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A Comparative Study of Two Resonance Frequency Analysis Instruments

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ABSTRACT

Primary implant stability (PIS) depends on the surgical technique, implant design, and the characteristics of the recipient bone, among other factors. This paper aims to study different parameters (recipient bone characteristics like bone density (BD) and mean alveolar crest width (MACW)) that may be related to implant primary stability outcomes. With that, it can be determined if they are reliable PIS methods and guide treatment decisions for successful implant outcomes. Thirty-five dental implants (25 BTI Interna® CORE and 10 Bioner Top DM) were placed in 10 patients in 2022 and 2023. All of them underwent Cone Beam Computed Tomography (CBCT) scans to obtain values for MACW and BD. PIS measurements used were implant stability quotient (ISQ) obtained through different resonance frequency analysis (RFA) methods (Osstell® ISQ and Penguin RFA®) and insertion torque (IT). The results for the following variables showed significance at $p<0.001$ and $p<0.05$. Highly significant relationships were observed between Osstell and Penguin RFA values ($p<0.001$). Regarding IT, a direct proportional relationship with ISQ was observed ($p<0.05$). PIS, as measured by ISQ and IT, did not show a significant correlation with the mean alveolar crest width of the edentulous ridge measured by CBCT, suggesting that wide or narrow alveolar crests did not have an effect on rotational or lateral PIS in both implant groups. The most significant predictor of lateral and rotational PIS in our patients was the Hounsfield Units (HU) value 0.5 mm away from the implant placement area ($p<0.001$) and ($p<0.05$), respectively. In conclusion, non-invasive PIS methods could be considered as a guide for clinicians in treatment decision-making and implant success. However, further research is needed to predict PIS.

Keywords

Implant primary stability, Resonance frequency analysis, Hounsfield units, Insertion torque, OSTELL, ISQ, Penguin, Bone density, Alveolar bone width.

Introduction

The replacement of teeth through implants is a predictable treatment with a high success rate. Currently, implant success is assessed based on aesthetic and mechanical-functional perspectives. Both aspects depend on the degree of implant osseointegration [1] that is in turn influenced by multiple factors such as the surgical technique, bone quality and the implant design. The term *osseointegration*, a concept coined by Professor Per Ingvar Brånemark in 1952 [2], refers to the direct, structural, and functional connection between the ordered, living bone, and the surface of a functionally loaded implant. Bone tissue undergoes constant remodeling to adapt to external stimuli, and implants must be designed to maximize favorable stress production at the implant-bone interface, as well as to provide better stability and increase the implant's contact surface area with the bone [3,4]. However, accurately assessing implant stability and osseointegration remains a challenge [1]. Implant stability refers to the control of micromovements at the bone-implant interface, which is a key factor in achieving and maintaining osseointegration [5]. Mechanical or primary stability results from a compressed bone that firmly holds the implant in place, providing initial resistance to micromovement immediately after implant placement [1,4], which is crucial for implant survival. Primary implant stability (PIS) is generally high immediately after implant placement, influenced by multiple patient-related factors [6] (e.g., bone quality and density [7]), operator-related factors (e.g., surgical technique), and implant-related factors (e.g., shape, length, and diameter). Biological or secondary stability results from new bone formation around the implant and integration of the implant into the bone [1,4]. This is the outcome of osseointegration, which generally increases over time. In other words, as a result of osseointegration, the initial mechanical stability is complemented and/or replaced by biological stability, and the final stability level for an implant is the sum of both types [1]. Therefore, since the concepts of osseointegration and implant stability are correlated, different approaches have been sought to evaluate the degree of implant osseointegration and determine the optimal timing for loading implants to maximize success rates [1]. In general, high PIS indicates increased bone growth around the implant, improving its survival. However, there is currently no consensus on the most appropriate method for evaluating PIS [7-9], leading to various invasive and non-invasive methods for its quantification [10].

Among the non-invasive methods, rotational stability analysis, also known as insertion torque (IT), is used. IT is defined as the torque or measure of the force capacity required to rotate a body (in this case, the implant) and is measured in Ncm. The maximum insertion torque of the implant represents the maximum force required at a certain point of insertion, which can vary based on the implant's geometry and bone quality. It provides a three-dimensional understanding of the amount of bone-implant contact during insertion. Implant insertion can be performed using manual instruments (torque wrenches) or electric instruments, with the latter typically having a maximum insertion torque between 50 and 70 Ncm [8,9,11].

