Influence of Smoking on Dental Implant Osseointegration: A Radiofrequency Analysis of 194 Implants

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Although many studies have related smoking to peri-implantitis and marginal bone loss, little is known of its potential impact on dental implant osseointegration. The present clinical study explores the influence of smoking on secondary stabilization based in radiofrequency analysis. A total of 194 implants in 114 patients were included. Implant stability was evaluated on the day of surgery and at a minimum of 90 days after implantation, when osseointegration is considered to have been completed. The evolution of implant stability was compared between 2 groups: smokers and nonsmokers. The following variables were also analyzed: implant brand and model, length, diameter, insertion torque, bone density according to the Misch classification, location of the implant, and patient age and gender. The results showed that smoking did not affect the primary stability of the implant, although it was associated with a marked decrease in secondary stability. The nonsmokers showed a gain of 2.69 points (95% confidence interval [CI]: 1.529–3.865; $P < .001$) in the osseointegration process. However, in the smokers group, implant stability was seen to decrease 0.91 points (95% CI: −3.424 to 1.600; $P < .004$), generating a difference of 3.61 points between smokers and nonsmokers. Smoking is thus concluded to be an important factor that must be taken into account when seeking good implant osseointegration outcomes.

Key Words: endosseous dental implantation, bone–implant interface, smoking, radiofrequency analysis, nicotine, osseointegration

Introduction

A number of studies have related smoking to an increased risk of peri-implantitis, marginal bone loss around dental implants, and implant loss,[1–8] although always after completion of the implant osseointegration process. It is therefore of interest to investigate how smoking may influence osseointegration.

Implant stability is defined as the absence of movement of a dental implant following its surgical placement under concrete loading conditions.[9] Primary stability is initially conditioned by the pressure exerted by the implant at insertion into the prepared socket and lasts only a few days—the time the osteoclasts take to induce bone reabsorption. In turn, secondary stability covers the period after bone remodeling at the implant surface. This period during which primary stability gives way to secondary stability is referred to as the *osseointegration process*, a term introduced by Brånemark in 1969 and defined as intimate microscopic binding between the living bone and the implant surface, which allows the implant to support functional loading without inflammation, mobility, or pain. The time required by the implant to achieve effective osseointegration has been investigated in experimental models and is reported to be 12 weeks or 90 days.[10–13]

Bone density has been assessed based on the classification of Misch,[14] which contemplates 4 types of density according to the score (in Hounsfield units [HU][15]) obtained by the dental scanner in the implant zone: type I (>1250 HU), type II (850–1250 HU), type III (350–850 JU), and type IV (150–350 HU).

Implant stability has been measured using the Osstell system, which is a radiofrequency device that causes vibration of the dental implant. Increased implant anchoring to the bone is correlated to higher resonance frequencies, which are recorded by the Osstell system to yield a numerical score (implant stability quotient [ISQ]) ranging from 1–100 according to the captured wavelength. This score indicates the degree of lateral stability of the interface between the bone and implant. Many studies have confirmed the suitability of this device for measuring implant stability, and it has been found to be objective, simple, and statistically valid when compared with other existing methods.[16–26]

The primary objective of the present study is to determine whether smoking has a negative impact on implant osseointegration, which would be determined by the difference in ISQ between the time of secondary stability and the surgical phase or primary stability. The secondary objectives are to explore the possible associations between the ISQ values and a series of independent variables: implant brand and model, length, diameter, insertion torque, bone density of the implant site, location of the implant, and patient age and gender.

Materials and Methods

A 2-year prospective, longitudinal, quantitative, analytical clinical observational study was carried out with the hypothesis that smoking has a negative impact on the dental implant osseointegration process.

The study was approved by the Clinical Research Ethics

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Committee of the Valencian Community (Spain) (Comité Ético Autonómico de Estudios Clínicos de Medicamentos y Productos Sanitarios de la Comunidad Valenciana [CAEC]; reference UCV/2015-2016/23) and abided with the ethical guidelines of the Declaration of Helsinki regarding medical research in humans. Written informed consent was obtained from all study participants.

