Research Article

CLINICAL PERFORMANCE OF TITANIUM-ZIRCONIUM IMPLANTS WITH A HYDROPHILIC SURFACE IN PATIENTS WITH CONTROLLED TYPE 2 DIABETES MELLITUS: TWO-YEAR RESULTS FROM A PROSPECTIVE CASE-CONTROL CLINICAL STUDY.

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ABSTRACT:

Objective: Analyze the 2-year clinical performance of single-unit titanium-zirconium (TiZr) alloy narrow diameter (3.3 mm) dental implants with a hydrophilic surface (Straumann® Roxolid®, SLActive®) in patients with controlled type 2 diabetes mellitus (T2DM), measured using the glycated hemoglobin A (HbA1c) concentration test, compared to results in individuals without T2DM.

Material and Methods: The studied sample consisted of 28 patients, 14 with T2DM (study group) and 14 without (control group). The plaque index, bleeding on probing, probing depth, clinical attachment level, gingival biotype and marginal bone loss (MBL) at the site of the implants were assessed. HbA1c levels were assessed in all patients during each check-up.

Results: Two years after implant placement and prosthetic restoration no implant failures were reported in either group, resulting in 100% survival and success rates in both groups. No statistically significant differences in MBL were found between the control and study groups ($p > 0.05$).

Conclusions: Within the limitations of this study, it can be concluded that reduced diameter TiZr alloy implants with a hydrophilic surface represent a safe and predictable treatment option for patients with well-controlled T2DM. The clinical performance was comparable to that observed in individuals without T2DM in the medium term.

Clinical relevance: The narrow implants placed in patients with T2DM with well-controlled glycemia (HbA1c) showed a marginal bone loss and success and survival rates similar to those of the control group without DM2, in the medium term.

Key words: dental implants, Ti-Zr alloy, hydrophilicity, type 2 diabetes mellitus, glycated hemoglobin A.

INTRODUCTION

Diabetes-related hyperglycemia can influence several aspects of the postoperative healing process. Altered vascularization and blood clot formation might occur due to an increase activation of platelets, as well as the formation of compact fibrin networks that are resistant to fibrinolysis, thus increasing thrombosis risk [1]. Diabetes-related hyperglycemia can also increase patients' susceptibility to infections, decreasing the capacity for tissue repair and increasing the risk of microvascular complications [2,3]. Changes in the behavior of bone cells in patients with type 2 diabetes mellitus (T2DM) are often linked to the presence of inflammatory cytokines that inhibit the formation of osteoclasts and repaired bone [4], thereby influencing bone matrix synthesis, bone mineralization and remodeling [5].

A wide array of publications has indicated that implant failure in patients is a rare event, even in patients with T2DM, according to a 2014 systematic review [6]. Some studies have found that patients with (T2DM) had worse periodontal and periimplant inflammatory parameters [7]. Another finding is that the mRNA levels of RANKL, RANKL / OPG, COL-I and BSP negatively influence the bone tissue of patients with T2DM when compared with healthy control patients [8]. Other authors found that in patients with worse glycemic control, the bone factors during healing were negatively modulated, but did not have any repercussion on the implant stability [9].

Other studies have found that when the perforation required for implant placement is less invasive, there is a potential reduction in peri-implant bone inflammation [10]. Narrow implants required a reduced drilling protocol; in consequence, it might help to improve osteoblast functioning, reduce swelling and bone loss [11] in patients where the inflammation is already set and playing a relevant role in the pathogenesis of the T2DM, now redefined as an immune disorder [12-14]. Therefore, narrow-diameter dental implants could be of great benefit to these patients because they might provide the same prosthetic success as a normal-diameter implant with less risk of complications due to overinflammation within the surgical zone.

