Five-Year Survival Distributions of Short-Length (10 mm or less) Machined-Surfaced and Osseotite® Implants

Sylvan Feldman, DDS, MLA;* Nicolas Boitel, DMD;† Dietmar Weng, DMD;‡ Sean S. Kohles, PhD;§ Renée M. Stach, DDS‖

ABSTRACT

Background: In cases of reduced alveolar bone height, implants of short length (10 mm or less) may be employed although there is a perceived risk that because of their small stature they will be unable to tolerate occlusal loads and will fail to osseointegrate.

Purpose: This report describes an analysis of prospective multicenter clinical studies evaluating the risk for failure of short-length implants, comparing dual acid-etched (DAE) Osseotite® implants (Implant Innovations, Inc., Palm Beach Gardens, FL, USA) to machined-surfaced implants.

Materials and Methods: Admission criteria were the same for both data sets. Baseline variables of demographics including age, gender and smoking status, bone quality, location, implant dimensions, and types of prostheses were compared to ensure balance among groups. Cumulative survival rates (CSRs) were calculated with the Kaplan-Meier estimator.

Results: The implant data included 2,294 implants for the DAE series and 2,597 implants for the machined-surfaced series. Patient demographics showed similar percentages of occurrence for all variables. The distributions of implants between short- and standard-length data sets for baseline variables including width, location, and restorative type were similar, qualifying these data sets for comparison of the independent variable of length. Overall, there was a 2.2% difference in 5-year CSRs between the machined-surfaced short- and the standard-length implants. For these implants a 7.1% difference was observed in the posterior maxilla and an 8.5% difference in the anterior maxilla. For DAE implants the overall difference between "standards" and "shorts" was 0.7%, which is not statistically significant.

Conclusion: In this analysis the difference in CSRs between short- and standard-length implants was greater for machined-surfaced implants than for DAE implants.

KEY WORDS: multicenter evaluation, short length dental implants, survival analysis

The selection of implant dimensions is determined by anatomic oral dimensions, which often dictate the requirement for implants of short lengths (10 mm or less) in regions of reduced alveolar bone height. Posterior regions of the maxilla and mandible where the maxillary sinus and the mandibular nerve encroach on available bone are locations where short implants are routinely used. These sites of reduced bone quantity are often also sites of diminished bone quality. If the bone is too soft, primary implant stability may not be achieved; without initial stability, lower integration success rates and reduced implant performance can be expected.[1] Short implants therefore fulfill an important role in implant dentistry by providing support for prostheses in regions of diminished bone, yet in these situations their performance is challenged.

The literature on machined commercially pure titanium screw-type implants describes a perceived risk factor for short implants to fail at a higher rate than longer implants when compared in the same system.[1,2] Numerous studies have shown higher failure rates with

*University of Maryland, Baltimore, MD, USA; †private practice, Zurich, Switzerland; ‡University of Wuerzburg, Germany; §Kohles Bioengineering, Portland, OR, USA; ‖Implant Innovations, Inc., Palm Beach Gardens, FL, USA

Reprint requests: Renée M. Stach, DDS, 4555 Riverside Drive, Palm Beach Gardens, FL, USA 33410; e-mail: rstach@3implant.com

shorter implants.[3–6] Even where short implants were successful, the authors recommended that they be used in combination with longer implants.[7] It is therefore understandable that clinicians may hesitate to use short implants if the preponderance of study data indicates that short implants cannot resist occlusal forces as well as do standard-length implants. This aversion to using short implants may have an impact on treatment planning such that the use of short implants is ruled out, therefore making necessary a more complex treatment, such as nerve transposition and vertical or sinus grafting.

The objective of this report was to convey the results of an analysis of pooled prospective multicenter clinical trial results evaluating the integration success and longevity of both machined-surfaced implants and dual acid-etched (DAE) Osseotite® implants (Implant Innovations, Inc., Palm Beach Gardens, FL, USA) while isolating the effect of implant length. The purpose of this report is to determine if the reputation of short-length implants is warranted. As was done for an analysis of smoking risks[8] and poor-quality bone,[9] this effort capitalized on the consistency in the available original data, which allows an analysis isolating length as the independent variable to determine if a difference in long-term success is observed between different implant lengths and surfaces.

