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In vitro evaluation of the type of implant bed preparation with osteotomes in bone type IV and its influence on the stability of two implant systems

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Abstract

Objectives: 1) To evaluate and compare the stability of two types of implants in an animal model after preparing the implant bed with various sequences of osteotomes in bone type IV. 2) To evaluate the hypothesis of whether or not the sequence of using osteotomes influences the primary implant stability.
Material and Method: We selected bone from cow ribs, which in its cross section (the most medullar area of the bone) would be equivalent to a type IV human bone. We used fifteen ribs, in which six implant beds were prepared in each rib block using different preparation protocols for seating three conical Swiss Plus SPB implants of 3.7 x 10 mm versus three MK III parallel wall implants of 4 x 10 mm.Three preparations, each with a diameter, were made for the implants, using osteotomes that progressively increased the diameter of the implant bed. In the first preparation, the complete sequence of osteotomes was used; in the second preparation, the last osteotome was left out; and in the third preparation, the implant was placed after only passing through the first osteotome. Once the implants were seated, we proceeded to evaluate the stability (Osstell® ISQ-value). The locations were randomly chosen (by a coin toss).
Results and statistical analysis: We performed a statistical analysis of the ISQ values that were obtained during the different preparations carried out for the Mk III and Swiss Plus implants. The average range and standard deviation were calculated. The hypothesis was compared by a two-way variance analysis (type of implant/ different sequences of preparing the implant bed). It was considered significant for a $p < 0.05$. The statistical results obtained for the values of the Mk III implant were significant ($p = 0.042$).
Conclusions: The results of this in vitro study conclude that the tapered shape provides more primary stability to the implant and suggest that a short sequence of osteotomes in bone type IV provide more primary stability than the complete sequence.

***Key words:** Bone integration, osstell, primary stability, bone density, osteotomes, implants*.

Introduction

Over the last two decades, dental implants have been widely used to replace the loss of teeth and for the subsequent support of dental prosthesis. Despite the high survival rate of such implants (1), there continue to be cases of failure due to bone loss, which results from a lack of primary and secondary stability. The primary stability is related to the quality of the bone, that is, the bone density and its height in the area surrounding the implant. The secondary stability can be increased by the formation and reshaping of bone in the bone-implant interphase (2).

The survival of an implant and its clinical success are demonstrated in numerous studies in relationship to the quantity and quality of the bone available in the implant bed (3,4). The primary stability was determined as a prerequisite in order to achieve osseointegration (5). Many authors suggest that the primary stability should be a useful prediction of osseointegration (6), and a high primary stability makes an immediate load more predictable.

The higher the primary stability is, the fewer the micromovements between the bone and the implant, depending on various factors such as design, length and diameter of the implants, as well as the insertion technique and the consistency between the implant and preparation of the implant bed. In addition, there are other important factors to consider, such as the quality and quantity of the bone and also the type of implant surface (6,7).

Therefore, the clinical manifestation of osseointegration in a dental implant is the absence of mobility, and a rigid implant settlement seems to be a prerequisite for a good long-term clinical result. The failure is thus clinically diagnosed either by X-ray or when a movement of the implant occurs.

In the past, the primary stability measurements used to be carried out using different methods, such as the Periotest (Gulden, Bensheim, Germany) or the Dental Fine Tester (Kyocera, Kyoto, Japan). However, these methods have since been challenged due to their lack of resolution, poor sensitivity and susceptibility to the operator. In the last decade, an easy, non-invasive and reproducible method has been developed for measuring the implant stability, which may be used right after the implant is inserted (6-8). This method is known as resonance frequency analysis (RFA).

This measurement is carried out with different types of connectors according to the type of implant, and the connectors are calibrated by the manufacturer, thereby obtaining a numeric value called an implant stability quotient (ISQ) (7) calculated by a device called Osstell® (Integration Diagnostics AB, Gothengurg, Sweden). Its range varies between 1 and 100, with 100 being the highest degree of implant stability. The literature reports ISQ values of 57 to 82 for a correct osseointegration, with an average of 69 one year after implant placement (9).

Depending on the bone mineral density, we will need a greater or lesser torque for the insertion of the implant. The exact torque needed in order to achieve a good primary stability is unknown. Normal values are considered to be between 5 and 50 N/cm, although it is held that they should be at least 30 N/cm (10). The insertion torque of the implant has been associated with the bone mineral density, where values less than 30 N.cm indicate a low mineral density; an average density would be between 30 and 40 N/cm, and above 40 N/cm would be considered a high mineral density.

