Conventional and Advanced Implant Treatment in the Type II Diabetic Patient: Surgical Protocol and Long-Term Clinical Results

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Purpose: *To investigate the effect of type-2 diabetes on implant survival and complication rate.* ***Materials and Methods:*** *Prospective study enrolling type-2 diabetic patients suffering from edentulism, having a mean perioperative HbA1c level of 7.2%, and compliant with a maintenance program. All the patients underwent dental and periodontal examinations and had laboratory testing for HbA1c, fasting plasma glucose, blood lipids, and microalbuminuria. Nondiabetic patients matched for implant treatment indication served as controls. The influence of clinical diabetes-related factors and periodontal parameters (Plaque Index, bleeding on probing, probing depth) on implant survival were assessed via univariate then multivariate methods.* ***Results:*** *Forty-five diabetic patients, followed for 1 to 12 years, mean age 64.7 years, received 255 implants: 143 following a classical protocol and 112 in cases of sinus floor elevation, immediate loading, and guided bone regeneration. Forty-five nondiabetic control patients received 244 implants: 142 following a classical protocol and 102 in cases of advanced surgery. Implant survival following conventional or advanced implant therapy was not statistically different between the well-controlled (HbA1c < 7%,* P = *.33) and the fairly well-controlled group (HbA1c 7% to 9%,* P =*.37). The overall survival rate for the diabetic group was 97.2% (control 98.8%) and was not significantly different for age, gender, diabetes duration, smoking, or type of hypoglycemic therapy. The mean peri-implant bone loss was 0.41 ± 0.58 mm (control, 0.49 ± 0.64 mm). PI and BOP fairly correlated with postoperative complications. HbA1c was the only multivariate independent factor affecting the complication rate (*P = *.04). No statistically significant difference was found for patients (*P = *.81) or for implants (*P = *.66) for the advanced surgery cases or the conventional approach in diabetic patients compared to nondiabetic patients.* Int J Oral Maxillofac Implants 2008;23:744–752

Key words: *diabetes, diabetes control, HbA1c, implant therapy, type-2 diabetes*

The worldwide prevalence of diabetes is high (20.1% of the individuals > 65 years) and is increasing drastically.[1] Type-2 diabetes represents about 90% of the total diabetic cases. Recent studies have demonstrated that hyperlipidemia and infections such as periodontitis can cause an insulin resistance syndrome similar to that observed in diabetes or even cause the loss of β cells through the elevation of serum proinflammatory cytotoxic cytokines IL1β and TNFβ.[2–4]

For a long time, diabetic patients were denied implant therapy because of their increased susceptibility to infection, delayed wound healing, and microvascular complications.[5–9] A Medline search of the English literature in relation to implant treatment in the diabetic patients yielded 9 studies on the topic (Table 1).[10–18] The majority of the treated patients suffered from type-2 diabetes. Implants were mainly used in totally edentulous jaws to support overdentures and in partially edentulous jaws to support fixed partial dentures. A total of 1,527 implants were placed in at least 395 patients (no mention of the number of patients treated could be found in the study by Morris et al).[10] The average survival rate was 94.3% (range, 85.6% to 100%). Although Fiorellini et al[11] found that well-controlled diabetic patients have