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The overall objective of this study was to prospectively evaluate the clinical performance of narrow-diameter implants made from titanium-zirconium (TiZr) alloy with a hydrophilic surface when used for single-unit restorations in patients with T2DM, compared to the results from a control group comprised of patients without T2DM. The specific objectives were to analyze the survival and success rates of implants in both groups 2 years after implant placement and final restoration, as well as to observe any possible radiological changes in the marginal bone loss (MBL) caused by T2DM.

MATERIALS AND METHODS

Among the patients seeking routine dental care at the University of Seville, Faculty of Dentistry, 14 subjects diagnosed with T2DM were included in the study group. An additional 14 patients who were within the age range of the T2DM group who reported no history of T2DM and did not receive treatment for T2DM served as control subjects. The total sample consisted of 28 subjects, 12 men (42.9%) and [24] women

(57.1%), aged 56.75 ± 14.76 years. The study was approved by the Ethics Committee at the Faculty of Dentistry.

The patients attended the protocol follow-up appointment at the dentistry practice of the Master's Degree in Special Care in Dentistry at the University of Seville. After signing the informed consent, the patients provided their medical history, a panoramic radiography was taken and the blood levels of glycated hemoglobin A (HbA1c) were measured at the same laboratory for all subjects. An oral examination was performed at each patient visit to assess the plaque index (PI) [15], bleeding on probing (BOP) [16], probing depth (PD) and clinical attachment level (CAL) [17], as well as gingival biotype [18,19] and soft tissue form, which was classified as either "normal" or "scalloped" [20].

The inclusion and exclusion criteria were in accordance with the standards and guidelines previously described in the short-term study published by Cabrera-Domínguez et al. (2017) [21]. The inclusion criteria called for patients of at least 18 years of age with no smoking history, a single-unit dental loss (canine, incisor or premolar) in the maxilla or mandible and with an O'Leary plaque index (Pl) of less than or equal to 25% at the time of surgery. In the study group, patients with controlled type 2 diabetes mellitus with at least 2 years of disease evolution with HbA1c values between 6% and 10% at the time of the implant placement were included. The control group did not include any patients with any sign of type 2 diabetes mellitus. The exclusion criteria involved patients who presented local factors or medical conditions that contraindicate oral surgery, patients with known metal allergies and patients who required guided bone regeneration procedures.

One experienced, "blinded" surgeon (JC) with over 10 years of experience performed all of the surgeries at least 8 weeks after dental extraction [22]. The implant surgery protocols were in accordance with the standards and guidelines previously described in the short-term study published by Cabrera-Domínguez et al. (2017) [21]. The surgeon assessed the bone quantity and quality at the implant sites according to the Lekholm and Zarb index [23] by observing the bone tissue's resistance to drilling [24]. Surgical stents were used as a guide to prepare the implants' bed. The drilling sequence with physiological serum irrigation were as follows: a 1.2-mm round bur at 1200 rpm was used to mark the implant site, a 2.3-mm round bur at the same speed was used to facilitate the positioning of the "pilot drill," then a 2.2-mm pilot drill at 800 rpm was used for the implant's length and a final 2.8-mm burr at 600 rpm was employed. When necessary, a countersink drill was used at 300 rpm to adapt the implant neck to the bone tissue. The implants' platform were immersed 2 mm below the gingival margin of the adjacent teeth and non-submerged healing abutments were attached to the implants and sutured with simple interrupted stitches using 3/0 or 4/0 natural silk. The primary stability of the implant was measured by the insertion torque during the implant placement by following the direction of the implant placed using NSK's Advanced Handpiece Calibration (AHC) and the Surgic Pro S-MAX SG20 Motor at 20 rpm and 8 Hz up to a maximum seating torque of 35 Ncm [25].

Standard narrow-diameter (3.3 mm) titanium-zirconium (TiZr) implants with a hydrophilic surface were used (SLActive® Roxolid®, Institut Straumann AG, Basel, Switzerland). Antibiotics (amoxicillin/clavulanic acid (875 mg/125 mg) was administered every 8 hours for 7 days), as well as analgesic and anti-inflammatory medication (ibuprofen (600 mg) was administered every 8 hours for 4 days) were prescribed

after surgery. The patients were also provided with instructions for postoperative care. The patients were previously checked for allergies to any of the medications used in the study. Sutures were removed 2 weeks after surgery and the patients were examined for any postoperative complications.

