 13	4 × 15
< 2	11	7	7
2 to 4	3	8	9
4 to 6	4	2	2
6 to 8	0	1	0
8 to 10	0	0	2
10 to 12	0	0	4
12 to 14	0	0	0
> 14*	0	6	3

Implant dimensions shown as width × length.
*Beyond apex.

Table 3 Dimensions of Implants and Treated Dehiscences

Length of dehiscence (mm)	Implant dimensions (mm)			
	4 × 8	4 × 11	4 × 13	4 × 15
< 2	1	0	0	0
2 to 4	7	27	12	10
4 to 6	1	28	9	30
6 to 8	0	4	8	4
8 to 10	0	3	9	1
10 to 12	0	0	2	1
12 to 14	0	0	3	2

Implant dimensions shown as width × length.

18 membranes 6 to 8 weeks postoperatively, and 12 membranes 12 weeks postoperatively. In addition, soft tissue primary closure was lost over 6 additional membranes 8 to 10 weeks postoperatively, resulting in premature membrane removal. The distribution of implant placement by treatment indication is shown in Table 1. Of the 607 implants followed, 104 were TPS hex-headed implants replacing missing single teeth, and all others were conventional IMZ TPS cylindrical implants. Initial fenestration and dehiscence dimensions are documented in Tables 2 and 3.

All patients were seen at least every 6 months posttherapy. At that time, all prostheses were removed, the individual implants were examined for mobility, and clinical parameters (Gingival Index, the presence of bleeding upon probing, and probing depth to the base of the sulcus on the aforementioned aspect of the implants) were recorded. Radiographs were obtained at yearly intervals and were compared to those taken at the time of implant restoration under 2× magnification. Probing depth measurements were also compared to those made in preparation for the study.

Implants were deemed successful if the implant was immobile; there was no pain, suppuration, or periimplant radiolucency; and vertical bone loss was less than 1.5 mm in the first year in function and less than 0.2 mm annually in subsequent years in function.[9]

Cumulative success rates were calculated using the following formula[10]:

$$CFR = PCFR + IFR \times \frac{100 - PCFR}{100}$$

where CFR represents the cumulative failure rate, PCFR is the previous cumulative failure rate, and IFR is the interval failure rate (percent failure in the interval). The IFR is defined as the number of failed implants during the interval divided by the number of implants at the beginning of the interval.

RESULTS

A total of 607 implants were placed in 319 patients and followed for 78 to 133 months after restoration; 331 maxillary and 276 mandibular implants were assessed. The loss of 7 implants in the first 51 months of function, and the failing status of 2 other implants during this time, are documented in a previous publication.[6] In the intervening 72 months since the statistical compilation for the previous publication, the 2 implants previously classified as "failing" were lost after 73 and 77 months in function, respectively, and have been reclassified accordingly (Tables 4 to 8). One other implant has been lost. In this instance, a male

patient reappeared after a "hiatus" of 4 years, during which time he received no professional maintenance care. The patient presented with 1 of the 2 implants placed to support a fixed prosthesis, as well as the fixed prosthesis, in his hand. The exfoliated implant was covered with calculus to within 1 mm of its apex. The other implant, which was still in the patient's mouth, demonstrated gingival inflammation and calculus accumulation but was stable and exhibited less than 1 mm of further bone loss from initial measurements. Two other implants, while clinically immobile, demonstrated alveolar loss on their buccal aspects of 2 to 3 mm. These implants were classified as failing implants, despite the absence of bleeding upon probing, exudate, pain, or sensitivity to home care efforts. Each of these implants had demonstrated a thin buccal alveolar bone plate (of less than 1 mm thickness in dimension) following regenerative therapy.

After 84 months in function, the cumulative success rate for TPS implants in regenerated bone was 98.8% for the maxilla if all failures from day 0 are included (99.4% if early failures from the previous publication[6] are discounted), 97.4% for the mandible (99.7% overall if early failures previously reported are discounted), and 98.3% overall if all failures are considered. As discussed in the previous publication, if the patient who subsequently underwent chemotherapy and lost 3 implants after 14 months of successful function is excluded from the statistics, the cumulative success rates of TPS implants placed in regenerated bone at 78 months in function were unchanged for the maxilla but were 99.0% for the mandible, yielding an overall cumulative success rate of 99.7%. The cumulative success rates of TPS implants placed in regenerated bone at 133 months were 97.8% for the maxilla if early failures are excluded and 97.2% if all failures are included; 97.4% for the mandible including all failures; 98.8% overall if early failures are excluded and 97.4% overall if all failures are included. Once again, exclusion of the 1 patient who underwent chemotherapy would positively affect cumulative success rates, as expected.

