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Influence of Mucosal Thickness, Implant Dimensions and Stability in Cone Morse Implant Installed at Subcrestal Bone Level on the Peri-Implant Bone: A Prospective Clinical and Radiographic Study

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Abstract: The objective of this observational clinical study was to analyze the behavior of peri-implant tissues around cone Morse dental implants installed in the subcrestal bone position considering different clinical variables: Mucosal thickness, implant diameter, and implant length. Thirty patients were selected and included in the present study. Initially the thickness of the mucosa was measured by periapical radiographic and clinically (after the mucosal displaced). According to the planning for each treatment, implants with different dimensions (in length and diameter) were selected and used. Periapical radiographs were obtained at different times: Immediate postoperative (time t1) and 90 days after implantation (time t2). The initial stability of the implants (ISQ) was measured immediately of the implant insertion and 90 days after. The means and standard deviations of the ISQ values were in time t1 was 63.2 ± 6.99 (95% confidence interval (CI): 41 to 83) and in time t2 was 69.7 ± 7.09 (95% CI: 61 to 87). Overall mean of mesial and distal bone loss 90 days after the implantations were 1.11 ± 1.16 mm and 1.11 ± 1.15 mm, respectively. When the variables were considered, in all situations proposed, the bone loss showed differences statistically significant. In conclusion, the implant diameter and mucosal thickness variables showed an important effect on bone loss values. However, the implant length did not show an effect on the peri-implant behavior.

Keywords: crestal bone; cone Morse implants; mucosal thickness; implant dimensions; resonance frequency analysis

1. Introduction

Implantology as a surgical procedure implies the management of a wound involving the soft and hard tissues. After the implant osseointegration, the bone and the mucosa required by its new function of protection of underlying peri-implant structures, is transformed into the peri-implantar mucosa acquiring particular morphological characteristics. For this new sealing function, the epithelial and connective tissues require an appropriate dimension, and if it does not exist it will be created at the expense of bone resorption. Berglund and Lindhe [1] carried out a study with the purpose of confirming this concept, where thinning the tissues also proves that the conformation of the seal requires a minimal mucosal dimension, otherwise it would be created at the expense of bone resorption.

In this way, the biology demands a dimension of minimal epithelial and connective tissue adequate for the protection of the underlying structures. In this sense, other authors begin to give importance to the mucosal thickness as a relevant factor independent of the aforementioned bone resorption, using in its clinical trials different types of technology in the area of the implant connection, noticing the inefficacy of these technologies in the control of crestal bone resorption when the mucosa shows little thickness [2–7].

In addition, other factors may affect the behavior of peri-implant tissues, such as: Microgap, micromovement, microtopography of the interface, repeated removal of the abutment, and the platform design (switching or no) [8–11]. Several studies carried out by our group demonstrated that Morse taper implants present a better condition and behavior when compared to implants of internal and external connection, referring to the factors previously described [12,13]. In this way, a recent important systematic review that was published about the performance of the Morse taper connection [14] showed evidence that this type of connection appeared to be superior in terms of bacterial sealing compared with the traditional ones emphasizing that no connection has a 100% bacterial sealing. Morse taper connection systems appear to be more resistant to abutment movement and increased under load space compared to internal and external hexagon implants [15]. Moreover, the Morse taper connection have greater resistance to torque loss than other connection models [16]. This system seems to have less tension on the abutment screw, the cone compensates for the high stresses and protects the screw from overload [17].

Marginal bone stability around dental implants has always been considered one of the main criteria for defining implant success [18]. Then, with the current advancements and new technologies in implant dentistry, we should strive both for bone loss close to zero and to seek out variables that cause higher or lower rates of resorption. Albrektsson et al. reported that the extensive bone resorption after the first year is generally due to an exacerbation of adverse body reactions caused by non-optimal implant components, adverse surgery or prosthodontics, and/or compromised patient factors [19]. In a recent review study of the evidence regarding marginal bone loss around dental implants, Sasada and Cochran concluded that there is a strong indication that contaminated implant-abutment connections may have an effect on peri-implantitis and failure over time [20].

Although the in vitro results show better results in implants of conical internal connection and in vivo results with lower marginal bone loss, all models show comparable rates in terms of implant success and survival. However, these Morse tapered implants need to be evaluated for their clinical behavior in relation to peri-implant tissues, as many manufacturers recommend their infra-osseous installation without explaining the need for this procedure. In this sense, the aim of the present study was to evaluate the clinical performance of an implant with Morse taper connection (submerged 2 mm infra-osseous) and comparing different clinical variables (mucosal thickness, implant dimensions, and implant stability) with the marginal bone behavior. It was hypothesized that mucosal thickness plays a fundamental role in the maintenance of peri-implant bone and soft tissues.