When we have a bone density that is too low for carrying out a mechanical implementation, one solution would be to perform the implementation manually, using an osteotome technique (11,12). With this technique, we can carry out two basic procedures: 1) the lateral compression of the trabecular bone instead of the conventional milling and 2) the bone surface of the maxillary sinus can be raised by using osteotomes (12-14).

The objective of the anatomic evolution of the implants is to achieve the best conditions for osseointegration. In recent years, root-shaped or conical implants have been developed, which are thought to allow us to obtain greater primary stability compared to cylindrical implants, which is precisely one of the purposes of our research. The conical or tapered design enables bone compression in soft bone, thereby achieving primary stability of the implant. Therefore, the hypothesis of our research raises the question of whether or not the design of the implant, as well as the use of osteotomes in type IV bone, influences the primary stability of the implant. The objectives of this *in vitro* study will focus on evaluating such hypothesis.

Material and Methods

We selected 15 fresh cow ribs of similar anatomical characteristics. All of the ribs were obtained from a butcher shop and all came from the same animal, a cow that was approximately two and half years old. These ribs served as a model of a toothless human jaw due to their macroscopic composition of cortical and medullary bone. The ends of the ribs, of greater diameter, with a smaller cortical and a greater proportion of medullary bone, resemble the type IV bone, according to the Leckholm & Zarb classification (15) or D4, according to the Misch classification (16). Bearing this in mind, we only use these ends, as the rest of the body of the rib is irrelevant to our study. Six implant beds were prepared in each rib block, 3 on each end of the ribs. An inter-implant distance of 7 mm was maintained. Each preparation was made according the manufacturer's protocol. Preparations corresponded to two different implant systems: A conical Swiss Plus SPB (SP group) of 3.7 x 10 mm (Zimmer Dental®) with a self-tapping design and double-lead thread and MTX™ micro-textured titanium surface, and a Nobel Biocare® Mk III (Mk group) of 4 x 10 mm, with parallel walls and a TiUnite® surface throughout the implant. Three preparations of a different diameter were made for each implant, using osteotomes that progressively increased the diameter of the implant bed.

The sequence of osteotomes for the placement of MK III implants was as follows:

a) Instrumentation recommended by the manufacturer for hard bone, comprising:

- osteotome 2.0<2.5; osteotome 2.5<3.0; osteotome 3.0<3.5.

b) Instrumentation recommended by the manufacturer for average bone hardness, comprising:

- osteotome 2.0<2.5; osteotome 2.5<3.0.

c) Instrumentation recommended by the manufacturer for soft bone, comprises:

- osteotome 2.0<2.5.

The sequence of osteotomes for the placement of Swiss Plus implants was as follows:

a) Instrumentation recommended by the manufacturer for hard bone, comprising:

- osteotome 2.0<2.5; osteotome 2.5<3.0; osteotome 3.0<3.5.

b) Instrumentation recommended by the manufacturer for average bone hardness, comprising:

- osteotome 2.0<2.5; osteotome 2.5<3.0.

c) Instrumentation recommended by the manufacturer for soft bone, comprises:

- osteotome 2.0<2.5.

The implants were seated in such a way as to completely cover their rough area, after which the transducer corresponding to each type of implant was inserted, pressing them down manually. The primary stability of each implant is then measured using the Osstell® mentor, obtaining 4 readings of each implant, always using the highest value. Special care was taken in placing the reading probe, always at a 90° angle to the transducer.

Once the values for each sequence of milling were obtained, the data was entered into a database using the program Microsoft Access (Microsoft Office 2000 SR-1 Premium Version). The data was then analyzed using the program SPSS 13.0 for Windows.

Statistical Analysis

After debugging the data, the Shapiro-Wilk Test was carried out in order to verify the normality of the differences. For data found to fall within normal limits, the Student T test was carried out for matching data, or where the data was found to be not normal, the Wilcoxon Test was carried out, according to whether or not the normality of the differences could be verified.

When significant data was detected, we tried to identify where it lined up with the repeated measures analysis of variance, checking the verification of the sphericity assumption by the Mauchy test. In cases where the result was not normal, we chose to base our decision on an unchanged statistic F, using a Greenhouse-Geisser correction factor. Once the differences were detected, post-hoc tests were carried out in order to reveal where the differences occurred, using the DMS method's comparison by matches (least significant difference).

Such method was used for analyzing the resonance values for the preparation sequence group of each type of implant, first independently and then comparing the results obtained from different implants.

The following steps were established:

1) Simple descriptive study of MK III (mean + percentiles).

2) Inferential analysis of MK III. As the results of the Shapiro Test did not fall within normal limits, we had to carry out the non-parametric Friedman test.