Table 4 Success/Failure of Implants in Function for 0 to 60 Months and 72 to 133 Months

	Maxilla	Mandible	Total
0 to 60 mo in function			
0 to 12	91 (2)	92 (0)	183 (2)
13 to 24	76 (0)	61 (5)	137 (5)
25 to 36	76 (0)	57 (0)	133 (0)
37 to 48	66 (0)	61 (0)	127 (0)
49+	32 (0)	14 (0)	46 (0)
Total	341 (2)	285 (5)	626 (7)
72 to 133 mo in function			
72 to 84	87 (2)	90 (0)	177 (2)
85 to 96	76 (1)	58 (0)	134 (1)
97 to 108	71 (2)	54 (0)	125 (2)
109 to 120	66 (0)	60 (0)	126 (0)
121 to 133	31 (0)	14 (0)	45 (0)
Total	331 (5)	276 (0)	607 (5)

Number in parentheses is number of implant failures during interval in question.

Table 5 Success/Failure of Implants by Jaw and Region (Total Sites/Failures)

Defect type	Maxilla			Mandible		
	Anterior	Premolar	Molar	Anterior	Premolar	Molar
Dehiscence	40/1	41/1	10/0	10/0	48/0	13/0
Fenestration	31/0	13/0	2/0	12/0	8/0	3/0
Immediate extraction	47/2	60/1	9/2	7/0	37/0	24/0
Buccolingual ridge augmentation	24/0	14/0	37/1	8/0	36/1	64/4
Apico-occlusal ridge augmentation	3/0	0/0	0/0	0/0	0/0	6/0

Table 6 Success/Failure of Implants by Diameter and Length (Total Implants/Failures)

Defect type	Length (mm)							
	4.0 mm diameter				3.3 mm diameter			
	8.0	11.0	13.0	15.0	8.0	10.0	13.0	15.0
Dehiscence	9/0	62/1	43/1	48/1	0/0	0/0	0/0	0/0
Fenestration	0/0	18/0	24/0	27/0	0/0	0/0	0/0	0/0
Immediate extraction	6/2	39/1	71/1	52/1	0/0	0/0	6/0	10/0
Buccolingual ridge augmentation	26/0	77/3	44/0	20/0	0/0	6/3	10/0	0/0
Apico-occlusal ridge augmentation	0/0	6/0	3/0	0/0	0/0	0/0	0/0	0/0

Table 7 Cumulative Success Rates for Maxilla, Mandible, and Total Implants Placed with Up to 60 Months in Function

Months in function	Implants at beginning of interval	Implant failures during interval	Interval failure rate (%)	Cumulative failure rate (%)	Cumulative success rate (%)
Maxilla					
0 to 12	341	2	0.6	0.6	99.4
13 to 24	250	0	0	0.6	99.4
25 to 36	174	0	0	0.6	99.4
37 to 48	98	0	0	0.6	99.4
49+	32	0	0	0.6	99.4
Mandible					
0 to 12	285	0	0	0	100
13 to 24	193	5	2.6	2.6	97.4
25 to 36	137	0	0	2.6	97.4
37 to 48	75	0	0	2.6	97.4
49+	14	0	0	2.6	97.4
Total					
0 to 12	626	2	0.3	0.3	99.7
13 to 24	443	5	1.1	1.4	98.6
25 to 36	306	0	0	1.4	98.6
37 to 48	173	0	0	1.4	98.6
49+	46	0	0	1.4	98.6

Table 8 Cumulative Success Rates for Maxilla, Mandible, and Total Implants Placed with 0 to 133 Months in Function

Months in function	Implants at beginning of interval	Implant failures during interval	Interval failure rate (%)	Cumulative failure rate (%)	Cumulative success rate (%)
Maxilla					
0 to 51	626	7	1.4	1.4	98.6
72 to 84	331	2	0.6	1.2	98.8
85 to 96	244	1	0.4	1.6	98.4
97 to 108	168	2	1.2	2.8	97.2
109 to 120	97	0	0	0	97.2
121 to 133	31	0	0	0	97.2
Mandible					
0 to 51	285	5	2.6	2.6	97.4
72 to 84	276	0	0	2.6	97.4
85 to 96	186	0	0	2.6	97.4
97 to 108	128	0	0	2.6	97.4
109 to 120	74	0	0	2.6	97.4
121 to 133	14	0	0	2.6	97.4
Total					
0 to 51	941	12	0.6	0.6	99.4
72 to 84	607	2	0.3	1.7	98.3
85 to 96	430	1	0.2	1.9	98.1
97 to 108	296	2	0.7	2.6	97.4
109 to 120	171	0	0	2.6	97.4
121 to 133	45	0	0	2.6	97.4

DISCUSSION

Success rates of implants placed in regenerated bone, or placed at the time of bone regeneration, have been shown to be comparable to success rates of implants placed in native host bone under function over time.[6–8,11–17] Attainment of such success rates does not appear to be dependent upon either the autogenous or nonautogenous materials utilized to effect regeneration of lost alveolar bone, or the surface characteristics of the implant to be placed. Intraoral and extraoral autogenous bone grafts and various allografts and xenografts have been employed beneath resorbable, nonresorbable, and nonresorbable reinforced membranes. These membranes were used either to affect bone regeneration prior to implant placement or to accomplish bone regeneration around implants demonstrating dehiscences or fenestrations at the time of placement.