After 6 weeks, impressions were taken to make single screw-retained metal ceramic crowns using the synOcta® transepithelial abutment (Institut Straumann AG, Basel, Switzerland). The crowns were attached to the implants and loaded after 8 weeks.

Throughout the course of the study, the overall health of the patients, any changes in their medication and their HbA1c levels were assessed through periodic blood tests at 1 and 2 years after the procedure. The glycemic condition was considered "controlled" when the HbA1c level was ≤ 7% and "uncontrolled" when HbA1Ac level was > 7% [26].

Digital standardized periapical radiographs (Gendex® Dental SystemGXS-700) were taken of the placed implants using the paralleling technique with film holding devices (with a Dentsply®Rinn XCP system) and processed using the measurement software VixWin™ (Gendex® Dental System). Digital periapical radiographs were taken to evaluate MBL at the bone crest around the implant by measuring the distance from the edge of the implant platform to the first bone-to-implant contact in two different positions: mesial (Bm) and distal (Bd) (Figure 1). Assessments were performed by (LC) at different periods: at the time of prosthesis placement, 6 months after prosthesis placement, 1 year after prosthesis placement and 2 years after prosthesis placement.

The implant survival rates were determined by assessing the stability and correct functioning of the remaining implant over time, as previously described by Cabrera-Domínguez *et al*. (2017) [21]. Implant success was calculated using the parameters proposed by Buser *et al.* 1991 [27]: the absence of radiotranslucent areas around the implant, absence of peri-implant infection, absence of symptoms as pain or suppuration and a lack of movement of the implant.

Statistical Analysis

A margin of error of 5% and a power of 80% were established, bearing in mind the prerequisites of the previous study published by Cabrera-Domínguez *et al*. (2017) [21]. Distal MBL was assessed after 2 years to estimate the corresponding standard deviation (SD). A difference of 0.15 between the groups was established as significant. With these values, a power of 87% was calculated for the variable with the SD and better results for the rest, always above 90% of power.

Statistical analysis was carried out using the statistical software IBM SPSS (IBM Analytics, Armonk, NY, USA). A descriptive analysis of all variables was also performed. Normality tests of all quantitative variables (Kolmogorov–Smirnov), univariate logistic regressions in the qualitative variables using the Chi-squared test, and linear correlation between the HbA1c values and the rest of the variables were also carried out. The Haberman standardized residuals test was used to identify the differentiating groups. ANOVA was used for normal variables and the Mann-Whitney U test was employed for those that were not normally

distributed. Statistical significance was established as $p \leq 0.05$, $p \leq 0.01$ or $p \leq 0.001$. Analysis of the statistical results was carried out by a blinded investigator (DT).

RESULTS

The mean age of the patients at the time of implant placement was 56.75 ± 14.76 years with no statistically significant differences between both groups. No statistically significant differences were observed with regard to gender, high blood pressure, cardiovascular pathology or medication intake between the study and control groups. Table 1 shows the most relevant sociodemographic variables and the medical history information that was obtained during the first patient visits.

The mean timespan between tooth loss and implant placement was 3.71 ± 8 [21] years (1.56 ± 3.57 years in the study group and 5.33 ± 10.25 years in the control group), with no statistically significant difference between the groups. Table 2 shows the remaining recorded dental variables.

No statistically significant differences were found between patients with T2DM and patients in the control group for variables related to implant placement, wound healing and postoperative swelling. Regarding bone quality in patients with T2DM, significantly more type III bone was found (92.2%) as opposed to type II bone (7.1%) (Table 3).