2. Material and Methods

2.1. Patient Population and Research Design

For the present study, patients aged between 20 to 63 years, that needed replacement of missing teeth in the posterior region of the mandible with adequate condition of remaining bone (height ≥10 mm and width ≥6 mm) and adequate prosthetic space to rehabilitation, were selected in a private clinic (Montevideo, Uruguay). A total of 30 patients, 18 women and 12 men, were consecutively included. All patients signed a written Helsinki informed consent for participation and permission to use the data obtained for research purposes prior to the procedures. The general health condition stability of the participants in the study was considered and their ability to withstand surgery to install the planned implants. Patients with systemic alterations (diabetes, hypertension, or osteoporosis) or local changes (oral pathology in soft or hard tissues, bruxism, and smoking) were excluded from this study.

In addition, patients with uncontrolled and/or untreated periodontal disease, lack of adequate bone tissue for implant insertion, and/or presence of inflammatory events were not included in the study.

Sixty dental implants of conical macro design with cone Morse connection manufactured in grade IV titanium (Implacil De Bortoli, São Paulo, Brazil) were used in the implantations. The implants dimensions used were 3.5 and 4 mm in diameter and 7, 9, and 11 mm in length. Moreover, five implants were used to the surface analysis. The Figure 1 show a representative image of the macro design and the connection characteristics of the implant used in the present study.

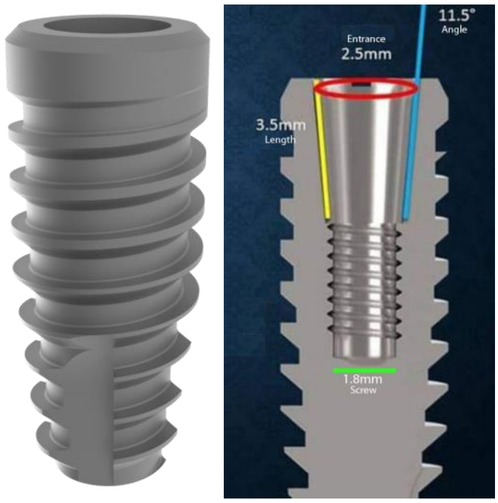

Figure 1. Representative image of the macro design and the connection characteristics of the implants used in the study, respectively.

2.2. Dental Implant Surface Topography

All implants are treated with sandblasted acid-etched surface technology as previously described by Gehrke et al. [21]. The implants were blasted with 50–100 µm TiO_2 microparticles and, following, the surface was ultrasonically cleaned with an alkaline solution, washed in distilled water, and pickled with maleic acid ($HO_2CCHCHCO_2H$). After these treatments, five implants were used to evaluate the surface characteristics by scanning electron microscopy (SEM, model JSM 5200, JEOL Ltd., Tokyo, Japan) and the roughness parameters, which was measured on the profilometer (Perthometer S2, Mahr GmbH, Göttingen, Germany), where Ra is the absolute value of all profile points, and Rz is the value of the absolute heights of the five highest peaks and the depths of the five deepest valleys.

2.3. Surgical Procedure of Implant Placement

All procedures (pre, trans, and postoperative) were performed by two specialists in implantology (MB and JGA). In all patients, mucosal thickness was measured at the local determined for implant installation through a periapical X-ray images. The measurement of the mesio-distal diameter of clinical crown of the tooth adjacent to the place where the implant will be installed was used to calibrate the program. The surgical procedures routinely used to install dental implants were applied. Surgical guides were prepared and used for the installation of all implants. All patients were given antibiotic premedication that was administered orally (2 g of Amoxicillin, 2 h before surgery) and continued in the postoperative for another five days (500 mg every 8 h). After the application of local anesthesia using Articaine 2% (DFL Ltd.a, Rio de Janeiro, Brazil), an incision was performed in the central area of the mucosal crest, and only the buccal flap was displaced, keeping the lingual mucosa in position for the proper measurement of its clinical thickness. The mucosa thickness was measured using a periodontal probe (Hu-Friedy, Chicago, IL, USA), from the crestal bone to the more apical area of the mucosa. Then, the lingual flap was raised, and the implant procedures were performed in accordance to the manufacturer's instructions.