Another non-invasive method of assessing stability is through Resonance Frequency Analysis (RFA) or lateral stability analysis. This method provides measurements of lateral micromobility in implants immediately after their insertion into the bone bed. Based on the studies by Meredith et al. [12], the company Osstell® developed a measurement scale called "Implant Stability Quotient" (ISQ), which allows us to assess implant stability. The ISQ measurement technique involves using a transducer screwed into the implant, which is magnetized (Smartpeg) and transmits stimulation to the implant through magnetic pulses from the electronic device. Each measurement provides two ISQ values, which refer to the difference in bone density surrounding the implant [1]. Based on these measurements, a mean value is obtained on the ISQ scale, ranging from 0 to 100. Clinical decision-making regarding the loading of a final restoration should be made after measuring ISQ. Various devices are available, such as Osstell ISQ® (Osstell, Gothenburg, Sweden) and Penguin RFA® (Integration Diagnostics, Gothenburg, Sweden) [12]. Generally, stability does not remain constant in the immediate period after implant placement. For example, there may be an initial decrease in stability followed by a subsequent increase as the implant osseointegrates. Osseointegration begins to occur a couple of weeks after implant placement and can be measured during patient follow-up visits. This ensures that the stability level is sufficiently high before loading the implant with the final restoration [1]. The IT is also related to the surgical technique and influences PIS. There is also a correlation between PIS and bone quality and distribution. In fact, higher success rates have been demonstrated for implants placed in higher-density bone [13]. Bone density (BD) can be evaluated in Hounsfield units (HU) using conventional computed tomography (CT). Specifically, HU values have been found to correlate with BD according to the classifications by Misch [14] and Lekholm and Zarb [7,15]. Cone beam computed tomography (CBCT) images and interactive software provide the basis for proper diagnosis and treatment planning based on bone topography, cortical thickness, BD, and proximity to adjacent vital structures, but this method cannot determine PIS. However, the diagnostic and planning phase can objectively estimate whether an implant will be stable within the bone [16]. The quantitative scale developed by Godfrey Newbold Hounsfield to describe radiodensity measured using CT has been adapted for use in CBCT studies, enabling BD assessment in HU [17]. This allows for three-dimensional treatment planning considering the patient's anatomy and visualization of the expected outcomes before surgery [18].

Objectives

1. To determine the significant correlation between the mean alveolar crest width (MACW) and preoperatively measured bone density in Hounsfield units using CBCT with the variables of PIS (IT, Osstell ISQ, and Penguin ISQ).
2. To determine if there is a correlation between ISQ measured with Osstell and ISQ measured with Penguin.
3. To determine if there is a direct relationship between the IT of different implants and their ISQ values.

Materials and Methods

Study Population

In this observational clinical study, patients from the continuous training dental center of the Official College of Dentists and Stomatologists of León were recruited, all providing informed consent. Variables such as temporomandibular dysfunction, masticatory parafunctions or bruxism, oral hygiene habits of each patient, cardiac diseases, or uncontrolled diseases were not considered. A conventional loading protocol for the implants was performed. The procedures were carried out between 2022 and 2023. As shown in Table 1, several variables have been described in relation to the 35 placed implants.

Dental Implants and Instruments

The surgeons used different diameters and lengths of two implant designs, namely BTI Interna® CORE and Bioner Top DM. The surgeons measured the insertion torque using the XO® OSSEO Implant Micromotor (Sweden&Martina S.p.A, Padua, Italy) calibrated by the manufacturer, and the final torque with the dynamometric wrench (Bioner LDR Dynamometric Ratchet Ncm 10 - 35 - ∞ and BTI LLMQ Dynamometric Ratchet Ncm 30- 70

- ∞). Data on ISQ values were collected using both the Osstell ISQ® Instrument (Osstell, Göteborg, Sweden) with SmartPegs™ Type 26 and 60 for BTI and Bioner implants, respectively, and the Penguin RFA® system (Integration Diagnostics, Göteborg, Sweden) with MultiUnig Type 43 and 38 for BTI and Bioner implants, respectively.