MBL, from the time of implant placement to prosthetic loading and to the 2-year follow-up visit, did not show statistically significant differences (Table 4) between the study and control groups or with regard to gender, age, gingival biotype or high blood pressure. However, statistically significant differences were found within the study group throughout the follow-up period. Greater distal MBL was observed 2 years after prosthetic loading in patients > 55 years of age with T2DM, in contrast with patients < 55 years of age ($p < 0.05$). Similarly, patients with T2DM and hypertension presented a greater mean MBL a year after implant placement, in contrast to patients with T2DM without hypertension ($p < 0.05$). This difference was no longer present at the 2-year follow-up appointment after implant placement and prosthetic loading.

In the control group, only one variable showed statistically significant differences; that is, those with a thin gingival biotype showed a greater tendency toward distal bone loss 2 years after implant placement compared to patients in the same group with a thick gingival biotype ($p < 0.05$).

The mean HbA1c levels were between 6.8–7.10% in patients with T2DM during the 2-year follow-up period. No significant correlation was found between the HbA1c levels and MBL of implants after 2 years (Table 5); however, after 6 months, a significant correlation was observed.

DISCUSSION

Some clinical and preclinical studies suggest that poor glycemic control is a contraindication for dental implant placement [28,29]. However, the limitations of these studies leave questions about the role of glycemic control in patients with type 2 diabetes mellitus [30-32].

Hyperglycemia has been proved to induce compromises in bone metabolism and changes to implant integration in animal models [33]. Subsequent clinical studies have found alterations in the differentiation of mesenchymal stem cells among patients with hyperglycemia, leading to changes in osteoblastic gene expression and subsequent alterations of their function, an increase in osteoclastic differentiation that resulted in aggravated bone resorption, decreased bone activity with degenerative changes in bone quality and changes to various metabolic pathways [34-38]. This may explain the high frequency of type III bone observed in patients with type 2 diabetes mellitus in the present study ($p < 0.05$). Even though it has been proposed that changes to bone metabolism could trigger potential damage to bone healing around implants, mainly when diabetes is uncontrolled, the present mid-term (2-year) study found no significant differences in bone healing around implants between the studied groups.

Feldbrin *et al.* (2015) found that patients with type 2 diabetes mellitus and high blood pressure showed altered type 1 collagen when compared with patients with type 2 diabetes mellitus without high blood pressure [39]. This protein affects bone metabolism and changes are linked to negative effects on bone formation. This might explain why the patients with diabetes mellitus and hypertension in our study showed higher average rates of MBL 1 year after implant placement compared to patients with diabetes mellitus but without hypertension ($p < 0.05$).

Al Amri et al. (2016) found that proper oral hygiene minimized hyperglycemia and parameters indicating inflammation around dental implants in patients with type 2 diabetes mellitus [11]. However, previous authors have observed a greater frequency of plaque formation in patients with type 2 diabetes mellitus [40]. The present study found no statistically significant differences in the presence of plaque between the two groups and all patients had acceptable oral hygiene (assessed using O'Leary's criteria) [15].

With regard to gingival biotypes, authors such as Linkevicius et al. (2009) have pointed out a significant correlation between thin gingival biotype and greater levels of MBL [41]. Nevertheless, no studies have successfully established a correlation between these two characteristics and diabetes. In the present study, the frequency of thick gingival biotype was significantly higher for patients with type 2 diabetes mellitus than for patients from the control group, in whom thin biotype was most common, but with no statistically significant differences. During the 2-year follow-up period, patients in the control group with thin gingival biotype presented greater MBL than those with a thick gingival biotype ($p < 0.05$), which is corroborated by previous studies [41,42]. In the study group, no statistically significant differences were found with regard to this parameter.