The dimensions of the implants were previously determined during the planning of each case. For osteotomies, a Driller BLM600 motor and a counter angle with a 20:1 reduction (Driller, São Paulo, Brazil) was used under intense external irrigation with 0.9% saline solution. All implants were positioned 2 ± 0.2 mm subcrestally. All sutures were performed using simple point with Nylon 5-0 (Ethicon US, Bridgewater, NJ, USA). For the post-operative pain and inflammation control was administrated Cetoprofeno (200 mg/day) for four days plus paracetamol (750 mg, in case of pain). Ninety days after performing the surgery for the installation of the implants, the rehabilitation procedures were started.

2.4. Clinical Stability and Radiographic Evaluations

The stability of all implants was evaluated by resonance frequency immediately after the installation (t1) and 90 days (t2) in the reentry surgery to install the healing abutment. This evaluation was performed using the Ostell^{TM} Mentor (Integration Diagnostics AB, Goteborg, Sweden) plus the Smartpeg^{TM} (Integration Diagnostics AB) devices. Smartpeg sensors were installed in each implant using a controlled torque of 10 Ncm, as recommended by a recent study [22]. A mean was performed with the values obtained in the measurements in the vestibule-lingual direction (V-L) and mesio-distal direction (M-D).

Three periapical radiographies were made for each patient to measure the mucosa thickness (before implant placement) and the marginal bone loss (immediately after the surgery and 90 days later). Parallel profile radiography using a digital ring holder was used to standardize the analysis and decrease the image distortions. The relation between the implant platform and the crestal bone position was measured. All radiographic measurements were performed using the ImageJ software for Windows (developed at the U.S. National Institutes of Health and available at http://rsb.info.nih.gov/ij). In the first radiography the mucosa width was measured and compared with the clinical measurements. Then, the implants were grouped according to the measured thickness of the mucosa in each implant: Patients with mucosal thickness (MT) between 1.0 and 2.0 mm (MT1); mucosal thickness between 2.1 and 3.0 mm (MT2); and, mucosal thickness more 3.1 mm (MT3). In the radiographs post-implantation, the cortical bone level to the platform was measured and recorded at the mesial-marginal bone loss (m-MBL) and distal-marginal bone loss (d-MBL) side of each implant.

2.5. Statistical Analyses

The methodology and statistical data analyses were reviewed by an independent statistician. The outcomes were longitudinally analyzed among the two initial stability of the implants (ISQ) tests and the bone level between the variables using the one-way analysis of variance (ANOVA) test for repeated measures. The comparison between the clinical and radiographic measurements was performed using the z-test for unpaired samples. The Kolmogorov-Smirnov normality test and the Levene's homogeneity of variance test were used. For bivariate analysis, Mann-Whitney U, and Students-t tests were used. Repeated-measures ANOVA was used to analyze the reduction in marginal bone loss. All comparison analysis was performed using GraphPad Prism 5 software for Windows (GraphPad Software, San Diego, CA, USA). The level of significance was set at $\alpha = 0.05$.

3. Results

The mean and standard deviation of the absolute values of all profile points (Ra) was 0.87 ± 0.14 µm, the root-mean-square of the values of all points (Rq) was 1.12 ± 0.18 µm, and the average value of the absolute heights of the five highest peaks and the depths of the five deepest valleys (Rz) was 5.14 ± 0.69 µm. In the Figure 2 are showed the implant macro design and the surface images of the morphology.