PIS: IT and ISQ

The final IT was determined using the dynamometric wrench, categorizing the results into the following groups: IT <30 Ncm, IT between 30 and 50 Ncm, IT >50 Ncm for BTI implants, and IT <20 Ncm, IT between 20 and 35 Ncm, IT >35 Ncm for Bioner implants. The ISQ value for each implant was recorded immediately after placement using the Osstell ISQ® transducer and the Penguin RFA® at a 90° angle to the axial axis of the SmartPeg and Multipeg, respectively, screwed into the BTI and Bioner implants. Two readings were taken: one with the device in the bucolingual direction (ISQ-BL) and another in the mesiodistal direction (ISQ-MD). An average value within the ISQ scale (ranging from 0 to 100) was obtained based on these measurements. The ISQ ranges from 0 to 100, with values below 60 indicating low stability, 60 to 69 indicating medium stability, and 70 indicating high stability (according to the implant manufacturer; https://www.osstell.com/guidelines/implant-stability-quotient-isq/).

Preoperative Radiological Assessment of Alveolar Ridge: BD and ACW

All patients underwent preoperative CBCT imaging (Carestream 9300, Carestream Health, Rochester, NY). The radiation dose was adjusted according to the patient's weight (591, 685, and 856 mGy/cm2 for patients weighing <60, 60-90, and >90 kg, respectively). BD and ACA were evaluated using the BTI Scan 3 software (BTI Biotechnology Institute SL, Miñano, Álava, Spain).

Preoperative Bone Characteristics: BD and ACW

A cross-sectional cut was obtained in the alveolar crest corresponding to the implant placement area. The chosen implant contour (from the BTI Scan 3 database) was superimposed on this cross-sectional cut with appropriate inclination. In all cases, the aim was to achieve implant positioning at a minimum distance of 1.5 mm from adjacent teeth and 1 mm below the bone crest. Then, three linear measurements (coronal, middle, and apical) were taken in mm perpendicular to the axial axis of the implant from the buccal to lingual cortical bone; but only the middle variable was used. Mean HU density values were obtained within the implant placement area and 0.5 mm outside this area.

Statistical Methods

IBM SPSS® Statistics for Windows version 25.0 (Armonk, NY) was used for statistical analysis. A p-value of $p<0.05$ was considered significant, and $p <0.001$ was considered highly significant, as indicated in the different result tables. Descriptive analysis was performed using frequency (n) and percentage (%) for qualitative data and mean (M), standard deviation (SD), or minimum and maximum for quantitative data. Contingency table analysis was conducted using appropriate statistical procedures for qualitative variables such as gender, smoker, implant placement site, IT, implant brand, bone type, anatomical zone, implant diameter, and length, as well as quantitative variables such as age, BD in HU, ISQ, and ACW for each pair of variables. Specifically, when one variable was quantitative and the other qualitative, a test of mean differences was used with effect size estimation using R2. When both variables were quantitative, a scatter plot and Pearson and Spearman correlation coefficients were used. Assistance from an independent statistician, external to our research group, was sought to design the statistical analysis.

Results

Study Population

During the years 2022 and 2023, 35 dental implants were placed by different surgeons at the Master of Oral Surgery, Implantology, and Periodontics at the University of León in patients with dental absences. There was a total of 10 patients (3 males and 7 females) ranging in age from 39 to 73 years (with a mean age of 56.94 years), of which 70% were non-smokers. Regarding bone type, it is worth mentioning that hard bone (types 1 and 2) is more common than soft bone (types 3, 4, and 5). The average bone density was 781.42 HU and 855.71 HU within and 0.5 mm outside the implant, respectively, in a mean bone width of 9.12 mm. Out of the 35 implants, a total of 10 were placed in posterior and 7 in anterior maxillary regions, 15 in posterior and 3 in anterior mandibular regions, considering the area between canines as anterior and the area from the first premolar to the first molar as posterior. Therefore, the majority of the implants were positioned in posterior sectors (Table 1).

Implant-related Variables

A total of 25 BTI Interna® CORE implants and 10 Bioner Top DM implants were used. The most commonly used implant had a standard diameter (3.75-4.25 mm), followed by narrow (3.3-3.5 mm), and lastly wide (4.5-6.5 mm). In terms of length, standard-sized implants (10-13 mm) were more frequently used than short ones (<8.5 mm).