The use of TiZr alloys for narrow implants has significantly increased biomechanical resistance in dynamic fatigue resistance tests. In addition, the use of a hydrophilic, chemically modified sandblasted large-grit acid-etched (SLA) surface (SLActive®, Institut Straumann AG, Basel, Switzerland) has been proven to have faster osseointegration than the SLA surface [43,44]. Recently, Iegami et al. (2017) performed a

systematic literature review in which the survival rate of narrow-diameter implants with TiZr alloys was analyzed and compared with that of narrow implants made of pure titanium (cpTi) [45]. The authors concluded that TiZr implants showed success rates and levels of bone resorption around the implant similar to those of cpTi implants. Hence, TiZr narrow implants were used in the present study.

Al Nawas et al. (2015) found a mean bone loss of 0.3 ± 0.5 mm 1 year after placement of narrow-diameter TiZr implants in the anterior area [46]. These results cannot be compared with those obtained in the present study as the implants used did not have a polished neck, whereas the implants used in the present study had a polished neck of 2.8 mm. The overall mean MBL at the smooth surface implant level 2 years after the implant placement was 1.55 ± 0.46 mm and 0.71 ± 0.58 mm 2 years after prosthesis placement. Several authors have advised that implants with a polished implant neck should not be implanted in a subcrestal position as this leads to greater bone loss [47]. However, there might be implant neck geometries/implant-abutment connections that allow for subcrestal placement without higher bone loss [48, 49].

The MBL obtained in the present study is the result of applying the Buser et al. (2004) criteria, which recommend that the implant platform be placed 2 mm below the gingival margin of adjacent teeth in order to achieve better esthetic results [44]. This technique may sometimes result in the polished implant neck being placed in a subcrestal position, causing marginal bone loss around the platform.

In the present study, no statistically significant differences were found for the survival and success rates of implants in patients with diabetes mellitus compared to the control group; implant survival was 100% in both groups. The mean HbA1c in the study group was 7%, indicating that glycemia was well controlled throughout the follow-up period [50-52]. The low complication rates and nice results (compared with the non-diabetic group) may be due to the good HbA1C levels, as other studies (where HbA1C was less well-controlled) indicated more problems. After a 2-year follow-up period, these results are consistent with those of previous studies [53-56].

The sample size in both groups is low due to the specificity of the study protocol. Forming the study group was a challenging process because the inclusion criteria called for controlled type 2 diabetes and only one specific gap in the area of incisors, canines or premolars. In any case, as clarified in the Material & Methods section, the power of the study was high (around 90%), which supports the present study. In this sense, this prospective study is one of the few efforts to observe the performance of dental implants in patients with type 2 diabetes mellitus over a time period of 2 years. Throughout this follow-up period, the findings of this study confirmed those of previous studies with regard to changes in the bone levels and implant stability, which could be linked to varying glycemic levels. This was not observed in the present study, likely a result of the good metabolic control exhibited by the studied patients with diabetes [57].

CONCLUSIONS

No differences in MBL change and survival and success rates of narrow-diameter TiZr alloy implants with a hydrophilic surface were found between implants placed in patients with and without type 2 diabetes

mellitus after a 2-year follow-up period. The HbA1c levels in patients with type 2 diabetes mellitus had no correlation with MBL or implant survival and success rates. Within the limitations of this study, we conclude that reduced-diameter TiZr alloy implants with a hydrophilic surface represent a safe and predictable treatment option in patients with type 2 diabetes with well-controlled glycemia (HbA1c). The clinical performance of the implants is comparable to that observed in individuals without type 2 diabetes mellitus in the medium term.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest: Profs. C-D and M-P have administered the funding received from Institut Straumann (research grant number IIS 18/10), but all the authors declare that they have no conflict of interest.

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Ethical approval: All procedures performed involving human participants were in accordance with the ethical standards of the institutional research committee and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The research protocol was approved by the Ethics Committee of the Faculty of Dentistry of the University of Seville (Spain).

Informed consent: Written informed consent was obtained from all individual participants included in the study.