Subjects

The study population consisted of all patients who received dental implant treatment in the private clinics in which the study was carried out (located in the town of Aldaya [Valencia], with a population of 31 492 inhabitants, and in the area of Safranar [Valencia], with 8802 inhabitants) and who met all the inclusion criteria and none of the exclusion criteria. The study sample comprised 194 implants in 114 patients between 18 and 75 years of age (45 men and 69 women).

Calculation of the minimum required sample size was based on the detection of differences in mean ISQ between a first and a second measurement. Given the estimated standard deviation (SD) of 7.871 for the first measurement and 5.629 for the second measurement, we expected to find differences of at least 2.559 between ISQ measurements, with a correlation coefficient between the first and second measurements of 0.203, a confidence level of 95%, and a statistical power of 80%. The resulting sample size was 140 subjects. Since the final sample consisted of 194 subjects, the confidence level of 95% was maintained, and the statistical power increased to 98.4%.

In relation to the validity of the study, an error of 10% was assumed in all estimates.

With regard to the internal consistency of the measurements, we used the same Osstell system and the same transducers (Smart-Pegs) with each implant brand and model in all the measurements, with prior control calibration in each case.

The inclusion criteria were as follows:

- Patients aged 18 years or older who read the information sheet, provided written consent, and signed the personal data protection form
- Patients with at least 1 missing tooth, with extraction having been performed at least 6 months before the study (ie, delayed implants, not postextraction implants, were involved in the study)
- Patients with no disease condition contraindicating implant treatment
- Patients with sufficient available bone to place implants measuring between 8.5 and 15 mm in length and 3.3 to 5 mm in diameter and with no need for bone-grafting procedures
- Patients with sufficient attached gingival tissue to allow implant treatment with no need for soft-tissue grafting

The exclusion criteria were as follows:

- Cases involving prosthetic loading in less than 90 days after surgery, as this could influence the study outcomes
- Cases of postextraction implant placement or cases in which implant placement took place without waiting 6 months after tooth extraction
- Patients receiving drug treatments capable of affecting the osseointegration process and/or healing of soft tissues (eg, bisphosphonates and immunosuppressors)
- Implant treatments accompanied by bone or soft-tissue grafting techniques
- Patients receiving implants measuring less than 8.5 mm or more than 15 mm in length
- Implants measuring less than 3.3 mm or more than 5 mm in diameter

Measurements and materials

Implant stability was assessed using the Osstell device.

Primary study variables

The primary study variables consisted of the following:

- The ISQ, which was scored from 1–100 and measured at the time of implant placement (ISQ1) and again once secondary stability was considered to have been reached (at least 90 days after implant placement) (ISQ2)
- Smoking habit, which was classified into 4 subgroups: nonsmokers, smokers of 1–10 cigarettes/d, smokers of 11–20 cigarettes/d, and smokers of more than 20 cigarettes/d

The secondary study variables were

- Implant brand and model (qualitative variable; Klockner Essential, Nobel Active, or Straumann BLT)
- Implant diameter (continuous quantitative variable): 3.3 mm (Straumann BLT); 3.5 mm (Nobel Active and Klockner Essential); 4 mm (Klockner Essential); 4.1 mm (Straumann BLT); 4.3 mm (Nobel Active), 4.5 mm (Klockner Essential), and 5 mm (Nobel Active)
- Implant length (continuous quantitative variable): 8 mm (Klockner Essential); 8.5 mm (Nobel Active); 10 mm (Klockner Essential, Nobel Active and Straumann BLT), 11.5 mm (Nobel Active), 12 mm (Klockner Essential and Straumann BLT), 13 mm (Nobel Active), and 15 mm (Nobel Active)
- Implant insertion torque (qualitative variable): 0–70 N/cm^2
- Density of bone housing the implant (continuous quantitative variable): Misch classification types I, II, III, and IV
- Age (discrete quantitative variable): 18–75 years
- Sex (qualitative variable): male or female