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a reduced implant survival rate, most studies reported reasonable to equal implant success in the diabetic patients as compared to the nondiabetic patients.[12–18] The increased failure rate could be related to the mechanical characteristics of the bone-implant contact[11] and poor wound healing. However, no data on the biologic profile of the diabetic patients were presented. No results of clinical significance on advanced implant therapy in the diabetic patients were reported. Diabetic parameters were mentioned in 2 studies,[12,13] and peri-implant bone loss was reported in 2 studies.[12,14] Two studies[10,12] had a control group. Although all the reports underlined the importance of the control of the diabetic condition before any implant treatment is considered, no upper limits for hyperglycemia or HbA1c values were proposed either perioperatively or postoperatively to indicate implant therapy and safely maintain long-term implant stability. Olson et al[13] found no association between the levels of diabetic control and implant failure, despite an elevated HbA1c level in more 50% of the treated patients in the perioperative period. No failures were reported by Kapur et al[12] in cases of implant-supported overdentures, despite relatively elevated HbA1c values (> 9%) in the operative period, and no statistically significant differences in the success rate between the insulin-treated and non-insulin–treated patients were found. Absolute and constant control of plasma glucose level is elusive in most diabetic patients.[19] Fluctuations in glucose level are very frequent, and self-monitoring of plasma glucose is not commonplace. The effect of plasma glucose fluctuations on implant survival and the maintenance of osseointegration remain unclear. The purpose of this study was *(1)* to determine the implant survival rate of well- to fairly well-controlled type-2 diabetic patients, based on HbA1c and fasting plasma glucose values; *(2)* to define a protocol for the implant treatment in diabetic patients, be it conventional or advanced, and compare the results to a healthy matched-control group; *(3)* to study the effect of age, gender, diabetic duration, Hba1c values, and smoking on the implant survival rate; and *(4)* to study the effect of periodontal parameters (Plaque Index [PI], bleeding on probing [BOP], and probing depth [PD]) on the implant survival and complication rate namely peri-implant bone loss.

Table 1 Analytic Results of Retrospective Studies on Implants in Diabetic Patients

Study		Patients (n)	Implants (n)	Follow-up (y)	Preparation to surgery	Diabetic parameters monitored	Diabetic medication	Survival rate (control)	Peri-implant bone loss (mm)	Antibiotic coverage	Rinse*	Stage 1 implant failure	Type of treatment
Morris et al[10]	2000	NA	255	3	–	No	Oral insulin	92.20 (93.20)	–	+	–	–	Not specified
Shernoff et al[18]	1994	89	178	5	+	Not specified	Oral insulin	92.70	–	–	–	+	Overdenture
Abdel Wassi	2002	25	113	3	+	No	Oral insulin	95.70	–	10 d	–	+	Not specified
Baichi	1999	34	227	–	–	No	–	94.30	–	+	–	+	Immediate loading fresh extraction; conventional
Kapur et al[12]	1998	52	104	5	–	Yes	Oral insulin, diet	100	0.12	–	–	–	Overdenture
Peled et al[14]	2003	41	141	5	–	No	–	94.40	0.5	5 d	–	+	Overdenture
Fiorellini et al[11]	2000	40	215	6.5	–	No	–	85.60	–	–	–	+	Conventional therapy
Farzad et al[17]	2002	25	136	1–9	–	No	–	94.10	–	7 d	–	+	Immediate loading and conventional
Olson et al[13]	2000	89	178	5	–	Yes	–	90	–	–	–	+	Overdenture

*Chlorhexidine.
+ sign = information is available; – sign indicates lack of data.

MATERIALS AND METHODS

Patient Population

All patients enrolled in this prospective study were type-2 diabetics attending a private periodontal prac-