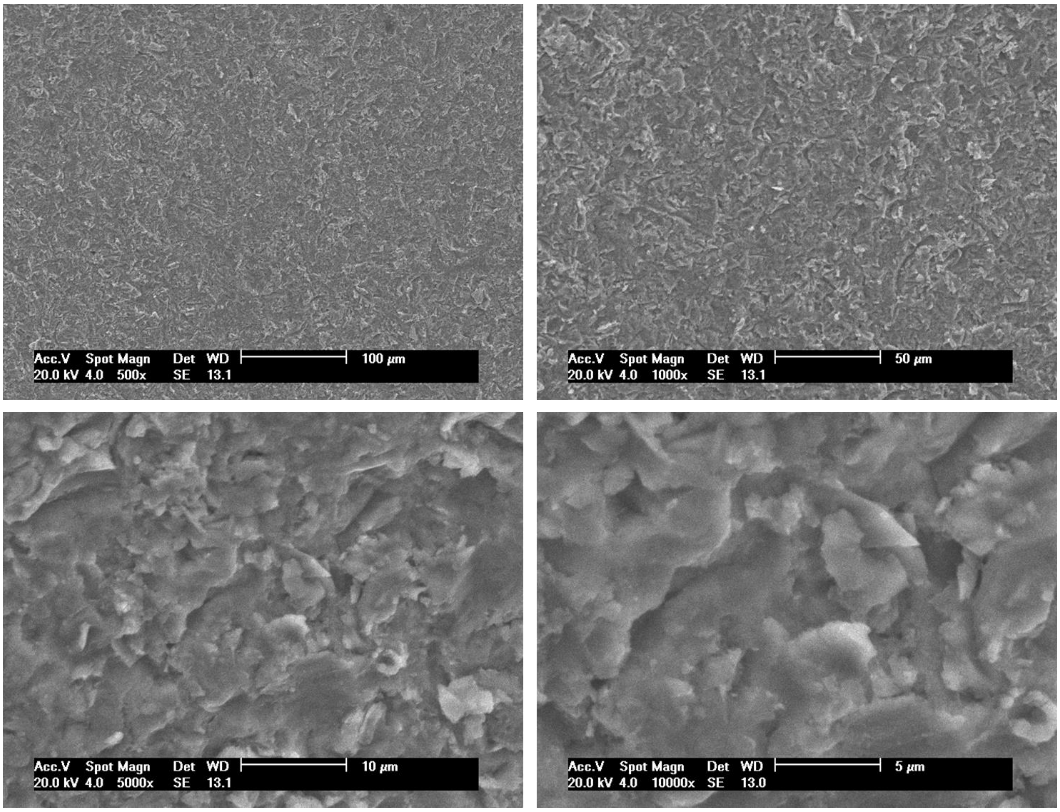

Figure 2. SEM images of the implant surface in different increases.

A total of 60 conical implants of Morse taper connections were installed and the evaluated variables were the diameter of 3.5 mm (n = 17) and 4 mm (n = 43), the different lengths that ranged from 7 mm (n = 21), 9 mm (n = 24), and 11 mm (n = 15) and the mucosa thickness MT1 (n = 19), MT2 (n = 24), and MT3 (n = 17). Thirty patients (18 women and 12 men; ages from 20 to 63 years) received dental implants. After the initial period of 90 days, only one implant was loose throughout the study period and re-implanted with success. Then, the analysis was performed with a total implant quantity (60 implants). No patient dropout was observed during the observation period.

The analyses between the radiographic and clinical measurements showed similar values for the mucosal thickness, no presenting statistical differences ($p = 0.634$), with a mean and standard deviation of 2.26 ± 0.72 and 2.34 ± 1.27, for clinical and radiographic measurements, respectively. The Figure 3 show a box plots graph to compare the measured values and the Figure 4 shows the clinical and radiographic representative image of these measurements.

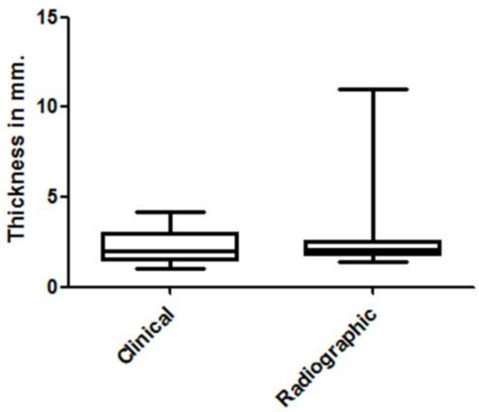

Figure 3. Box-plots graph of the values measured clinical and radiographically.

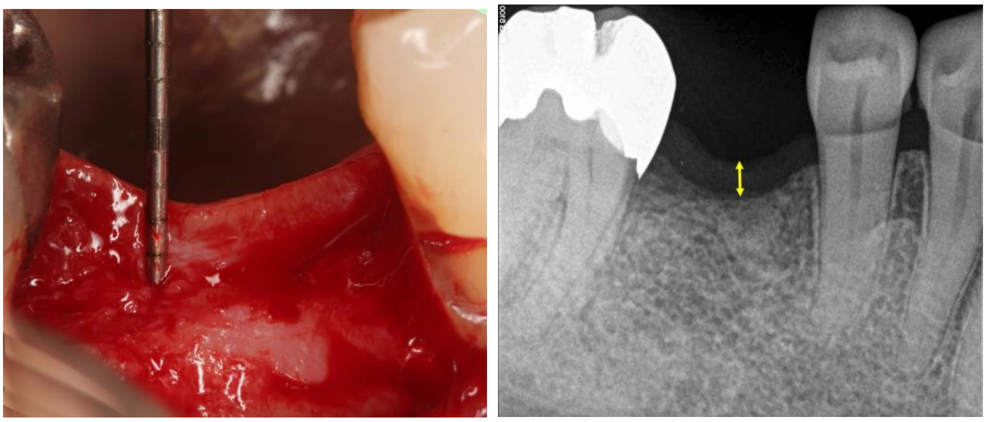

Figure 4. Representative clinical image of the mucosal thickness measurement after the mucosal flap and a periapical x-ray image of the mucosal measurement.