Statistical analysis

All characteristics were summarized as the mean and SD for continuous variables or as proportions for categorical variables. A descriptive study of the variables was made, followed by bivariate analysis (based on the Student *t* test and analysis of variance [ANOVA] with post hoc Bonferroni correction for univariate normal distributions), contrasting the 2 study time points (Wilcoxon test for univariate nonnormal distributions). Finally, multivariate analysis was performed to determine which of the secondary variables had a greater impact on implant osseointegration. $P < .05$ was considered statistically significant. The data were entered in a Microsoft Excel spreadsheet, followed by analysis using the IBM SPSS version 19 statistical

package and EPIDAT 3.1. The methodology was reviewed by an independent statistician.

Procedures

The ISQ was measured at 2 different time points: at the time of implant placement (ISQ1) and following the osseointegration period, at least 90 days after implant placement (ISQ2). Since the study involved 3 different brands and models of implants, the waiting period for the second measurement was always at least 90 days, to ensure that osseointegration had been completed and that we were measuring the bone–implant interface with mature bone, with minimum primary stability, and with maximum secondary stability.[10–13] This is independent of the fact that some hydrophilic implant surfaces (such as the Straumann SLA surface) have been shown to acquire high degrees of secondary stability in only 6 weeks.[27]

Each measurement was obtained in 2 different spatial orientations: buccal or palatine/lingual (ISQ Bu/Pt) and mesial or distal (ISQ Ms/Dt). These 2 measurements were analyzed separately and after calculating the mean of both values (ISQ1m: mean of ISQ measured Bu/Pt and Ms/Dt at implant placement, and ISQ2m: mean of ISQ measured Bu/Pt and Ms/Dt at least 90 days after implant placement). All measurements were made in 2 different private clinics but always by the same surgeon, using 2 different Osstell devices (1 in each clinic). Each device was calibrated before each measurement to ensure reliable readings.

An individual data sheet was used to record the initials of each patient, with a code corresponding to that of the patient in the files of the dental clinic, to ensure the anonymity of all subjects participating in the study. After obtaining written consent, a 3-dimensional dental scan was made of the treatment zone, with a view to selecting the implant best suited to each case, evaluating bone availability to choose the appropriate implant length and diameter. Likewise, bone density was analyzed based on the classification of Misch, which contemplates 4 types of density (in HU), from I–IV, in order to choose the appropriate implant design, brand, and model.

Results

Descriptive and bivariate analysis

Variation in ISQ Score During the Osseointegration Process

One case was excluded from the study because the implant failed and had to be removed during the osseointegration process, thereby precluding the second Osstell measurement (ISQ2). In contrast, all implants exhibited sufficient primary stability to allow Osstell measurement on the day of surgery.

The mean ISQ1 score (ISQ1m) was 74.15 (95% CI: 73.14–75.16), whereas the mean ISQ2 score (ISQ2m) was 75.90 (95% CI: 75.08–76.71), with both scores being significantly correlated (Pearson correlation coefficient = .290; $P < .001$). The mean value increased between the 2 measurement time points (ISQ2–ISQ1), with an average difference of 1.74 (95% CI: 0.65–2.84) and a median increase of almost 2 points (Wilcoxon $P = .001$; Figure a).

Variation in ISQ score and smoking

The average number of cigarettes smoked per day was 3.85 (95% CI: 2.69–5.00). More than half of the global patients were nonsmokers. Because of the important variability of the sample, 4 subgroups were established: nonsmokers (143 implants; 73.7% of the sample), smokers of 1–10 cigarettes a day (23 implants; 11.9%), smokers of 11–20 cigarettes a day (16 implants; 8.2%), and smokers of more than 20 cigarettes a day (12 implants; 6.2%).