tice. The patients suffered from various degrees of edentulism and requested implant treatment. Preoperative planning included a full medical history. Information such as patient age at diabetes onset, diabetes duration, type of medication used to control the diabetic condition, frequency of glucose monitoring, and occurrence of any complication related to diabetes (retinopathy, nephropathy, neuropathy, or macrovascular complications). Laboratory testing was done preoperatively for HbA1c, fasting plasma glucose (FPG), cholesterol (HDL, LDL), blood lipids, and microalbuminuria. The inclusion criteria were *(1)* a diagnosis of type-2 diabetes, partial or full edentulism, and a request for implant therapy; *(2)* an HbA1c value ≤ 7.2% during the perioperative period (ie, from the week the surgery was performed until the completion of initial healing); *(3)* control of periodontal disease when present before any implant treatment; and *(4)* the compliance of the patient with a maintenance program. Periodontal parameters (PI, BOP, and PD) were recorded before implant therapy. Conventional implant treatment was done when bone volume was adequate; bone augmentation procedures (sinus floor elevation and guided bone regeneration) were applied in case of bone deficiency. Extraction was followed by immediate implant placement, and loading was also applied when indicated. The control group consisted of nondiabetic consecutively treated patients attending the clinic during the same time period. The first nondiabetic patient of the series of attending patients who matched with the diabetic patient for the type of implant treatment applied and when, possible for age and gender, served as a control. The medical condition of the nondiabetic group was checked. Periodontal therapy was applied, when indicated, before any implant treatment, and the implant treatment was performed under the same operative conditions. All implant surgeries and clinical measurements (BOP, PI, PD) were performed by the same calibrated operator (GT). Patients who smoked were asked to stop smoking in the perioperative period and encouraged to discontinue this habit postoperatively. All patients received antibiotic treatment (1 g amoxicillin and clavulanate potassium twice a day for 7 days starting 1 hour before the procedure) or clindamycin (300 mg three times per day for 7 days in case of allergy to penicillin). Topically, 0.2% oral mouthrinse with chlorhexidine was prescribed starting the day after the surgery and continued for 2 weeks.

Patient Follow-up and Radiographic Evaluation

During the postoperative period, soft tissue healing was evaluated for wound dehiscence, ulceration, or infection. Complications such as infection, peri-implant bone loss, or implant loss were recorded. Periodontal parameters (BOP, PD, PI) were recorded at the last control visit. All patients were placed on a maintenance program and recalled every 6 months for evaluation and prophylaxis. Peri-implant bone level was evaluated based on periapical radiographs obtained at the last control visit using a long-cone technique and a noncustomized paralleling device (XCP Rinn positioner, Elgin, IL). These measurements were performed by another calibrated operator who was blinded as to the type of surgery done and the medical status of the patient. The radiographs were considered for analysis when the threads on the mesial and distal sides of the implants were distinctly visible. The reference point for evaluation of bone loss was the edge between the conical and the cylindric part of the implant head. All measurements were made under a magnifying loupe (×8) using a Digimatic caliper (Mitutoyo Corp, Tokyo, Japan). Since several patients were operated more than once for the placement of implants according to their specific needs during the follow-up period, implants as well as patients were accounted for in the evaluations. The follow-up period ranged from 1 to 12 years (mean, 42.4 months).

Statistical Analysis

Continuous data were presented as means ± standard deviations and as ranges (minimum to maximum). Continuous data between 2 groups were compared using the Student *t* test when normality was not violated (as assessed by the Shapiro-Wilk statistic), otherwise the Mann-Whitney test was performed. One-way analysis of variance was used to compare continuous data among more than 2 groups; the results were corrected by the Kruskall-Wallis statistic if normality assumptions were not met. Comparison between baseline and follow-up data was made with the Wilcoxon signed-rank test. Qualitative data were represented as frequencies, percentages, and odds ratios (OR) along with their 95% confidence interval (95% CI) and were analyzed using the χ^2 square test, corrected by the Fischer exact test when appropriate. Implant survival rate was reported as percentage with reference to the total number of implants. Association between ordinal data was performed using the Kendall τb statistic. Furthermore, a multivariate backward stepwise ordinal regression (using the complementary log-log link function) was performed to identify significant multivariate factors independently associated with the success rate. All tests were 2-sided. A *P* value less then .05 was considered statistically significant. All statistical computations were made using Stata6 software (Stata Corporation, College Station, TX).