The measured ISQ values showed an overall mean and standard deviation in each proposed time as following: In time t1 was 63.6 ± 2.90 (95% CI: 53 to 70) and in t2 was 69.0 ± 4.14 (95% CI: 49 to 75). The values (mean, SD, and median) are summarized in the Table 1. Figure 5 showed a box-plots graph of the ISQ evolution in each time. No statistical difference of ISQ was observed regarding the implant diameter and length ($p > 0.05$). However, comparing the values of t1 versus t2, an expected statistical difference was found ($p < 0.0001$).

Table 1. Initial stability of the implants (ISQ) analysis and measurements at initial day (baseline) and 90 days after the implant installation. Results as mean and medians.

ISQ Value	Baseline		90 Days	
	Mean ± SD	**Median**	**Mean ± SD**	**Median**
Mesio-distal	63.4 ± 2.94	63.75	68.0 ± 3.85	69.53
Vestibule-lingual	63.7 ± 2.89	64.45	69.9 ± 4.14	70.80

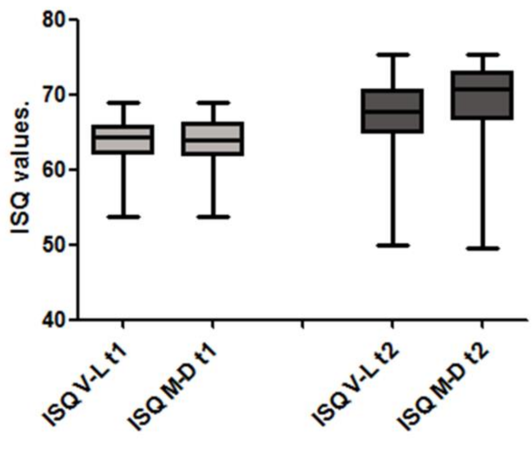

Figure 5. Box-plots graph of the ISQ measured values in the time 1 (t1) and time 2 (t2). V-L = vestibule-lingual direction and M-D = mesio-distal direction.

The comparative data measured between mesial and distal marginal bone loss with the observed variables. Overall mean of mesial and distal MBL were 1.11 ± 1.16 mm and 1.11 ± 1.15 mm, respectively, resulted in non-statistically significant differences ($p > 0.05$). The comparison of the bone loss between the patient's sex showed non-statistically significant differences ($p > 0.05$), where the woman patient's show an MBL mean value of 1.1 ± 1.25 mm and the man patient´s 1.0 ± 0.93 mm. The images of the Figure 6 show a sequence of measurements of the MBL.

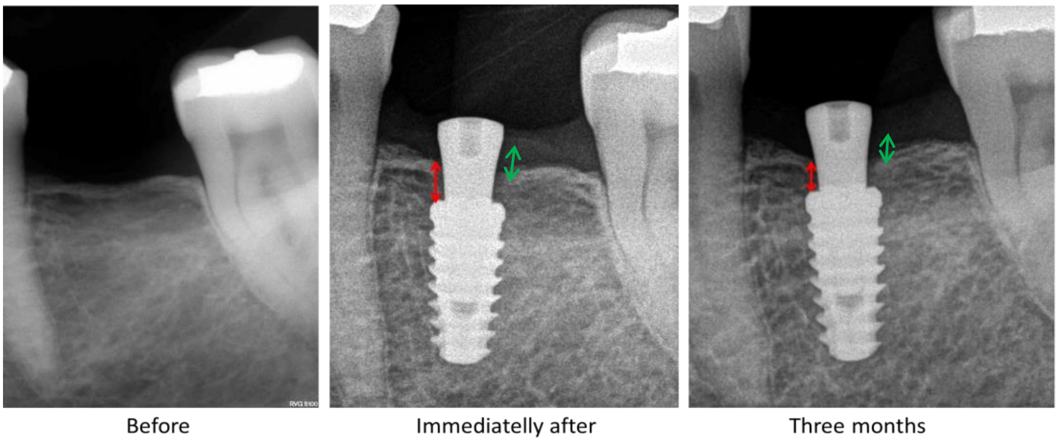

Figure 6. Radiograph sequence used to evaluate and measure the bone level. The measurements were performed from the implant platform to the crestal bone (red arrows = m-MBL and green arrows = d-MBL).