MATERIALS AND METHODS

The series of machined-surfaced implants (ST®, II®, and ICE®, all manufactured by Implant Innovations, Inc.) analyzed in this report is derived from three prospective multicenter studies[10–12] (n = 2,597 implants). The patients enrolled in these studies were treated at 15 private practice centers and 7 university centers, after meeting admission criteria and providing informed consent. Six prospective studies[12–15] provided data for the series of DAE implants in these evaluations (n = 2,294 implants) and were conducted at 22 private practice centers and 3 university centers. All implant data consisted of results from the same general implant design and were studied under similar conditions, except for surface treatment. The machined-surfaced implants have a functionally equivalent design, the only difference being the self-tapping apical cutting threads, which are a convenience feature. Admission criteria were the same in all studies. Prior to surgery demographic data were recorded, as were data on concomitant medical conditions and smoking status. Exclusion criteria consisted of active periodontal infection, uncontrolled diabetes, pregnancy, recent irradiation to the head or neck, habitual smoking of more than 10 cigarettes per day, the need for concomitant bone augmentation, and evidence of parafunctional habits. Implants in both series were placed according to a two-stage surgical protocol that required 4 months of submerged healing in the mandible and 6 months of healing in the maxilla (delayed loading protocols). Short-length implants were 7 mm, 8.5 mm, and 10 mm. Standard-length implants were 11.5 mm, 13 mm, 15 mm, 18 mm, and 20 mm. Prosthetic determination was based on individual patients' needs for incorporating implants into their restorative treatment and included single-tooth replacement, short-span fixed partial dentures, and implant-supported full-arch restorations.

Data were obtained from prospective multicenter studies that began in 1992 and that continue to be audited by clinical study monitors. All studies included in this report have similar designs and use similar definitions, nomenclature, standards, and ranges in the individual field variables. These similarities allow a pooling of the data, and the resulting data set is sufficiently large to detect a subtle effect of implant length on long-term performance.

In the statistical analysis of the examined clinical data, long-term implant survival was evaluated by using nonparametric survival analysis. The data were organized such that the event variable for each implant was matched with units of time as it was clinically judged as (1) still viable, (2) failed, or (3) lost to follow-up. Cumulative survival rates (CSRs) were calculated with the use of the Kaplan-Meier estimator of the

TABLE 1 Distribution of Implants According to Implant Length

Implant Type	Length	No. of Implants
DAE	All	2,294
	Short	797
	Standard	1,497
Machined	All	2,597
	Short	1,218
	Standard	1,379

DAE = dual acid-etched.

TABLE 2 Demographics of Study Populations According to Implant Length

Implant Type	Length	Males (%)	Females (%)	Age (yr)	SD	Smokers (%)	Cig/Day
DAE	All	40	60	54.5	13.0	18	12.2
	Short	37	63	55.5	11.0	18	13.8
	Standard	43	57	54.7	11.8	17	11.5
Machined	All	44	56	50.5	11.9	19	12.2
	Short	41	59	54.7	11.0	19	13.2
	Standard	45	55	49.6	10.2	20	11.7

Cig = cigarettes; DAE = dual acid-etched.

TABLE 3 Proportions of Implants by Location According to Implant Length

Implant Type	Length	Anterior (%)	Posterior (%)	Maxilla (%)	Mandible (%)
DAE	All	31.9	68.1	37.5	62.5
	Short	13.6	86.4	28.4	71.6
	Standard	42.4	57.6	41.7	58.3
Machined	All	24.9	75.1	42.9	57.1
	Short	7.3	92.7	29.0	71.0
	Standard	40.4	59.6	55.3	44.7

DAE = dual acid-etched.

TABLE 4A Distribution of Implants by Length

		Length (mm)							
Implant Type		7.0	8.5	10.0	11.5	13.0	15.0	18.0	20.0
DAE	Total	37	204	556	209	683	427	158	20
	%	1.6	8.9	24.2	9.1	29.8	18.6	6.9	0.9
Machined	Total	106	221	891	120	794	432	32	1
	%	4.1	8.5	34.3	4.6	30.6	16.6	1.2	0.0

DAE = dual acid-etched.

TABLE 4B Distribution of Implants by Diameter

		Diameter (mm)				
Implant Type		3.25	3.75	4.00	5.00	6.00
DAE	Total	67	1,277	554	346	50
	%	2.9	55.7	24.1	15.1	2.2
Machined	Total	127	1,538	276	545	101
	%	4.9	59.2	10.6	21.0	3.9

DAE = dual acid-etched.