RESULTS

Forty-five consecutive type-2 diabetic patients, 33 men and 12 women, with a mean age of 64.7 years (range, 43 to 84 years) were treated and followed for 1 to 12 years (mean, 42.4 mo). Two hundred fifty-five Brånemark implants (75 turned surface and 180 TiUnite; Nobel Biocare, Göteborg, Sweden) were placed: 143 implants in sites with adequate bone volume following a conventional protocol and 112 implants in sites requiring sinus floor elevation, guided bone regeneration, or immediate loading. Implant distribution according to the years of follow-up appears in Fig 1. HbA1c and FPG were evaluated on a regular basis during the follow-up period. The patients were grouped in 3 categories according to the severity and degree of control of the disease based on the mean values of HbA1c in the pre- and postoperative period: < 7%, 7% to 9%, and > 9% (Table 2). Implant distribution according to the type of surgery performed is shown in Table 3.

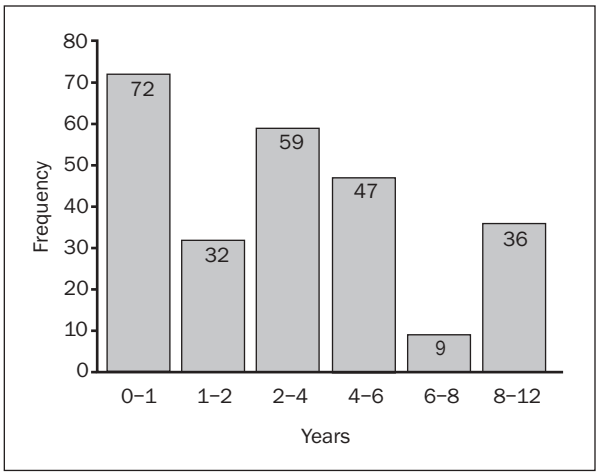

Fig 1 Implant distribution according to years of follow-up.

Of the 45 patients that were treated, 22 were well controlled (HbA1c < 7%) and received 103 implants. Eight of 22 patients were checking daily their blood glucose level (self-monitored). Mean diabetic duration was 12.7 ± 11.3 years, and the implants were in function for a mean period of 43.8 months. Sixty-nine implants were placed following a conventional protocol. Ten implants were placed following sinus floor elevations, 18 were immediately loaded, and on 6 implants, guided bone regeneration (GBR) was applied. One implant failed in a case of sinus floor elevation, for an overall survival rate of 99.1%. Mean peri-implant bone loss was 0.24 ± 0.28 mm. When conventional therapy was compared to advanced therapy in the well-controlled group, no statistical difference was found ($P = .33$).

Twenty-two patients belonged to the fairly controlled group (HbA1c 7% to 9%) and received 141 implants. Six of the 22 patients were self-monitoring their glucose level. Mean diabetic duration in that group was 12.5 ± 7.2 years, and the implants have been in function for a mean period of 41.6 months. Sixty-six implants were placed following a conventional therapy, 24 in cases of sinus floor elevation. Thirty-seven were immediately loaded and 14 with GBR. Five implants failed, 4 in case of SFE and 1 in case of conventional therapy. The overall survival rate was 96.5%. Mean peri-implant bone loss was 0.52 mm ± 0.75. No statistical difference in implant survival was found between the conventional and the advanced therapy groups ($P = .37$).

Only one patient had a mean HbA1c value > 9%. He was also a heavy smoker and suffered from alcohol abuse despite promises of compliance. He received 11 implants of which 3 were immediately loaded. One implant failed.

Six of the 7 failures occurred between abutment connection and the first postoperative year, and 1 implant failed 3 years postloading.

Forty-five nondiabetic patients (24 men and 21 women) with a mean age of 59.6 years (range, 29 to 85 years) served as a control group (Table 4). They received 244 implants (104 turned surface and 140 TiUnite): 142 implants were placed using a conventional protocol in bone of adequate volume and 102 implants in sites needing augmentation procedures or advanced implant therapy.

When the results in the diabetic patients were compared to those obtained in the matched nondiabetic controls, no statistical differences were found for either patients ($P = .81$) nor for implants ($P = .66$) for the advanced surgery cases or the conventional approach (Table 5). When HbA1c values were related to the postoperative complications, no statistical differences were seen for soft tissue complications ($P = .85$), but significant differences were observed for peri-implantitis ($P = .05$) and peri-implant bone loss ($P = .01$; Table 6).