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FIGURE

Figure 1. Radiographic protocol of the marginal bone loss assessment performed in patients participating in the study: (A) Initial radiography; (B) Implant placement; (C) Two months after the implant placement, prior to placing the prosthetic restoration; (D) 6 months after placing the prosthetic restoration; (E) 1 year after placing the prosthesis; (F) 2 years after placing the prosthesis.

Table 1. Sociodemographic and control variables collected during first patient visits.

Group	All		Diabetes		Control		
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	
Diabetes	14	50,0					
Control	14	50,0					
All	**28**	**100,0**					
Studied Variables							
Gender	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Male	12	42.9	9	**64.3**	3	**21.4**	n/s
Female	16	57.1	5	**35.7**	11	**78.6**	n/s
Sig.				**<0.05**		**<0.05**	
Age at the time of implantation	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
< 55 years	13	46.4	4	28.6	9	64.3	n/s
> 55 years	15	53.6	10	71.4	5	35.7	n/s
Associated pathology	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Yes	19	67.9	14	**100.0**	5	**35.7**	n/s
No	9	32.1	0	**0.0**	9	**64.3**	n/s
Sig.				**<0.001**		**<0.001**	
Hypertension	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Yes	9	32.1	7	**50.0**	2	**14.3**	n/s
No	19	67.9	7	**50.0**	12	**85.7**	n/s
Sig.				**<0.05**		**<0.05**	
Cardiovascular disease	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Yes	4	14.3	4	**28.6**	0	**0.0**	n/s
No	24	85.7	10	**71.4**	14	**100.0**	n/s
Sig.				**<0.05**		**<0.05**	
Consumption of medications	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Yes	19	65.5	15	**100.0**	4	**28.6**	n/s
No	10	34.5	0	**0.0**	10	**71.4**	n/s
Sig.				**<0.0001**		**<0.0001**	
	All		**Diabetes**		**Control**		**Sig.**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Glycated hemoglobin	5.92	0.99	6.64	0.85	5.19	0.38	**<0.001**

Sig. Significance; n/s: non-significant; SD: standard deviation

Table 2. Dental history of patients recording during first patient visits.

Variables							
Cause of tooth loss	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Traumatism	1	3.8	1	7.7	0	0.0	n/s
Periodontal disease	2	7.7	1	7.7	1	7.7	n/s
Failed endodontics	2	7.7	2	15.4	0	0.0	n/s
Dental caries	7	26.9	4	30.8	3	23.1	n/s
Agenesis	1	3.8	0	0.0	1	7.7	n/s
Fractured tooth	12	46.2	5	38.5	7	53.8	n/s
Others	1	3.8	0	0.0	1	7.7	n/s
Years since tooth loss	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Less than 1	10	47.6	5	55.6	5	41.7	n/s
From 1 to 4	8	38.1	3	33.3	5	41.7	n/s
10 or more	3	14.3	1	11.1	2	16.7	n/s
Probing depth (mm)	**All**		**Diabetes**		**Control**		**Sig.**
	Percentage	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Distal	2.46	0.68	2.61	0.50	2.33	0.78	n/s
Bucal	1.64	0.62	1.83	0.56	1.48	0.64	**<0,05**
Mesial	2.50	0.69	2.48	0.75	2.52	0.64	n/s
Oral	2.10	0.73	2.13	0.68	2.07	0.78	n/s
Clinical attachment level (mm)	**All**		**Diabetes**		**Control**		**Sig.**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Distal	3.12	1.17	3.57	1.16	2.74	1.06	**<0,05**
Bucal	2.26	1.17	2.74	1.20	1.85	0.99	**<0,01**
Mesial	2.90	0.98	3.00	1.14	2.81	0.83	n/s
Oral	2.50	1.09	2.57	1.07	2.44	1.12	n/s
Soft tissue biotype	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	
Width	10	35.7	8	**57.1**	2	**14.3**	n/s
Thin	18	64.3	6	**42.9**	12	**85.7**	n/s
Sig.				**<0.05**		**<0.05**	
Soft tissue morphology	**All**		**Diabetes**		**Control**		**Sig.**
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	Percentage	
Normal	18	64.3	11	78.6	7	50.0	n/s
Scalloped	10	35.7	3	21.4	7	50.0	n/s
Bacterial plaque	**All**		**Diabetes**		**Control**		**Sig.**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Number of surfaces with bacterial plaque	4.96	4.47	3.86	3.80	6.07	4.94	n/s
Total number of surfaces	84.14	27.62	79.71	24.98	88.57	30.30	n/s
Percentage of surfaces with bacterial plaque	5.83	4.99	4.89	4.53	6.77	5.41	n/s
Bleeding on probing	**All**		**Diabetes**		**Control**		**Sig.**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Number of teeth with bleeding	2.25	2.15	1.71	1.54	2.79	2.58	n/s