TABLE 5 Distribution of Restorative Cases by Implant Length

Implant Type	Length	STR (%)	SSFB (%)	LSFB (%)
DAE	All	25.5	55.7	18.8
	Short	13.2	72.9	13.9
	Standard	26.0	56.3	22.7
Machined	All	27.9	65.2	6.9
	Short	12.0	81.8	6.2
	Standard	31.9	59.1	9.0

DAE = dual acid-etched; LSFB = long-span fixed bridge (> 5 units); SSFB = short-span fixed bridge (≤ 5 units); STR = single-tooth restoration.

survival function. Differences between survival distributions characterizing the survival of various combinations of implant characteristics (here, implant length) were evaluated by using rank post hoc analyses. The log-rank test (also known as the Mantel-Cox or Mantel-Haenszel test) was applied as it gives equal weight to all observations. This technique is best suited for detecting differences among survival curves for which the underlying hazard functions are proportional. This proportionality was confirmed for each paired comparison by an indicated parallel natural log cumulative hazard plot. A statistical difference between survival distributions was noted for $p < .05$. An initial qualifying evaluation

TABLE 6 Five-Year Cumulative Survival In Short-Implant Series

Interval* (mo)	Implants at Risk at Start of Interval†	Failures During Interval‡	No. of Implants Lasting for Extent of Duration§	Censored‖	Interval Survival# (%)	Cumulative Survival** (%)
			DAE Implants			
0–6	797	10	0	3	98.7	100.0
6–12	784	2	0	13	99.7	98.7
12–18	769	3	0	14	99.6	98.5
18–24	752	1	4	8	99.9	98.1
24–30	739	0	1	17	100.0	98.0
30–36	721	1	1	7	99.9	98.0
36–42	712	0	2	10	100.0	97.8
42–48	700	1	38	17	99.9	97.8
48–54	644	0	73	14	100.0	97.7
54–60	557	0	78	14	100.0	97.7
			Machined-surfaced Implants			
0–6	1,218	33	0	4	97.3	100.0
6–12	1,181	40	0	4	96.6	97.3
12–18	1,137	20	0	3	98.2	94.0
18–24	1,114	6	2	10	99.5	92.3
24–30	1,096	0	1	10	100.0	91.8
30–36	1,085	0	2	23	100.0	91.8
36–42	1,060	2	0	11	99.8	91.8
42–48	1,047	1	4	12	99.9	91.7
48–54	1,030	0	26	46	100.0	91.6
54–60	958	0	51	76	100.0	91.6

DAE = dual acid-etched.

*Number of months from time of implant placement surgery.

†Number of implants continuing at the beginning of the time interval.

‡Number of implants declared as failed within the time interval.

§For survived implants, the time from implant placement surgery to the date of the last documented determination of survival.

‖Number of survived implants in patients who died or were declared lost to follow-up.

1-number of failed implants divided by the number at risk minus one-half of the censored plus those in the Extent of Duration column = 1-number failed ÷ (number at risk − 1/2 (number of deaths + number of durations)).

**Interval Survival multiplied by previous row's Cumulative Survival.

was done to ensure that all groups maintained similar distributions of other relevant baseline variables, including smoking, demographics, anatomic location of implants, and type of prosthesis. All analyses were performed with commercially available software (StatView® 5.0.1, SAS Institute Inc., Cary, NC, USA). Illustrations of paired survival distributions were generated by using the life table method.

RESULTS

The distribution of short- and standard-length implants is summarized in Table 1. The demographics of the study populations (Table 2) show similar percentages of occurrence for gender, age, smoking, and smoking habits (ie, cigarettes per day). Table 3 shows the proportion of implants by location and length; most of the short implants were located in the posterior and in the mandible. Implant diameter and width show similar distributions for the machined-surfaced and DAE implants (Tables 4A and B). In Table 5 the types of prostheses distributed among the short- and standard-length implants are shown; the short-span fixed prosthesis is the most common for both data sets. With the proportions of baseline variables being equivalent, the two data sets were found equivalent for making comparisons of the independent variable of implant length when implants are compared in the same anatomic location.

The 5-year CSRs for all data series were calculated by using the Kaplan-Meier estimator and are presented in Table 6 for the short DAE implant series (n = 797) and the short machined-surfaced implant series (n = 1,218), according to life table analysis methods. Table 7 illustrates the difference in CSRs between standard and short implant groups according to anatomic location. There is an overall 2.2% difference in CSRs between the machined-surfaced short-length implants (91.6%) and standard-length implants (93.8%) at 5 years, which is statistically significant ($p < .05$). The difference between short-length and standard-length implant performance, however, increases dramatically in the maxilla, with a 7.1% difference in the posterior maxilla and an 8.5% difference in the anterior maxilla. The percentage differences in CSRs are shown in Figure 1. For machined-surfaced implants placed in the mandible, reduced length does not compromise performance, and short machined implants actually outperform the standard-length implants by 0.1% in the anterior, by 2.9% in the posterior, and by 1.1% combined.