Regarding the implant dimensions, the diameter showed a mean value of MBL in 0.73 ± 0.8 mm for the implants of 3.5 mm and 1.05 ± 1.1 mm for the implant of 4.0 mm, with significant statistical difference ($p < 0.001$). The bar graph of the Figure 7 shows the values of mesial and distal MBL measurements.

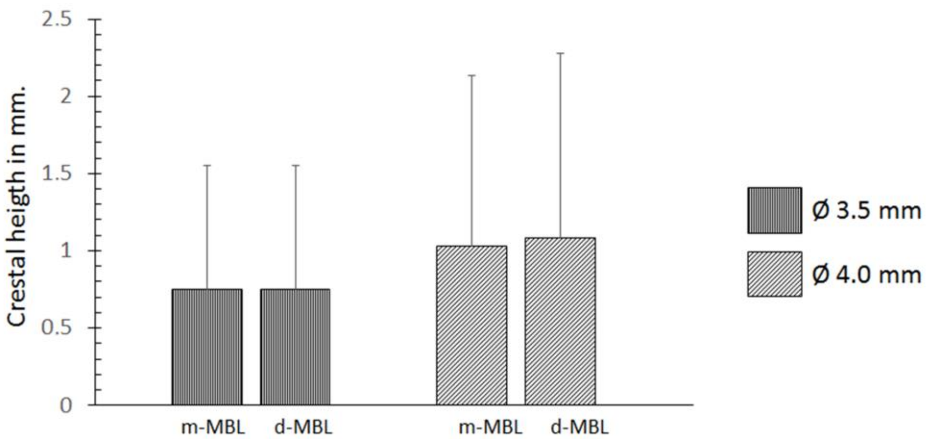

Figure 7. Bar graph showing the mean and standard deviation of the MBL values measured in mesial (m-MBL) and distal (d-MBL) position of each implant in the two implant diameters.

However, the MBL values measured at different implant lengths showed very similar values (Figure 8), without statistically significant differences ($p > 0.05$).

The mucosal thickness (MT1, MT2, and MT3) resulted in statistically significant differences ($p < 0.05$). The mean value of MBL in the MT1 was 1.5 ± 0.8 mm, in the MT2 was 0.75 ± 0.5 and in the MT3 was 0.9 ± 0.8 mm. The bar graph of the Figure 9 shows the values for mesial and distal measurements. In general, the better behavior was observed in the MT2 (mucosal thickness between 2.1 and 3.0 mm), with 0.7 ± 0.6 mm for m-MBL and 0.8 ± 0.5 mm for d-MBL.

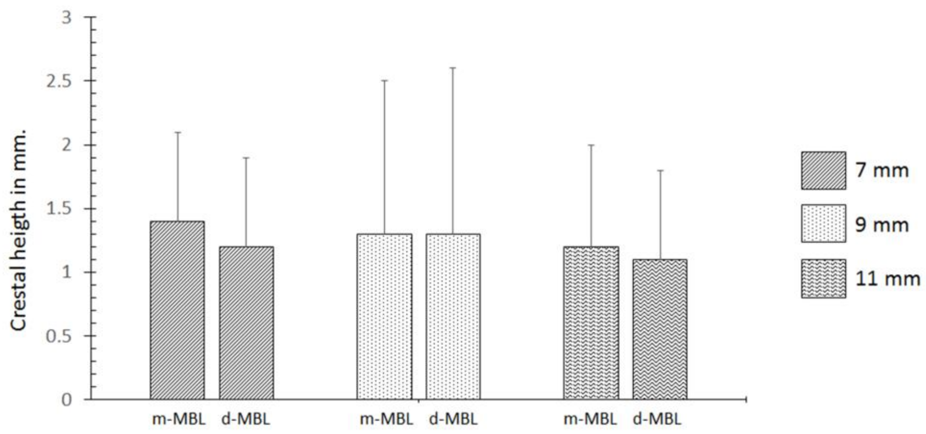

Figure 8. Bar graph showing the mean and standard deviation of the MBL values measured in mesial (m-MBL) and distal (d-MBL) position of each implant in the three implant lengths used.