In relation to the influence of smoking on the implant stability scores, no statistically significant differences were observed between smokers and nonsmokers at the first time point (ISQ1; Student *t* test, $t = -0.698$, degrees of freedom [*df*] = 192; $P > .400$), thus suggesting that there is no evidence of an influence of smoker status upon primary implant stability. In contrast, at the second time point (ISQ2), the stability scores were significantly lower among the smokers (Student *t* test, $t = 2.989$, $df = 191$; $P = .003$). On comparing the evolution of implant stability during the osseointegration process, the nonsmokers gained implant stability (ISQ2–ISQ1: 2.697), whereas the smokers lost implant stability (ISQ2–ISQ1: −0.912). This difference of 3.609 points between smokers and nonsmokers was statistically significant (Student *t* test, $t = 2.916$, $df = 191$; $P = .004$; Figure b).

The results suggest that the greater the number of cigarettes smoked per day, the poorer the implant osseointegration process (ANOVA, $F = 5.100$, $df1 = 3$, $df2 = 189$; $P = .002$). However, while smoking more than 20 cigarettes a day reduced the implant stability as compared with the nonsmokers (−8.155, Bonferroni; $P = .002$), the difference between smoking more than 20 cigarettes a day and smoking less than 20 cigarettes a day proved nonsignificant (1–10 cigarettes a day −5.045, Bonferroni; $P = .361$ and 11–20 cigarettes a day −7.240, Bonferroni; $P = .073$); no direct correlation therefore could be established between a greater number of cigarettes a day and poorer implant osseointegration (Figure c).

Variation in ISQ score and gender

The study sample consisted of 194 dental implants: 108 in women (55.7%) and 86 in men (44.3%). Gender differences in stability score were observed at the second measurement time point (ISQ2; women 76.841 and men 74.721; $P = .010$) but not at the first time point (ISQ1; $P > .400$). The difference in score between the 2 time points (ISQ2–ISQ1) proved significant in women, with a difference of 2.65 points ($P = .002$), whereas in men. the difference was 0.62 points ($P = .392$). Thus, it can be concluded that the osseointegration process was better on average in women than in men.

Variation in ISQ score and age

All patients were adults (older than 18 years), and the oldest patient was 75 years old. The mean patient age was 53 years (95% CI: 51.75–54.91).

There was no evidence relating age to significant variations in either ISQ1 score (Pearson = .071; $P = .327$) or ISQ2 score (Pearson = .005; $P > .400$). Likewise, age showed no influence

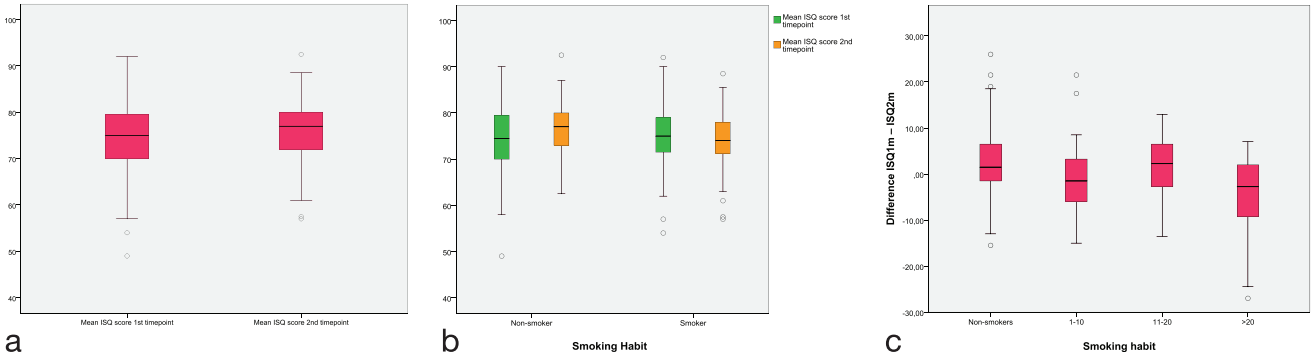

Figure. (a) Dispersion plots showing the increase (1.74 points) in mean implant stability between the first study time point (implant placement; primary stability phase; ISQ1m) and at the second study time point (at least 90 days after implant placement; secondary stability phase; ISQ2m). Mean implant stability quotient (ISQ) score first time point/mean ISQ score second time point. (b) Variation in mean implant stability between the first study time point (implant placement; primary stability phase; ISQ1m) and the second study time point (at least 90 days after implant placement; secondary stability phase; ISQ2m), with comparison between smokers and nonsmokers. (c) Variation in mean implant stability between the first study time point (implant placement; primary stability phase; ISQ1m) and the second study time point (at least 90 days after implant placement; secondary stability phase; ISQ2m) according to the number of cigarettes smoked daily by subgroups.

on the variation in ISQ score between the 2 measurement time points (Pearson = −.050; $P > .400$).