For the DAE implants, the difference in CSRs between the short (97.7%) and standard implants (98.4%) for all locations is 0.7%, which is not a statistically significant difference ($p > .05$). In the mandible, where the majority of the short implants were placed, the difference is 0.4%, similar to the overall difference.

The percentage of implants placed in poor-quality bone was similar for the DAE implants, 21.9% for the short implants and 22.6% for the standard-length implants (Table 8). For the machined-surfaced implants there was a greater difference between short and standard implants, 22.1% and 15.8%, respectively,

TABLE 7 Five-Year Cumulative Survival-Rate Percentages for Implants, by Location

	Machined Implants			DAE Implants		
Location	Standard	Short	Diff	Standard	Short	Diff
All	93.8	91.6	2.2	98.4	97.7	0.7
Anterior	96.0	89.9	6.1	98.7	97.1	1.6
Posterior	92.5	91.7	0.8	98.2	97.8	1.1
Maxilla	95.0	86.8	8.2	97.6	95.8	1.8
Mandible	92.4	93.5	−1.1	97.3	96.9	0.4
Anterior maxilla	96.8	88.3	8.5	98.0	92.2	5.8
Posterior maxilla	93.6	86.5	7.1	97.3	96.6	0.7
Anterior mandible	95.1	95.2	−0.1	99.2	100.0	−0.8
Posterior mandible	90.6	93.5	−2.9	99.0	98.2	0.8

DAE = dual acid-etched; Diff = difference (ie, standard-implant cumulative survival rate [CSR] minus the short-implant CSR).

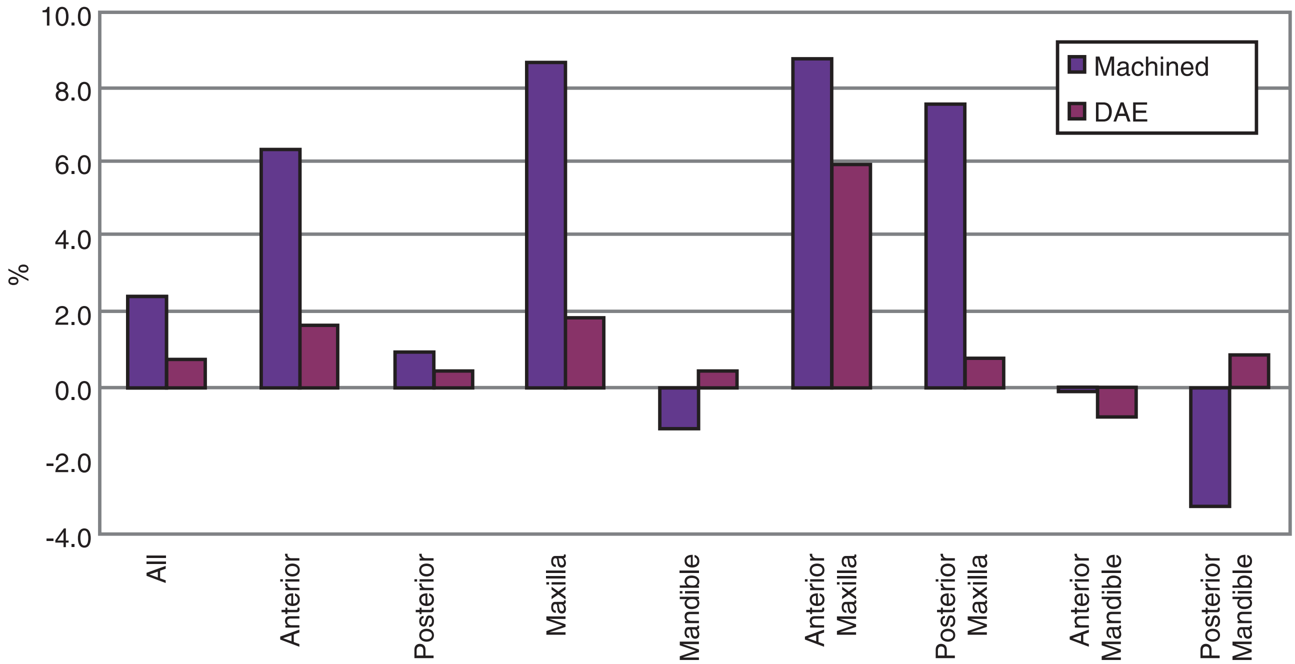

Figure 1 Comparison of 5-year cumulative survival rates of machined-surfaced implants and dual acid-etched (DAE) implants, by location.