Stability Variables: IT and ISQ

The mean values for BL (69.29 ± 7.38) and MD (70.29 ± 6.63) were obtained with the Osstell instrument, while the BL (70.94 ± 8.22) and MD (72.31 ± 8.22) values were obtained with the Penguin instrument. Notably, the data obtained by Penguin (144.03 ± 17.38) were slightly higher than those obtained by Osstell (139.57 ± 13.73) (Table 1). The comparison between the ISQ values obtained by the Osstell and Penguin systems was highly statistically significant ($p<0.001$) (Tables 2 and 3) (Figure 4). These differences may partially explain the correlation patterns mentioned below, particularly the finding that lateral stability correlations with BD were stronger for ISQ values obtained with the Penguin system than those obtained with the Osstell system (Tables 2 and 3).

Table 1*:* Descriptive table of the sample (N=10; n=35).

Variables related to the pateint		Mean (M)	Standard deviation (SD)
Age (Years)		56.94	11.69
HUs 0.5 mm ouside the implant		855.71	374.91
HUs inside the implant		781.42	391.84
Crestal width	**Coronal**	6.38	1.17
	Middle	9.12	1.85
	Apical	11.3	3.27
		Frequency (n)	**Percentage (%)**
Sex	Female	7	70
	Male	3	30
	Total	*10*	*100.0*
Smoker	*YES*	*3*	*30*
	NO	*7*	*70*
	Total	*10*	*100.0*
Type of bone inside	Hard (1 y 2)	20	57.1
	Soft (3,4 y 5)	15	42.9
	Total	*35*	*100.0*
Type of bone 0.5mm outside	Hard (1 y 2)	26	74.3
	Soft (3,4 y 5)	9	25.7
	Total	*35*	*100.0*
Anatomical zone	Anterior Maxilla	7	20
	Posterior Maxilla	10	28.55
	Anterior Mandible	3	8.55
	Posterior Mandible	15	42.9
	Total	*35*	*100.0*
Variables related to the implant		**Frequency (n)**	**Percentage (%)**
Brand	BTI	25	71.4
	Bioner	10	28.6
	Total	*35*	*100.0*
Diameter	Narrow (3.3-3.5mm)	15	42.9
	Standard (3.75-4.25mm)	19	54.3
	Ancho (4.5-6.5mm)	1	2.8
	Total	*35*	*100.0*
Length	Short <8.5 mm	9	25.7
	Standard 10-13mm	26	74.3
	Total	*35*	*100.0*
Stability variable		**Frequency (n)**	**Percentage (%)**
Torque (N) BTI	<30	0	0
	30-50	22	88
	>50	3	12
	Total	25	*100.0*
Torque (N) Bioner	*<20*	0	*0*
	20-35	2	*20*
	>35	8	*80*
	Total	10	*100.0*
		Mean (M)	**Standard deviation (SD)**
OSSTELL ISQ-BL		69.29	7.38
OSSTELL ISQ-MD		70.29	6.63
SUM OSSTELL ISQ		139.57	13.73
PENGUIN ISQ-BL		70.94	8.22
PENGUIN ISQ-MD		72.31	8.22
SUM PENGUIN ISQ		144.03	17.38

Table 2*:* Comparison of Pearson's Correlation degree between the OSSTELL ISQ value and other potentially associated quantitative variables.

	r	Valor-p
Middle bone width	-0,05519029	0.753
HUs 0.5 mm outside **	0,53534128	**0.00092**
HUs inside*	0,36259364	**0.0323**
Penguin ISQ**	0,66718779	**1.2e-05**

**. Mean difference is highly significant at the 0.001 level (bilateral).
*. Mean difference is significant at the 0.05 level (bilateral).

Table 3: Comparison of Pearson's Correlation degree between the PENGUIN ISQ value and other potentially associated quantitative variables.

	r	Valor-p
Middle bone width	0,18500101	0.287
HUs 0.5 mm outside **	0,59990269	**0.00014**
HUs inside*	0,41276089	**0.0137**
Osstell ISQ**	0,66718779	**1.2e-05**

**. Mean difference is highly significant at the 0.001 level (bilateral).
*. Mean difference is significant at the 0.05 level (bilateral).

A significant relationship ($p<0.05$) was observed between the two variables used to evaluate PIS: IT and ISQ (data obtained by both instruments), in BTI implants (Table 4). However, there was no significant correlation in Bioner implants (Table 5), which could be attributed to the small sample size of Bioner implants. Therefore, data from the IT intervals of both implant types were combined, revealing a significant correlation between IT and ISQ ($p<0.05$) (Table 6). It should be noted that the ISQ values obtained with the Penguin system showed a slightly stronger correlation with IT in all measured implants.