Diabetes Duration as a Prognostic Factor in Implant Survival

The mean diabetic duration was 12.7 years for the HbA1c < 7% group, 12.5 years for the HbA1c 7% to 9% group, and 14 years for the patient who had an HbA1c > 9%. The patients were divided in 4 groups according to diabetes duration: < 2 years, 2 to 5 years, 5 to 10 years, and >10 years, as shown in Table 7.

Table 2 Follow-up of Diabetic Patients

	HbA1c ≤ 7%	HbA1c 7% to 9%	HbA1c ≥ 9%
Patients	22	22	1
Implants	103	141	11
SMBG (no. of patients)	8/14	6/16	–
Diabetes duration (y, M ± SD)	12.7 ± 11.3	12.6 ± 7.2	14
Months in function (M)	43.8	41.6	32.3

SMBG = self-monitored blood glucose.
M ± SD: mean ± standard deviation.

Table 3 Implant Distribution According to the Type of Surgery

	Diabetic (n)	Control (n)
Conventional implant therapy	143	142
External sinus lift	33	26
Internal sinus lift	1	2
Immediate loading	58	59
Guided bone regeneration	20	15

Table 4 Characteristics of the Diabetic and Matched Control Group

	Diabetic	Control
Patients (n)	45	45
Mean age (y)	64.7	59.6
Implant (n)	255	244
Sex ratio (M/F)	33/12	24/21
Smoking (yes/no)	22/23	18/27

Table 5 Comparative Survival Rates Between Diabetics and Controls for Conventional and Advanced Implant Surgery

	Diabetic (n)		Control (n)	
	Implants	Failure	Implants	Failure
Sinus lift	34	3	28	0
GBR	20	3	15	0
Immediate loading	58	0	59	1
Conventional treatment	143	0	142	0

GBR = guided bone regeneration.

Table 6 Relation Between HbA1c and Peri-implant Complications and Survival Rate

HbA1c level	< 7%	7%–9%	> 9%	τb	*P*
Patients (n)	22	22	1		
Soft tissue complications (no./no. implants)	6/103	11/141	1/11	.040	.85
Peri-implantitis (no./no. implants)	0/103	6/141	1/11	.146	.05
Peri-implant bone loss in mm (M ± SD)	0.24 ± 0.28	0.5 ± 0.7	1.62	.412	.01
Implant failure (n)	1	5	1		
Diabetes duration in years (M ± SD)	12.7±11.3	12.6 ±7.2	14		

n and no. = number; M ± SD: mean ± standard deviation; τb: Kendall's τb.

Table 7 Relation Between Diabetes Duration, Implant Survival, and Occurrence of Complications

	Group			
	1	2	3	4
Diabetes duration (y)	< 2	2–5	5–10	> 10
Patients (n)	3	8	9	25
Implants (n)	10	54	27	164
Implant survival (%)	100	100	96.3	96.3
Complications (soft tissue; %)	0	12.9	3.7	3.7
Early infection (%)	0	0	3.7	1.2
Bone loss (mm; m ± sd)	0.20 ± 0.10	0.42 ± 0.39	0.72 ± 0.65	0.34 ± 0.61
Peri-implantitis	0	0	7.4	3

M ± SD: mean ± standard deviation.

Eleven patients in whom 64 implants were placed belonged to the first 2 groups. No failure, early infections, or peri-implantitis were observed here. A few soft tissue complications were seen in the 2- to 5-year groups in the early postoperative healing period. Peri-implant bone loss was 0.2 ± 0.1 mm in the < 2-year group and 0.42 ± 0.39 mm in the 2- to 5-year group. Nine patients accounting for 27 implants belonged to the 5- to 10-year group. One failure was observed, 1 case of soft tissue complication, 1 case of

Table 8 Relation Between Age, Implant Survival, and Occurrence of Complications in Diabetic and Control Patients