which reflects the positioning of short implants in the posterior where bone quantity is diminished and bone quality is less dense. The data on failed implants were summarized to determine if a greater proportion of failed short implants occurred in poor-quality bone. A higher percentage of machined-surfaced implants failed in poor-quality bone; the short implants had a 5-year CSR of 86.5%, and the CSR for standard-length implants was 90.6%. This difference of 4.1% between the machined-surfaced implants is statistically significant ($p < .05$). Of the DAE implants placed in poor-quality bone, a similar pattern was observed, namely, a 2.4% difference in the CSRs between short and standard-length implants.

TABLE 8 Comparison of Implants in Poor-Quality Bone

Implant Type and Length	No. of Implants in PQB	% of Implants in PQB	5-Year CSR of Implants in PQB (%)
DAE short	170	21.9	96.0
DAE standard	332	22.6	98.4
MACH short	266	22.1	86.5
MACH standard	216	15.8	90.6

CSR = cumulative survival rate; DAE = dual acid-etched; MACH = machined-surfaced; PQB = poor-quality bone.

DISCUSSION

That overloading the surrounding bone by short implants possibly leads to failures has become an accepted belief.[4,7] This concern is based on the premise that occlusal forces are best dissipated over a large implant area to preserve alveolar bone. Orthodontic experiences show that compression by a tooth into bone leads to resorption, and this contributes to the belief that occlusal loads should be transferred across a large surface area and that therefore the longest possible implant length (with the greatest surface area) should be employed. These conditions contribute to the guarded prognosis for short implants. A study by Lum[16] that reviewed finite element modeling analysis showed, however, that the use of short-length implants might be efficacious because occlusal forces are transferred primarily to crestal bone. If these occlusal forces transmitted to the bone are within the physiologic limits, then short-length implants are not at risk as routinely perceived.

The results of the current study are promising for the previously perceived high-risk situation of diminished bone quantity requiring the use of short-length implants. It is apparent from this pooled analysis that the short-length (10 mm or less) DAE implant performs as well as standard-length implants. This level of performance, however, does not apply to the machined-surfaced implants, which failed at a higher rate when used in short lengths. As illustrated in Figure 1, the percentage differences in CSRs between short- and standard-length DAE implants is less than the percentage differences in CSRs for machined implants in most cases, the exception being implants placed in the mandible. Most likely, the presence of high-quality dense bone in the mandible masks the difference in performance between the two groups of implants. For maxillary cases a more pronounced difference is seen for machined-surfaced implants. The presence of poor-quality bone in the maxilla may be the reason for the greater discrepancy in CSRs for the machined-surfaced implants. A CSR difference of 8.5% between the short and standard machined-surfaced implants is observed. The risk for implant failure is not observed in the DAE series, in which the difference in CSRs is only 0.7% for the posterior maxilla and 1.8% for the maxilla overall. Although the difference is 5.8% in the anterior maxilla (where the short DAE implants performed at their lowest CSR of 92.2%), a relatively low number of implants were placed in this location ($n = 68$), so the effect on the overall CSR is minimal.

Evidence of poor-quality bone affecting the implant surface is further explored in Table 8. A greater proportion of these machined-surfaced implants failed in poor-quality bone. Thus the perception that machined-surfaced implants fail more readily than rough-surfaced implants when placed in regions of diminished bone quantity and quality remains valid. In the present analysis it appears that the rough-surfaced topography of the DAE implant may have compensated for the shorter implant length. Therefore, it would appear that the surface characteristics account for the difference in dimensional performance. The microsurface of the DAE implant has been described as clot retentive and osteoconductive due to its ability to promote fibrin attachment and retention during healing. This allows the migration of osteogenic cells to close proximity with the implant surface, allowing them to deposit bone directly onto the implant surface.[17] Histomorphometric studies comparing two surfaces on the same implant in the same patient showed a statistical difference in bone-implant contact (BIC) on DAE implant surfaces (72.9% BIC) compared with machined surfaces (33.9% BIC) ($n = 11$) after 6 months of healing in the posterior maxilla.[18] Histology revealed a thin layer of bone deposited onto the DAE surface, which appeared to be flowing and forming a shell around the implant.[19] These biologic findings may correlate with the improved clinical performance of the DAE implant in high-risk situations, including those in which insufficient bone quantity is present and short-length implants must be used.