Table 4: Difference in means between BTI IT and other potentially associated quantitative variables.

	R^2	Valor-p
Middle bone width	0	0.387
HUs 0.5 mm outside *	0.145	**0.0343**
HUs inside	0.0415	0.167
Osstell ISQ*	0.264	**0.00509**
Penguin ISQ*	0.327	**0.00167**

*. Mean difference is significant at the 0.05 level (bilateral).

Table 5: Difference in means between Bioner IT and other potentially associated quantitative variables.

	R^2	Valor-p
Middle bone width	0	0.484
HUs 0.5 mm outside	0.0338	0.285
HUs inside	0	0.355
Osstell ISQ	0	0.665
Penguin ISQ	0.108	0.186

Table 6: Difference in means between BTI and Bioner IT and other potentially associated quantitative variables.

	R^2	Valor-p
Middle bone width	0.00967	0.325
HUs 0.5 mm outside*	0.119	**0.0497**
HUs inside	0.0397	0.198
Osstell ISQ*	0.196	**0.0115**
Penguin ISQ*	0.202	**0.0102**

*. Mean difference is significant at the 0.05 level (bilateral).

Our results demonstrate a statistically significant relationship between alveolar ridge bone density variables and PIS. Specifically, both IT and ISQ were associated with the HU value 0.5 mm outside the implant placement area, with the correlation with ISQ (both Osstell and Penguin) being highly significant (p<0.001) (Table 2) (Figure 3), and with IT being significant (p<0.05) (Table 6). It is worth mentioning that ISQ had a significant correlation (p<0.05) with the HU value within the implant placement area (Table 2) (Figure 2), whereas IT did not show a significant correlation with these values (Table 6). Therefore, the variable with the most significance in predicting lateral and rotational PIS of these implants was the HU value 0.5 mm outside the implant placement area.

Furthermore, the results showed no significant relationship between mean crestal cortical bone thickness and IT or ISQ, indicating that wide or narrow alveolar crests had no effect on rotational or lateral PIS in both implant groups (Tables 2, 3, and 6) (Figure 1).

Discussion

In this study, using CBCT, we found that PIS values were positively correlated with the available bone density in the edentulous alveolar ridge. Additionally, the best variable lateral and rotational PIS of these implants was the HU value 0.5 mm outside the implant placement area. Bayarchimeg et al. [19] showed that their study results had increasing IT and initial stability with increasing bone density, resulting in a strong positive correlation.

In a clinical study by Turkyilmaz et al. [20], the authors found a strong relationship between bone density and ISQ values. There is considerable evidence that BD determines PIS. This relationship has been previously studied, and BD has been quantified in various ways, either subjectively (tactile sensation of bone resistance during drilling) or objectively (radiological studies), with human research quantifying BD in HU using CT or CBCT. Regarding the use of CBCT, Arisan et al. [21] found a significant relationship between HU values and PIS values in a sample of 108 implants. An important conclusion of that study was that densitometric measurements made with CBCT are reliable and comparable to those made with CT scanners when devices are properly calibrated. In relation to this, Sennerby et al. [22] validated a CBCT system and found that BD 1 mm outside the implant placement area was strongly associated with ISQ and IT. The study by Elio Oliveros et al. [23] adds to the body of evidence on the use of CBCT to evaluate BD prior to implant placement. Specifically, our results indicate that the use of a calibrated CBCT system is reliable for densitometric measurements and studying their relationships with PIS variables. In accordance with the results of Arisan et al. [21] and Sennerby et al. [22], we found that the periphery of the implant placement area is the most interesting area to study the effect of BD on PIS. A reasonable explanation is that PIS is determined by the bone surrounding the implant, not the bone originally present in the area where the implant is to be placed.

In our analysis, it is worth mentioning that ISQ has a significant correlation (p < 0.05) with the HU value inside the implant placement area, unlike IT, which did not show a significant correlation with these values. Nevertheless, a study by Fuster-Torres et al. [24] obtained significant results only in the anteromandibular region, relating CBCT-based HU values within the implant placement area to IT (p < 0.05) and DO values with ISQ only in men (p < 0.05).