	Diabetic			Control		
Age group	≤ 60 y	> 60 y	*P*	≤ 60 y	> 60 y	*P*
Patients (n)	13	32		27	18	
Implants (n)	81	174		132	112	
Failure (n)	1	6	.44	0	2	.21
Survival rate (%)	98.8	96.54	.31	100	98.22	.46
Soft tissue complications (%)	9.87	5.7	.23	5.3	0.9	.07
Peri-implantitis (%)	1.2	3.4	.31	0	0	.99

early infection, and 2 cases of peri-implantitis. Bone loss was 0.72 ± 0.69 mm. In the > 10-year group, there were 25 patients and 164 implants. Six of 164 implants failed, 5 of 164 manifested peri-implantitis, 3.7% had soft tissue complications, and 1.2% of the cases had early postoperative infections. Statistical analysis showed no significant differences in implant survival in the 4 groups ($P = .23$) and no difference for the occurrence of peri-implantitis ($P = .69$) or for early infections ($P = .93$).

Diabetic Patient Age and Implant Survival

Patients ≤ 60 years and > 60 years were compared. Thirteen patients (81 implants) belonged to the former group (group 1) and 32 patients (174 implants) to the latter group (group 2) as shown in Table 8. One of 81 implants failed in group 1 and 8 of 174 in group 2. Soft tissue complications were seen in 9.9% of the cases in group 1 and 5.7% of the cases in group 2. Peri-implantitis was observed in 1.23% of the cases in group 1 and 3.4% of the cases in group 2. No statistical differences were seen between the 2 groups with regard to implant failure ($P = .31$), soft tissue complication ($P = .23$), or peri-implantitis ($P = .31$).

Diabetes Treatment and Implant Survival

The influence of the type of medications on the postoperative course was also addressed. Two patients were on insulin therapy with a mean diabetic duration of 35 years and presented no failure, soft tissue complications, or peri-implantitis on the 6 implants placed. Their mean bone loss was .1 mm. On the other hand, 37 patients were on oral hypoglycemic agents, of whom 4 received daily insulin injection for diabetes control because of exacerbation of the disease. Mean diabetes duration was 11 ± 7.6 years. Seven of 196 implants failed in that group. Soft tissue complications were observed for 18 implants, and 7 developed peri-implantitis. The mean bone loss was 0.42 ± 0.62 mm. Another group of 6 diabetic patients were not under medication but on diet control and exercise. Here, no implant losses of 36 implants placed, and no soft tissue complications or peri-implantitis were observed. The mean bone loss was .41 ± .61 mm. Statistical analysis showed no difference for implant failure, soft tissue complication, or mean peri implant bone loss ($P = .38$) among the tested groups.

Combined Effect of Diabetes and Smoking on Implant Survival

All patients were asked to stop smoking in the perioperative period. Although they were encouraged to discontinue this habit postoperatively, most of them resumed smoking after the initial healing took place. The survival rate in diabetic patients and controls was studied in relation to smoking. Twenty-two patients with diabetes (143 implants) were smokers, and 5 failures occurred in that group. In the 23 remaining nonsmoking patients with diabetes (112 implants) there were 2 failures. Eighteen patients (102 implants) in the control group were smokers, and no failures were seen. Twenty-seven patients (142 implants) were nonsmokers. Two implants failed in that group (Table 9). Statistical analysis showed no difference between the diabetic patients ($P = .47$) and the controls ($P = .52$) concerning the effect of smoking on the failure rate.

PI, BOP, and Implant Complications

PI and BOP as evaluated at the last control visit were studied in relation to the survival and complication rate. PI was categorized as either PI < 1, PI between 1 and 2, and PI > 2. BOP was categorized as either BOP < 15% and BOP > 15%. These parameters were related to implant failure, peri-implant soft tissue complications, peri-implantitis, and peri-implant bone loss (Table 10). A fair correlation was found in the diabetic patients between PI and peri-implant bone loss (Kendall's $\tau b = .34$) and between BOP and peri-implant bone loss (Kendall's $\tau b = .42$), as shown in Table 11. PD was excluded from the analysis, because 95.4% of the probings following periodontal therapy were in the range of 3 to 5 mm and only 4.6% of the pockets exceeded 5 mm.