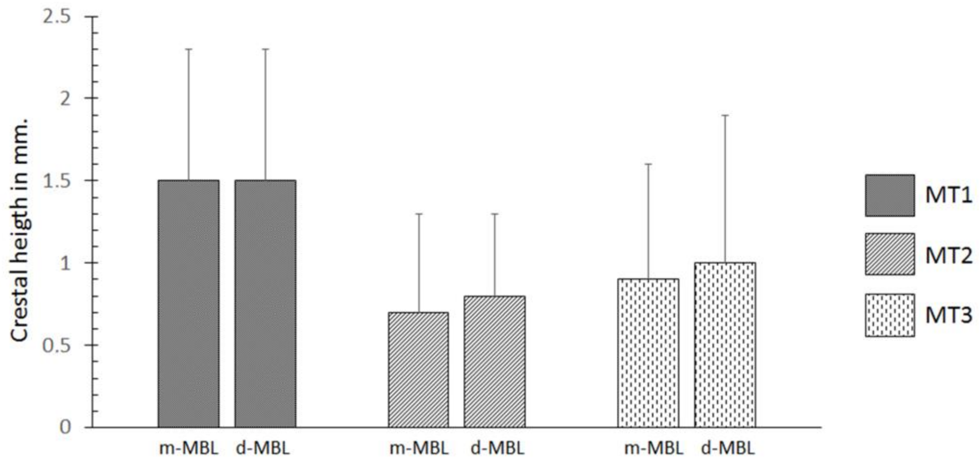

Figure 9. Bar graph showing the mean and standard deviation of the MBL values measured in mesial (m-MBL) and distal (d-MBL) position of each implant in the three mucosal thickness.

4. Discussion

This clinical study describes an analysis the marginal bone behavior considering of different variables after the implants installed in the posterior area of mandible: Patient sex, implant dimensions (diameter and length), and mucosa thickness. One implant was loose throughout the study period and re-implanted, and the survival rate of dental implants considered was of 98.3%. This study was made without patient selection, the only criterion was the posterior inferior region selection, this makes a random distribution of the ridges with the difficulty of achieving uniformity in the height and width of the ridge and the trouble of achieving the 2 mm of supracrestal bone in all cases, as well as having bone in around the 100% of the perimeter, simply because of the anatomy of the area. These could be factors that may affect the mucosal position and the behavior around the implant.

All implants measured the mucosa thickness on the radiographic images and compared with the clinical measurements, and the results confirmed no statistical differences among these collected data. Then, the measurement of the mucosa in radiographic images can be used for planification of the implant position (depth position). Therefore, the ISQ and the bone height in relation of the implant platform were measured immediately after the implant placement (baseline) and after 90 days. The relation of the marginal bone behavior and the variables with significant statistical differences are discussed separately follow.

Surface topography refers to the degree of surface roughness and the orientation of surface irregularities, which can directly stimulate osseointegration, increasing and/or accelerating the events involved in this process [8,21]. In this sense, we use implants with a surface roughness considered moderate, similar to that used by many other brands of implants. This data is important so that in future studies researchers can compare their results or reproduce in new investigations. In addition, since stability measurements were taken 90 days after implantation, the results are directly affected by the type of surface used in the implants.

4.1. Initial Implant Stability

The initial stability of the implants, a measure that can be represented by ISQ, is of fundamental importance for osseointegration. Several studies describe a direct relationship between bone density and measured ISQ values [23–27]. Both the thickness of the cortical bone and the pattern presented by the medullary portion (trabecular), which are in contact with the installed implant, are determinant factors for stability (bone and implant contact) [28]. The aim of this study was to observe the consequences of the placing Morse taper implants subcrestally and the relation between bone remodeling and soft tissue thickness. The initial results in these three months of studies show that the sectors in which the mucosal thickness was 1 to 2 mm suffered greater bone remodelation compared to the sectors where the width of the soft tissue was 2 mm or more.

The clinical methods that are commonly used to verify implant stability and osseointegration include percussion, mobility, and radiographic studies. However, these methods have an important limitation in their standardization, since they have a great dependence on the sensitivity and susceptibility with respect to the professional executor [29,30]. In this sense, more precise and non-invasive techniques were developed. These analyzes are called according to the method by which they are performed, i.e., resonance frequency analysis (RFA), and are used to verify and measure the stability of implants installed in bone tissue at different clinical periods [30,31]. The use of this technique is mainly based on being easy to perform, fast, and direct and, moreover, can be applied routinely in the clinic because it does not present discomfort to the patient.