Neither ISQ nor IT showed a significant association with MACW, unlike the studies by Elio Oliveros et al. [23,25] indicating that ISQ values, but not IT, were significantly associated with ACW in coronal, middle, and apical areas. They also mentioned that narrow alveolar crests were associated with significantly higher BD values (Type 1), as expected due to the proximity of the vestibular and lingual/palatal cortices, while wide crests were associated with lower BD values (Type 4) and containing a larger volume of cancellous bone than narrower crests. These results contrast with the present study, in which the size of the alveolar crests did not have an effect on rotational or lateral PIS in both groups of implants obtained. Crestal bone properties are crucial in achieving PIS, but we did not find scientific evidence in the literature demonstrating a relationship between overall ACW and PIS.

In our analysis, our results showed a strong direct association (p < 0.001) between IT and ISQ variables when recorded with both measurement devices in both measurement directions. It is important to note that rotational and lateral PIS are different concepts, but both are affected by the same conditions and determine the success of implant osseointegration. This is also reflected in recent studies by Elio Oliveros et al. [23] and Brouwer et al. [26] Additionally, Gomez-Polo et al. [27] indicate that higher IT values are associated with higher primary ISQ.

A study by Baldi et al. [28] concluded that the specific tested implant presented a positive linear correlation between PIS and IT up to 50N/cm, supporting that higher torque values can cause unnecessary stress to the bone-implant system without additional benefits in terms of stability. This observation is comparable to the findings of a recently published clinical study by Markovic et al. [29] or McCollough et al. [30] and Lages FS y cols. [31] which concluded that IT and ISQ variables are independent and incompatible methods for measuring the primary stability of dental implants, so these two parameters should be evaluated independently [32,33].

Finally, it should be mentioned that in our study, the two RFA instruments were highly correlated (p<0.001). This observation

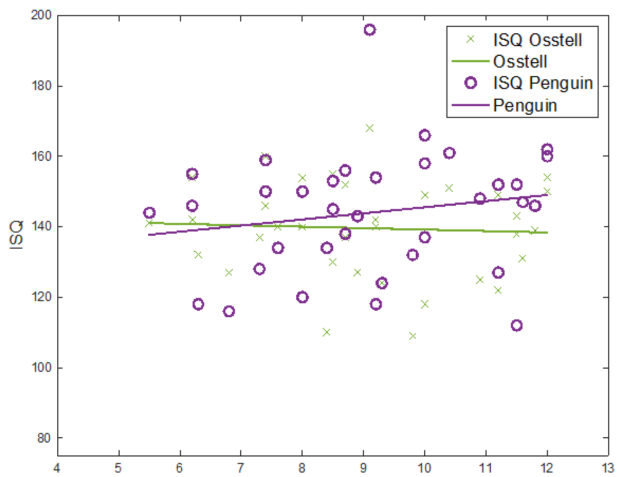

Figure 1: Correlation between Penguin and Osstell ISQ and middle bone width.

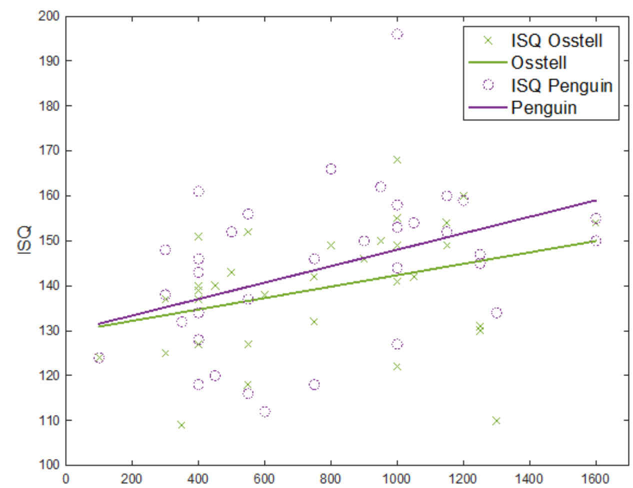

Figure 2*:* Correlation between Penguin and Osstell ISQ and HU within the implant.