Variation in ISQ score and implant brand and model

We used 3 implant brands with their respective models in this study: 122 Nobel Active implants (62.9%), 57 Klockner Essential implants (29.4%), and 15 Straumann BLT implants (7.7%).

On comparing the mean ISQ1 and ISQ2 scores and their variation over time, the Klockner implants were seen to afford better primary stability than the Nobel or Straumann implants (ANOVA, $F = 3.832$; $P = .023$ and $F = 3.752$; $P = .025$). The differences decreased at the second measurement time point; however, the Nobel and Straumann implants showed a greater stability gain, although statistical significance was not reached (ANOVA, $F = 0.169$; $P > .400$; Table 1).

Variation in ISQ score and implant diameter

The implant diameters were 3.3, 3.5, 4.0, 4.1, 4.3, 4.5, and 5.0 mm. The most frequent implant diameter was 4.3 mm (69 implants; 35.6% of the cases), followed by 3.5 mm (52 implants; 26.8%). The least frequently used diameter was 5.0 mm (3 implants; 1.5%).

On relating the diameter of the implant to the ISQ1 and ISQ2 scores, and to the difference in score between the 2 time points (ISQ2 − ISQ1), an increasing diameter was found to be associated to higher ISQ1 (Pearson = .207; $P = .004$) and ISQ2 scores (Pearson = .209; $P = .004$).

Variation in ISQ score and implant length

The implant lengths were 8.0, 8.5, 10.0, 11.5, 12.0, 13.0, and 15.0 mm. The most frequent implant length was 10.0 (111 implants; 57.2% of the cases), followed far behind by a length of 11.5 mm (31 implants; 16.0%). The least frequently used length was 8.0 mm (4 implants; 2.1%). The mean implant length was 10.778 mm (95% CI: 10.577–10.979), with a median of 10.0 mm.

Implant length was not correlated to improved ISQ1 and ISQ2 scores or to differences in score between the 2 time points (ISQ2–ISQ1; $P > .265$).

Variation in ISQ score and insertion torque

Implant insertion torque was measured in Newtons (N)/cm^2. The mean torque in the study sample was 45.515 N/cm^2 (95% CI: 44.338–46.693; range, 15–60), with a median of 50 N/cm^2.

Insertion torque influenced only the first measurement time point (ie, primary stability; Pearson = .435; $P < .001$), with no impact on secondary stability or the difference in stability between the 2 time points (ISQ2 − ISQ1).

Table 1

Mean implant stability quotients at the first study time point (implant placement; primary stability phase; ISQ1m) and at the second study time point (at least 90 days after implant placement; secondary stability phase; ISQ2m), and difference in stability quotients between the 2 time points (during the implant osseointegration period; ISQ2m − ISQ1m)

		ISQ1m		ISQ2m		ISQ2m − ISQ1m	
	n	Mean	SD	Mean	SD	Mean	SD
Klockner Essential	57	76.2895	8.34306	77.5789	6.07967	1.2895	10.32592
Nobel Active	122	73.1803	6.53062	75.0950	5.25012	1.9917	6.34067
Straumann BLT	15	74.5000	4.91354	75.9667	6.95256	1.4667	6.80459
Total	194	74.1959	7.11619	75.8964	5.72523	1.7435	7.72714
ANOVA Sig.		0.023		0.025		>0.400	

TABLE 2

Variables with the greatest influence on the variation in implant stability between the 2 measurement time points (during the implant osseointegration period; ISQ2 − ISQ1)*

	Nonstandardized Coefficients		Standardized Coefficients			95% CI for B	
	B	Standard Error	Beta	t	Significance	Lower Limit	Upper Limit
(Constant)	17.395	2.914		5.970	0.000	11.648	23.142
Insertion torque	−0.289	0.063	−0.312	−4.630	0.000	−0.413	−0.166
Smoker	−1.689	0.585	−0.195	−2.888	0.004	−2.844	−0.535

*Increased insertion torque is seen to have a positive effect on implant stability, whereas smoking has a negative impact.