Table 9 Comparative Survival Rate Between Diabetics and Controls in Relation to Smoking

	Diabetic			Control		
	No. of implants	No. of patients	Failures	No. of implants	No. of patients	Failures
Smokers	143	22	5	102	18	0
Nonsmokers	112	23	0	142	27	2

Table 10 Relation Between Plaque Index and BOP and Peri-implant Bone Loss and Complications in the Control Patients

	PI		BOP	
	< 1	1–2	< 15%	> 15%
Patient (n)	28	17	28	17
Implant (n)	137	107	136	108
Failure (n)	1	1	1	1
Soft tissue complications (no. of implants)	3	5	7	1
Peri-implantitis (no. of implants)	0	0	0	0
Peri-implant bone loss (mm; m ± sd)	0.21±0.3	0.21± 0.3	0.21± 0.3	0.21± 0.3

PI = Plaque Index; BOP = bleeding on probing.

Table 11 Relation Between Plaque Index and BOP and Peri-implant Bone Loss and Complications in the Diabetic Group

	PI			BOP	
	< 1	1–2	> 2	< 15%	> 15%
Patients (n)	35	7	3	37	8
Implants (n)	212	22	21	205	50
Failure (no. of implants)	2	4	1	3	4
Soft tissue complications (no. of implants)	12	5	1	10	8
Peri-implantitis (no. of implants)	3	3	1	3	4
Peri-implant bone loss (mm); m ± sd)	.4 ± .6	. 6 ± 1.0	.5 ± .9	.3 ± .5	.7 ± .9

PI = Plaque Index; BOP = bleeding on probing.

Microalbuminuria results could be obtained from 30 patients. Only 4 of them had values over the normal ranges (20 to 200 µg/min).

Finally, a multivariate ordinal regression was performed to identify independent risk factors associated with the complication rate. Using this approach to control for univariate exploratory analysis, HbA1c was found to be the only multivariate independent factor significantly associated with success rate (P = .04); all other covariates were equal, HbA1c level was independently associated with success rate.

DISCUSSION

Diabetes control is critical for reducing the long-term micro- and macrovascular complications of the disease. Patients with glucose fluctuation within the day and from day to day may be more at risk for diabetic complications.[19] Since absolute control is difficult to obtain, an acceptable level of control can be defined as an FPG in the range of 90 to 130 mg/dL and an HbA1c < 7%. For diabetic patients undergoing major surgeries (eg, coronary artery bypass, total knee or hip replacement), it has been well established that absolute control of glucose plasma level by intensive insulin therapy in the perioperative period drastically reduces the postoperative complications (ie, deep wound infection and surgical site infection) as compared to lowering glycemia to < 200 mg/dL irrespective of the patient's diabetes history.[20–22] Also, strict normoglycemia in the critically ill substantially improves the outcome of illness.[23] In the current investigation, 1 of the inclusion criteria was an HbA1c < 7.2% in the perioperative period. Under this condition, conventional and advanced implant surgeries, including lateral window sinus elevation, immediate loading, and GBR were performed, and the results matched with healthy controls. No statistically significant differences in terms of implant survival, soft tissue complications, or postoperative infection were found between the 2 groups. This indicates that an