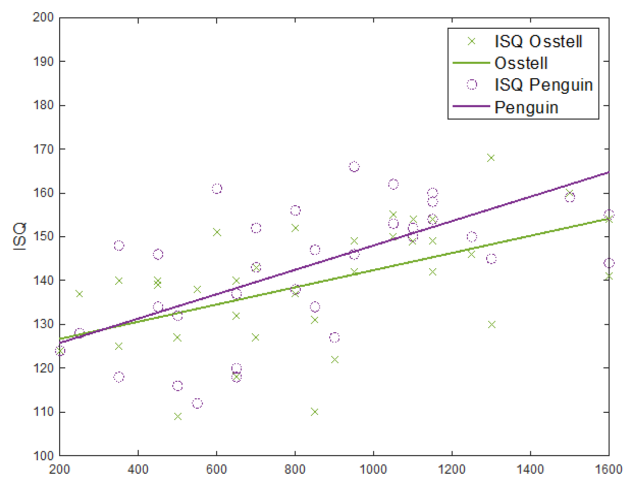

Figure 3*:* Correlation between Penguin and Osstell ISQ and HU at 0,5mm outside the implant.

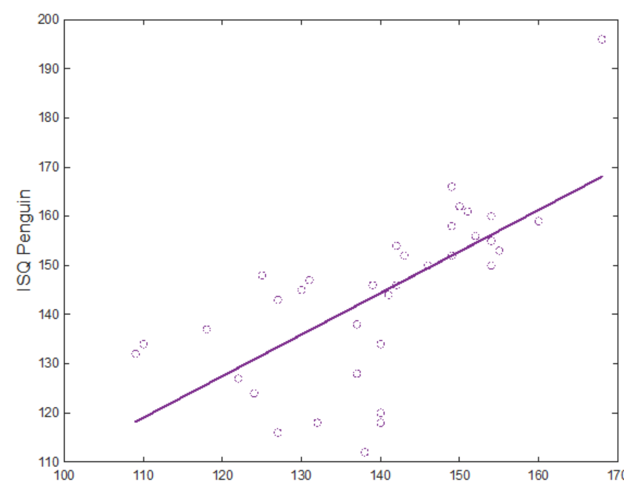

Figure 4: Correlation between Penguin and Osstell ISQ.

is in line with the findings of other clinical research such as Elio Oliveros et al. [25] and Brouwers et al. [26], which revealed no significant difference between RFA values when recorded in two different directions and with two different measurement devices, as well as Herrero-Climent et al. [34] However, it contradicts certain observations in the studies by Bural et al. [35] and Norton et al. [36], revealing significant differences between measurements using the Osstell and Penguin devices. Additionally, it is worth noting that both devices have functional differences in terms of handling and sustainability from a clinical standpoint, so these controversial results remain inconclusive and should be the subject of future research. Our findings support the application of both measurement devices as reliable and useful tools for determining implant stability, concluding that the data obtained with Penguin were slightly higher than Osstell. This is also shown in the studies by Becker et al. [37] and Norton et al. [38], who obtained marginally higher values with the Penguin system than with the Osstell system and commented that the Penguin system was slightly easier to use. This finding contrasts with the results of Elio Oliveros et al. [25], where the ISQ values obtained with the Penguin system were slightly lower than those of the Osstell ISQ instrument.

We acknowledge that there are several limitations in our study

1. The significant variability in the biological conditions of each patient: bone type, oral hygiene habits, edentulous time of the surgical area, smoking habits, medication, healing capacity, oral parafunctions or bruxism, underlying medical conditions, the opposing dentition to be rehabilitated, etc.

2. The implants were placed by multiple operators with varying levels of experience from the Master's program in Oral Surgery, Implantology, and Periodontics at the University of León.

Conclusions

1. The PIS measured in terms of ISQ and IT showed a positive correlation with preoperatively measured BD using CBCT. This means that the clinical value of the current study includes the potential use of PIS and BD as factors for predicting primary stability and successful implant treatment. However, our findings did not show a significant relationship between average ACW and stability variables. Therefore, the size of the alveolar crests did not have an effect on rotational or lateral PIS in both groups of implants obtained.
2. There was a highly significant positive association between the different RFA instruments used for the PIS of these implants, with Penguin showing higher values and thus having a stronger correlation among the studied variables. This is interesting when choosing between different instruments for measuring PIS.
3. Lateral and rotational PIS also showed a significant correlation. However, further research is needed to help predict PIS.

Acronyms

MACW: Mean alveolar crest width; BD: Bone Density; CBCT: Cone Beam Computed Tomography; CT: Computed Tomography; HU: Hounsfield Units; ISQ: Implant Stability Quotient; ISQ-BL: Implant Stability Quotient measured in the buccolingual direction; ISQ-MD: Implant Stability Quotient measured in the mesiodistal direction; IT: Insertion Torque; PIS: Primary Implant Stability.

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