Buser and associates[11] and von Arx and colleagues[12] reported preliminary results on 12 and 27 TPS implants, respectively, placed in regenerated bone and followed for 5 years and 1 to 3 years after loading, respectively. Neither study reported any implant loss. A subsequent report by Buser and associates[13] documented the results of 66 TPS implants placed in bone previously augmented with autografts and nonresorbable membranes for a period of 5 years. Three patients with 5 implants dropped out of the study, and 1 implant demonstrated peri-implant infection; after 5 years in function, the cumulative success rate was 98.0%.

A previous publication[6] by the present author reported on success and failure rates of 626 implants placed in bone regenerated with a variety of nonautogenous materials and membranes and followed for 6 to 53 months under function. Success rates were reported that were comparable to documented success rates of TPS and machine-surfaced implants placed in native host bone.

Numerous authors have reported comparable success rates with machine-surfaced implants placed in previously regenerated bone or placed at the time of bone regeneration. Nevins and colleagues[7] analyzed 526 machined-surface implants placed in bone regenerated utilizing autogenous and allogeneic bone grafts in combination with barrier membranes, either prior to implant placement or at the time of implant placement. These implants were followed for 6 to 74+ months postloading. Eight implants were lost, yielding a success rate of 97.5% under function. Simion and coworkers[8] evaluated 123 machine surfaced implants placed at the time of vertical ridge augmentation procedures utilizing titanium reinforced e-PTFE membranes alone or in conjunction with allografts or autografts. At 1 to 5 years postloading, 2 implants demonstrated an increased crestal bone loss (3.5 mm and 4 mm) at the 1-year examination. No continued crestal bone loss was noted around any of the implants during the observation period of the study. Bahat and Fontanessi[14] reported on 329 implants placed following grafting with bone harvested from the iliac crest and followed for 12 to 96 months after loading (mean 36.3 months). The implant success rate under function was 93.0%.

Corrente and associates[16] placed 52 machined-surface implants at the sites of peri-implant bone defects and utilized calcium carbonate allograft materials with and without a fibrin-fibronectin healing system to fill the defect. Sixty implants were placed in nonaugmented bone in the absence of peri-implant bone defects to serve as controls. In a mean follow-up of 55 months in function, the success rate for the test implants was 91.7% and for the control implants 93.2%. However, test implants that demonstrated complete bone fill of the previously existing peri-implant bone defects demonstrated a success rate of 97.6%, while a success rate of 59.1% was documented for test implants that demonstrated residual peri-implant bone defects following augmentation therapy.

Becktor and colleagues[17] analyzed survival rates of 437 implants that were functioning in regenerated bone and 683 implants that were functioning in nonregenerated bone at a mean follow-up time of 5 to 6 years under function. The implant survival rate was 75.1% in the grafted group and 84.0% in the nongrafted group. In the anterior regions the authors stated that implant failure appeared to be related to original jaw bone volume. However, in the premolar region, where an inlay graft technique was utilized, implant survival rates were comparable for the grafted and nongrafted groups. As the majority of implant failures occurred before loading, the authors cited occlusal overload during healing as a possible causative factor. Such a situation could help explain the lower survival rates of implants in both the grafted and nongrafted groups in this study as compared to the other studies examined.[6–8]

While the long-term success and failure rates of TPS implants in regenerated bone are comparable to the success rates reported for osseointegrated implants in nonregenerated bone in function, a few caveats should be mentioned. As the understanding of treatment potentials and limitations has evolved and expanded over time, modified treatment plans and prosthesis designs have led to increased success rates for implants under function in both regenerated and nonregenerated bone.

The materials and techniques now available to effect guided bone regeneration are vastly improved over those utilized 7 to 10 years ago. Flap design modifications to help ensure maintenance of the primary soft tissue closure throughout the course of regeneration, the development of titanium-reinforced membranes to better protect the healing clot in the regenerating site and to afford space for bone regeneration, and the introduction of various grafting materials to better stabilize the aforementioned clot have all contributed to the predictability of regenerating greater quantities of bone, thus avoiding the need to depend upon thinner buccal and/or lingual septa to remain stable under function. The 3 implants classified as failures in the present series that demonstrated no untoward clinical signs other than an unacceptable degree of buccal bone loss had all presented with thin regenerated alveolar buccal bone following completion of GBR therapy utilizing materials available at the time of treatment. It is reasonable to assume that the buccal alveolar bone around these 3 implants would have demonstrated less resorption had it been of a greater initial buccolingual dimension when functional forces were applied.

Other than the loss of 3 implants with thin buccal alveolar bone, and the loss of an implant related to plaque and calculus accumulation in a patient who discontinued follow-up visits, only 2 other implants, which had been identified as failing at the 37-to-48-month interval, were lost over the subsequent 7 years of maintenance care and examination.

It therefore seems reasonable to assume that, if implants are housed in an adequate quantity of regenerated bone, and problematic implants are identified relatively early after functional loading, these osseointegrated implants should demonstrate long-term success rates comparable to those of implants placed in nonregenerated native host bone.

CONCLUSIONS

The stability of regenerated bone around TPS cylindric implants in function was examined for up to 133 months in this patient population. This regenerated bone proved capable of supporting implants and withstanding functional forces in a variety of clinical situations in a healthy, predictable manner.

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