The measured values of ISQ varied during the phases of osseointegration evaluated. At the trans-operative time, the mean and standard deviations of the ISQ values measured was 63.6 ± 2.90 varying of 53 to 70, indicating adequate primary stability, similar to the results reported in other studies that presented averages from 60.3 to 62.6 [31–34]. While, in the second time measured, 90 days after the implantations, the means and standard deviations of the ISQ values was 69.7 ± 7.09 varying of 49 to 75. Such overall result for the ISQ values for the time of 90 days are within the mean values shown in several similar studies, where the values varied from 67.0 to 72.1 [31,32,35,36].

4.2. Mucosal Thickness

Linkevicius and colleagues studied the main factors related with the bone remodeling [2,3], understanding and trying to make a relation between mechanic factors and mucosal thickness. Isolating the connection factor even when this was 2 mm supracrestal and the mucosa was thin, there was bone remodeling consequence of the biological width formation [2]. Using implants with platform switching concept did not prevent the bone remodeling also when the mucosal thickness shows little thickness [3,4]. The use of Morse-cone implants for this study is based on the minimal number of microorganisms penetrating the implant/abutment microgap as well as the absence of movement [37]. This rigid type of connection eliminates a potential remodeling bone factor and with the subcrestal position opens a new way in which the biologic width can be conformed [37–40]. Studies showed the possibility of having no bone remodeling reaction at the abutment-implant interface and making a new configuration of the biological space and the mucosa characteristics surrounding the implant [41–44].

The results are in agreement with the studies mentioned previously, although in our study the evaluation time was less than one year, the first case (MT1), where the mucosa was between 1 and 2 mm, suffered much more bone loss than de MT2 and MT3 where the mucosal width was two or more millimeters. The group MT2 and MT3 had very similar measures in respect of bone remodeling. However, the MT3 not show superior behavior in comparison with the MT1 and MT2, possibly because in this group the biological space exceeded the value considered ideal for the position of implant-abutment junction (IAJ). Conversely, controversial information is available regarding implants placed subcrestally. Some authors recommended placement of the implant platform 1 or 2 mm below the alveolar crest to better maintain marginal bone levels [45,46]. However, other studies reported an increased extension of inflammatory infiltrate due to deep positioning of the IAJ, resulting in greater MBL compared to implants placed equicrestally [47,48]. In the case of implants with mucosal thickness 3 mm (MT3), added to 2 mm positioning subcrestal implants, the final positioning distance of the AIJ was greater than 5 mm, which probably explains the behavior of the implants in this condition.

Clinically the time bone loss around implants can influence the planned aesthetic results, mainly because it alters the final positioning of the tissue because its final volume decreased.

4.3. Implant Dimensions (Diameter and Length)

Several studies showed that the implant dimensions have direct influence on the stress distribution to the bone [41–45] as the implant directly affects the area of possible bone retention [49]. Moreover, other authors have advocated the use of implants as long and wide as possible [50]. However, when bone loss around the implants was evaluated, there is a controversy regarding the influence of length in these alterations, and some studies present results of larger losses in the short implants, other authors report that the length of the implant has little influence on the quantity of vertical load stress, and may have a lower effect on the distribution of stresses to bone tissue when compared to the variation in implant diameter [49,51]. In this way, Koutouzis and collaborates not found statistical difference in the values of bone resorption in larger diameter implants, comparing small diameter (3.5 mm) with larger diameter (4.5 mm) [52]. Unlike most of the cited reports, an important fact that the research revealed was the better behavior of the 3.5 mm implants when compared to the 4.0 mm diameter implants in terms of bone remodeling, that is, the smaller implants diameters showed lower bone resorption. On the other hand, when the implants were compared in terms of length (7, 9, and 11 mm), the results obtained in the present study did not present statistical differences, with very similar values among the sizes used. However, in the present study the implants evaluated were not placed under masticatory loads, which may be the reason for the difference in results between the studies. Previous FEA studies have shown that a decrease in diameter increases the stress transferred to crestal bone [53].

5. Conclusions

Within the limitations of this prospective study, although in our study the evaluation time was short after the implantation, we concluded that cone Morse implants placed 2 mm subcrestal level showed different values of bone loss depending of the mucosal thickness and implant diameter. However, the initial stability and implant length not showed influence on the marginal bone loss.

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Conflicts of Interest: The authors declare no conflict of interest.

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