CONCLUSIONS

In these large series of implants, the short-length DAE implants achieved and maintained integration, their 5-year CSR being 97.7%, which was not significantly different from the performance of a matched set of standard-length DAE implants. Short-length machined-surfaced implants, however, did not perform as well against matched standard-length machined-surfaced implants. The performance of these short implants was especially compromised in the maxilla and under conditions of poor-quality bone. The difference between the types of implants may be attributed to the ability of the acid-etched surface to establish and maintain greater amounts of apposing bone.

REFERENCES

1. van Steenberghe D, Lekholm U, Bolender C, et al. The applicability of osseointegrated oral implants in the rehabilitation of partial edentulism. Int J Oral Maxillofac Implants 1990; 5:272–281.
2. Friberg B, Jemt T, Lekholm U. Early failures in 4641 consecutively placed Branemark dental implants. Int J Oral Maxillofac Implants 1991; 6:142–146.
3. Grunder U, Polizzi G, Goene R, et al. A 3-year prospective multicenter follow-up report on the immediate and delayed-immediate placement of implants. Int J Oral Maxillofac Implants 1999; 14:210–216.
4. Goodacre CJ, Rungcharassaeng K. Clinical complications of osseointegrated implants. J Prosthet Dent 1999; 81: 537–552.
5. Bergendal T, Engquist B. Implant-supported overdentures: a longitudinal prospective study. Int J Oral Maxillofac Implants 1998; 13:253–262.
6. Bahat O. Treatment planning and placement of implants in the posterior maxilla: report of 732 consecutive Nobelpharma implants. Int J Oral Maxillofac Implants 1993; 8:151–161.
7. ten Bruggenkate CM, Asikainen P, Foizik C, Krekeler G,

Porter SS. Short (6mm) nonsubmerged dental implants: results of a multicenter clinical trial of 1 to 7 years. Int J Oral Maxillofac Implants 1998; 13:791–798.

8. Bain CA, Weng D, Meltzer A, Kohles SS, Stach RM. A meta-analysis evaluating the risk for implant failure in patients who smoke. Compend Contin Educ Dent 2002; 23:695–699, 702, 704.
9. Stach RM, Kohles SS. A meta-analysis examining the clinical survivability of machined-surfaced and Osseotite implants in poor-quality bone. Implant Dent 2003; 12: 87–96.
10. Davarpanah M, Martinez H, Celletti R, Alcoforado G, Tecucianu JF, Etienne D. A prospective multi-center evaluation of 1583 3i implants: 5-year analysis. Int J Oral Maxillofac Implants 2002; 17:820–828.
11. Weng D, Jacobson Z, Tarnow D, et al. A prospective multicenter clinical trial on machined-surfaced implants: results after six years of follow-up. Int J Oral Maxillofac Implants 2003; 18:417–424.
12. Khang W, Feldman S, Hawley CE, Gunsolley J. A multicenter study comparing DAE and machined-surfaced implants in various bone qualities. J Periodontol 2001; 72:1384–1390.
13. Grunder U, Gaberthuel T, Boitel N, et al. Evaluating the clinical performance of the Osseotite implant defining prosthetic predictability. Compend Contin Educ Dent 1999; 20:628–640.
14. Testori T, Wiseman L, Woolfe S, Porter SS. A prospective multicenter clinical study of the Osseotite implant: a four-year interim report. Int J Oral Maxillofac Implants 2001; 16:193–200.
15. Mayer TM, Gunsolley JC, Feldman S. The single-tooth implant: a viable alternative for single tooth replacement. J Periodontol 2001; 7:687–693.
16. Lum LB. A biomechanical rationale for the use of short implants. J Oral Implantol 1991; 17:126–131.
17. Davies JE. Mechanisms of endosseous integration. Int J Prosthodont 1998; 11:391–401.
18. Lazzara RJ, Testori T, Trisi P, Porter SS, Weinstein RL. A human histologic analysis of Osseotite and machined surfaces using implants with two opposing surfaces. Int J Periodontics Restorative Dent 1999; 19:117–129.
19. Trisi P, Lazzara R, Rebaudi A, Rao W, Testori T, Porter SS. Bone-implant contact on machined and Osseotite surfaces after 2 months of healing in the human maxilla. J Periodontol 2003; 74:945–956.