Variation in ISQ score and bone density

The most frequent bone density in the study sample corresponded to Misch type II (79 patients; 39.2% of the sample), followed by type III (61 patients; 31.4%). The implants placed in type I and II bone showed significantly higher ISQ1 scores than those placed in type III and IV bone ($P < .001$). However, at the second time point (ISQ2), the stability scores were similar for all 4 types of bone (I, II, III, and IV; $P = .267$). Thus, at the second measurement time point, bone of density type III and IV was able to compensate for the poorer stability performance recorded at the time of implant placement (ISQ1).

Multivariate analysis

Multivariate analysis was carried out to determine which of the study variables exerted the greatest influence on the implant stability scores at the 2 measurement time points (ISQ1 and ISQ2) and the difference in scores (ISQ2 − ISQ1).

The model that best explained the variability in ISQ1 score included the following predictors: insertion torque, Misch bone density, and implant diameter. These variables accounted for 25.9% of the variability of the dependent parameter (R^2; $P < .001$).

$$\text{ISQ1m} = 53.378 + 0.269 \times \text{insertion torque} - 1.817 \times \text{Misch bone density} + 3.272 \times \text{diameter}$$

The model that best explained the variability in ISQ2 score included the following predictors: primary stability (ISQ1 score), smoking, gender, and age. These variables accounted for 21.8% of the variability of the dependent parameter (R^2; $P < .001$).

$$\text{ISQ2m} = 66.006 + 0.225 \times \text{ISQ1m} - 3.563 \times \text{smoker} - 2.083 \times \text{gender} - 0.099 \times \text{age}$$

Lastly, the model that best explained the difference in stability score between the 2 measurement time points (ISQ2–ISQ1) included the following predictors: insertion torque and smoking. These variables accounted for 15% of the variability ($P < .001$; Table 2).

$$\text{ISQ1m} - \text{ISQ2m} = 17.395 - 0.289 \times \text{insertion torque} - 1.689 \times \text{smoker}$$

DISCUSSION

A review of the literature revealed no studies on the influence of smoking on the evolution of dental implant osseointegration using radiofrequency analysis. Our findings therefore cannot be compared with data published by other authors. Nevertheless, the results suggest that the smokers in our series had poorer secondary implant stability than the nonsmokers did. This could be interpreted in terms of the cytotoxicity of the different components found in tobacco (mainly nicotine, carbon monoxide, and hydrogen cyanide) and that have a negative impact upon the inflammatory process involved in dental implant osseointegration. Smoking induces increased catecholamine, fibrinogen, and carboxyhemoglobin levels; increases platelet adhesion; and also affects polymorphonuclear cell function—these phenomena result in diminished vasodilatation and cell perfusion and hence poorer wound healing.[1–9]

However, many studies have related dental implant stability to the rest of the variables considered in the present study:

- In the same way as in our own study, a number of authors have analyzed the evolution of dental implant osseointegration based on the ISQ scores. Boronat-López et al[28] and Bischof et al[29] recorded an increase in ISQ score 12 weeks after implant placement. This is consistent with our own observations but differs from the findings of Nedir et al,[30] who found the ISQ score to increase only when the primary stability score (ISQ1) was less than 60. In the rest of the cases, the ISQ score was seen to remain constant, with no improvement after 3 months of osseointegration.
- With regard to the dental implant brand and model, we found Klockner Essential (a self-threading implant with parallel walls) to yield better primary stability scores than Nobel Active (a self-threading conical implant). This coincides with the data published by Shiigai,[31] who found the best ISQ1 scores to correspond to parallel-wall Zimmer implants versus conical design implants. In contrast, Alves and Neves[32] obtained higher ISQ1 scores with conical implants.
- We found the ISQ1 and ISQ2 scores to increase with the diameter of the implant, in coincidence with the observations of Boronat et al,[28] Horwitz and Machtei,[33] and Renouard and Nisand.[34]
- On the other hand, and in agreement with our own results, Horwitz et al,[33] Bischof et al,[29] Meredith et al,[35] Friberg et al,[36] and Balleri et al[37] found no relationship between the length of the implant and the ISQ score.
- With regard to the correlation between bone density and the ISQ scores, Zix et al[38] concluded that Misch density types III and IV result in poorer primary stability but in compensation gain more secondary stability during the osseointegration process, in coincidence with our own

observations. In this same line, Huwiler et al[39] and Balshi and Wolfinger[40] concluded that there is no correlation between the bone density of the implant site and the secondary stability achieved.
- Lastly, in the presence of similar primary stability scores in men and women, subsequent secondary implant stability was seen to be slightly greater in women in our series. The observed gender difference of 2.05 points proved statistically significant. We have found no other studies with which to either confirm or refute our results. It therefore would be very interesting to conduct further studies in this field, involving a larger sample size, to identify possible variables or factors capable of explaining this difference.

The present study has a number of limitations. First, we should mention the limited sample size, as we were able to analyze only 51 implants in smokers. This figure is probably too low considering that the primary objective of the study was to evaluate the impact of smoking on the implant osseointegration process. It proved more difficult than expected to recruit smokers undergoing implant treatment, because these individuals represented only 26.3% of the study cohort, whereas nonsmokers undergoing implant treatment accounted for 73.7%. As a result, although the data appeared to indicate that increased smoking is associated with poorer osseointegration, the findings were statistically inconclusive. Likewise, the sample size of 194 implants was too small to draw conclusions regarding the variables of age and position of the implants.

Another limitation of our study is the time factor, since we analyzed only the variation of ISQ during the implant osseointegration process, which is estimated to last 90 days. Future studies involving longer implant follow-up periods are advisable to evaluate the ISQ2 values at different time points beyond this period, with a view to determining whether smoking affects the evolution of secondary stability.

Other limitations are the heterogeneity of the implant brands, surfaces, lengths, and diameters used and the diversity of the number of implants of each brand and model placed. Furthermore, the time to secondary stability measurement (ISQ2) ranged considerably from 90 to 265 days (mean 126.04 $\pm$ 34.429; 95% CI: 121–130.91; median 112 days). Such variability was attributable to problems with some patients in arranging the appointment for the second measurement visit.

The main objective of our study was to determine whether smoking has a negative effect on osseointegration, and the results obtained appear to confirm a negative effect. In any case, further studies involving larger sample sizes are needed to draw firmer conclusions regarding the influence of those study variables for which statistical significance was not reached in our series.

Conclusions

- In the course of the osseointegration process, the ISQ scores in our patient series increased from the primary stability to the secondary stability period.
- Smoking did not affect primary stability in our study but was associated with a marked decrease in secondary stability.
- Increased implant diameter was associated with improved primary and secondary stability.
- Increased implant insertion torque was associated with improved primary stability, but secondary stability scores were not improved as a result.
- Misch bone density types I and II resulted in higher primary stability scores in our patients. However, bone density types III and IV showed a greater increase in implant stability during the osseointegration process, resulting in similar secondary stability scores for all 4 bone density types.
- The variables associated with the greatest increases in primary stability were implant insertion torque, followed by Misch bone density and the diameter of the implant. With regard to secondary stability, smoking resulted in the greatest decrease, whereas a higher primary stability (ISQ1) score was associated with the greatest increase, followed by female gender.

Abbreviations

HU: Hounsfield units
ISQ: implant stability quotient
RFA: radiofrequency analysis

Note

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