acceptable level of diabetes control in the perioperative period and a reasonable fluctuation of the Hba1c levels in the postoperative period may be sufficient to perform implant surgery safely with no risk of postoperative infection, but that similar results, not evaluated in the current investigation, may be obtained under different, possibly more risky perioperative and postoperative glycemic levels. However, diabetic duration and overall diabetes control and their effect on cell function and vascular damage have to be accounted for, for a full evaluation of the patient profile.[24,25] The risk of complications increases with the duration of hyperglycemia through the production of advanced glycation end-products that irreversibly accumulate on long-lived vessel walls, cause micro- and macrovascular complications, and alter the phenotype of many cells (ie, macrophages, polymorphonuclear cells, fibroblasts, and endothelial cells), which causes increased susceptibility to infection, vascular changes, and impaired healing.[26] Screening for microalbuminuria is also essential in type-2 diabetic patients[27,28] to evaluate the effect of diabetes on microcirculation and for the prevention of renal failure and cardiovascular disease. In the current study, only 4 of 30 tested diabetic patients had microalbuminuria values above the normal level (20 to 200 μg/min), which is a good indicator of the level of control of the disease in the present group of patients.

Although the number of failures in the current study is relatively limited, multivariate regression analysis, while controlling for other covariates, demonstrated a significant statistical correlation between HbA1c values and peri-implantitis ($P = .05$) and peri-implant bone loss ($P = .01$). On the other hand, no association could be found between diabetes duration and implant failure, postoperative complications, and peri-implant bone loss ($P = .38$). These results are in conflict with those reported by Olson et al,[13] who found that diabetes duration is a predictive factor for failure. One possible explanation for this discrepancy may be the lower level of diabetes control in their study, since 55 of the 87 monitored patients had elevated HbA1c values. According to Schernoff et al,[18] 2.2% of the failures in their study could be attributed to poor metabolic control, although 7 of the 11 patients studied who experienced failures had excellent glycemic control. No association with failure and type or level of metabolic control was found by Fiorellini et al[11] or Peled et al.[14] In the study of Kapur et al[12] on implant-supported overdentures, no implant failure or implant complications were found, although the patient metabolic control was rated good, with HbA1c values ranging from 5.1% to 12.7%. However, several shortcomings were noted in these studies, which seriously complicate the interpretation of the results. Only two[12,13] reported HbA1c values, but none monitored them during the observation period. Specific information on the patient diabetic profile was lacking in all cases. Only 1 study had a control group.[10] Only 2 studies reported peri-implant bone loss.[12,14]

The failure rate in the current study of 2.8% was not statistically different from the healthy matched controls, which conflicts with the results of Fiorellini et al,[11] who concluded that dental implants placed in a well-controlled diabetic population have reduced survival rates due to the mechanical characteristics of the bone-implant interface and wound healing. Comparing the survival rate between a diabetic and a control population, Morris et al[10] found that the difference between the 2 groups was only marginally significant. It is important to note that, to the author's knowledge, there are no references in the literature on the percentage of bone-implant contact in the diabetic patient. In the animal studies only, it was shown that uncontrolled diabetes hinders bone formation, bone remodeling, and wound healing[29–31] and causes reduction in bone-implant contact and bone thickness,[32] while insulin upregulates bone formation [33–35] and maintains bone-implant contact.[36] These experimental results, although significant, do not directly apply to type-2 diabetic patients with a different disease history and a distinct set of clinical conditions.

The patients' age was not a significant factor for the survival and complication rate. No statistically different results were found between the < 60 years group and the ≥ 60 years group for the survival rate, soft tissue complications, or peri-implantitis in accordance with the results of Olson et al.[13]

According to the recommendations of the American Diabetes Association, HbA1c must be monitored twice a year but should be monitored more frequently if glycemic control is inadequate, and the patient must self-monitor his glucose level daily, although the optimal frequency is not clearly defined. In this study, 14 of 45 patients controlled their blood glucose level daily.

CONCLUSION

Well- to fairly well-controlled diabetic patients with a mean HbA1c of 7.2% in the perioperative period had the same overall survival rate as controls in conventional and advanced implant therapy. Implant survival rate was independent from age, gender, diabetes duration, and smoking in a well- to fairly well-controlled diabetic population. More complications occur when PI and BOP increase. HbA1c is the most important factor affecting implant complication rate.

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