Total number of teeth	21.04	6.90	19.93	6.24	22.14	7.57	n/s
Percentage of teeth with bleeding	11.77	10.37	9.69	8.00	13.84	12.26	n/s

Sig.: Significance; n/s: non-significant; SD: standard deviation

Table 3. Variables studied during implant placement and healing.

Implant location	**All**		**Diabetes**		**Control**	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Incisor	4	14.3	1	7.1	3	21.4
Canine	5	17.8	4	28.6	1	7.1
Bicuspid	19	67.9	9	64.3	10	71.4
Implant length	**All**		**Diabetes**		**Control**	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
10 mm	22	78.6	10	71.4	12	85.7
12 mm	6	21.4	4	28.6	2	14.3
Bone quality	**All**		**Diabetes**		**Control**	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Type II	8	28.6	1	**7.1**	7	**50.0**
Type III	20	71.4	13	**92.9**	7	**50.0**
Sig.				**<0.05**		**<0.05**
Primary stability	**All**		**Diabetes**		**Control**	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Sí	28	100.0	14	100.0	14	100.0
No	0	0.0	0	0.0	0	0.0
Location of bone loss	**All**		**Diabetes**		**Control**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Distal	-1.83	0.55	-1.89	0.55	-1.77	0.57
Mesial	-2.20	0.52	-2.26	0.54	-2.14	0.51
Middle	-2.02	0.46	-2.08	0.47	-1.96	0.47
Glycated hemoglobin	**All**		**Diabetes**		**Control**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Glycated hemoglobin	6.70	0.99	6.70	0.99		
Normal healing	**All**		**Diabetes**		**Control**	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Yes	28	100.0	14	100.0	14	100.0
No	0	0.0	0	0.0	0	0.0
Local inflammation	**All**		**Diabetes**		**Control**	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Yes	0	0.0	0	0.0	0	0.0
No	28	100.0	14	100.0	14	100.0

SD: standard deviation

Table 4. Variations in bone loss after implant placement

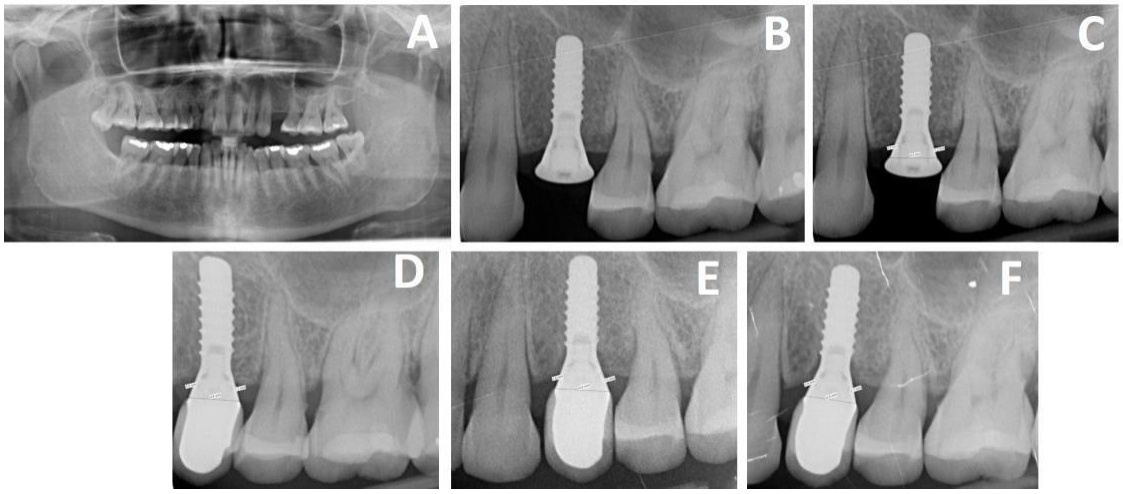
Marginal Bone Loss							
At the time of prosthesis placement	**Distal**		**Mesial**		**Middle**		**Sig.**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
All	0.84	0.63	0.84	0.71	0.84	0.56	n/s
Diabetes	1.02	0.71	0.99	0.73	1.00	0.56	n/s
≤ 7% HbA1c	0.88	0.68	0.90	0.78	0.89	0.52	n/s
> 7% HbA1c	1.33	0.90	1.43	0.51	1.38	0.70	n/s
Control	0.66	0.49	0.69	0,69	0.68	0.54	n/s
6 months after prosthesis placement	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Sig.**
All	0.29	0.49	0.41	0.48	0.35	0.44	n/s
Diabetes	0.19	0.55	0.36	0.48	0.28	0.48	n/s
≤ 7% HbA1c	0.28	0.63	0.42	0.52	0.35	0.54	n/s
> 7% HbA1c	-0.10	0.17	0.03	0.06	-0.03	0.10	n/s
Control	0.40	0.41	0.46	0.48	0.43	0.40	n/s
1 year after prosthesis placement	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Sig.**
All	0.53	0.57	0.66	0.64	0.59	0.55	n/s
Diabetes	0.42	0.61	0.66	0.68	0.54	0.60	n/s
≤ 7% HbA1c	0.55	0.67	0.80	0.73	0.68	0.64	n/s
> 7% HbA1c	0.00	0.26	0.13	0.15	0.07	0.18	n/s
Control	0.63	0.52	0.65	0.62	0.64	0.53	n/s
2 years after prosthesis placement	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Sig.**
All	0.58	0.62	0.84	0.70	0.71	0.58	n/s
Diabetes	0.54	0.75	0.81	0.74	0.68	0.67	n/s
≤ 7% HbA1c	0.71	0.81	1.01	0.79	0.86	0.70	n/s
> 7% HbA1c	0.10	0.36	0.33	0.30	0.21	0.28	n/s
Control	0.62	0.46	0.87	0.68	0.75	0.49	n/s

Sig.: Significance; n/s: non-significant; HbA1c: Glycated hemoglobin; SD: Standard deviation

Table 5. Correlation between glycated hemoglobin and marginal bone loss around implants in patients with type 2 diabetes mellitus throughout the 2-year study period

	Study planning		Surgery		Prosthesis placement		6 months after prosthesis placement		1 year after prosthesis placement		2 years after prosthesis placement	
	Corr.	Sig.	Corr.	Sig.	Corr.	Sig.	Corr.	Sig.	Corr.	Sig.	Corr.	Sig.
Distal	-0.2508	n/s	-0.3270	n/s	-0.1943	n/s	-0.5146	n/s	-0.4411	n/s	-0.3399	n/s
Mesial	-0.4397	n/s	-0.4740	n/s	-0.4571	n/s	-0.5286	n/s	-0.5073	n/s	-0.4248	n/s
Middle	-0.3827	n/s	-0.4442	n/s	-0.3607	n/s	-0.5790	**p<0,05**	-0.5262	n/s	-0.4242	n/s

Corr.: Correlation; Sig.: Significance; n/s: non-significant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