3) Simple descriptive study of SP: Average + 95% confidence interval.

4) Inferential analysis. After verifying standard deviation (Shapiro-Wilk Test), an analysis of repeated measurements was carried out, in which the differences observed were significant. We tried to clarify where this difference between types of osteotome sequences existed, with an intrasubject test with repeated measures analysis of variance. However, by not verifying the sphericity assumption by the Mauchy test, we chose to base our decision on an unchanged statistic F, using a Greenhouse-Geisser correction factor (p=0.036).

5) Inferential analysis of MK versus SP: Standard deviation testing was carried out (new Shapiro method) revealing that only the preparations 1 and 3 met the standard. Therefore, a match comparison was carried out on related samples, using the Student T test.

Results

The ISQ values of the Mk III implant ranged from 44 to 61 for hard bone, from 42 to 62 for average bone hardness, and from 52 to 63 for soft bones. The ISQ values for the Swiss Plus implant ranged from 55 to 63 for hard bone, from 57 to 65 for average bone hardness and 57 to 67 for soft bones. The average obtained for the ISQ values of the Mk III implant and the Swiss Plus implant were 56 and 60.7 respectively.

-Simple descriptive study of MK III (Table 1): similar ranges.

-Inferential analysis of MK III. No significant differences were detected.

-Simple descriptive study of SP (Table 2): greater stability with fewer preparations.

-Inferential analysis of SP: Once the differences were detected, post-hoc testing using the LSD method (least

Table 1. Simple descriptive study of MK III.

	25	**50**	75
MKIII preparation 1	55.0	**58.0**	60.0
MKIII preparation 2	55.5	**57.0**	60.5
MKIII preparation 3	55.0	**56.0**	61.5

Table 2. Simple descriptive study of SP.

	Average – D	Upper limit	Lower limit
SP preparation 1	59.400 – 2.02	58.2767	60.5233
SP preparation 2	60.2667 – 2.25	59.4444	59.0000
SP preparation 3	62.6000 – 3.43	59.0201	61.5132

Table 3. Inferential analysis of MK III vs.

		Average	D. T.
Par 1	M KIII Prep1	56.6667	4.80575
	SP Prep1	59.4000	2.02837
Par 2	M KIII Prep3	57.2000	3.89505
	SP Prep3	62.6000	3.43927

SP (p=0.042)

significant difference) for match comparisons was carried out in order to explain where the differences occurred. The overall differences that we had detected were then verified that they were due to the discrepancies between the preparation 1 and the preparation 2, as no differences were detected between the other comparisons.

-Inferential analysis of MK versus SP: (Table 3). The Student T test revealed significant differences both in the preparation 1 (p=0.003) and in the preparation 3 (p=0.001).

The confidence interval was established for these comparisons, revealing the band where the difference for any sample type is located. The comparison between SP (where the higher values are observed) and MKIII for the preparation 1 had an interval of values ranging from 0.2526 to 5.21, whereas the comparison between values SP and MKIII for the preparation 3 had an interval ranging from 2.5 to 8.2. Thus, the value may be higher in the preparation 3 than in the preparation 1.

Finally, given that the preparation type 2 did not meet fit within normal parameters, we proceeded to carry out non-parametric test (Wilcoxon), comparing significant differences (p=0.042) in favor of SP (higher values).

Discussion

When we eliminate the cortical bone in a milling process, we are reducing the primary stability of the implant that we are going to insert (17). Such stability will depend both on the adequate milling and on the bone surface in contact with the implant when it is being placed. This primary stability was considered to be influenced by the macroscopic form of the implant, revealing an increase in primary stability with a conical implant. Such difference has been observed in this experimental study, revealing that the Swiss Plus implant offers a greater primary stability due to its tapered shape. The evaluation of the primary stability when inserting an implant will determine the prognosis of such an implant, and thus, the loading time. The most common bone classification is the Lekholm & Zarb (15), which uses radiology to evaluate bone quality from 1-4. The importance of a correct primary stability as being associated with the success of the osseointegration is widely documented in the literature.

Numerous studies on the use of dental implants mention that the implant may be lost due to poor quality of the surrounding bone tissue. On the other hand, a bone that is well-mineralized with adequate degrees of corticalization, such as the area of the symphisis, the success rate is 99%, proven in a period of 15 years with the Branemark® implant system (Nobel Biocare, Gothenburg, Sweden). Therefore, the importance of mineral density as a determining factor of the primary stability of endosseous implants plays a fundamental role in making a prognosis of the implants. This stability may be evaluated by resonance frequency analysis, obtaining stability values using the Osstell® mentor system (Integration Diagnosis AB, Sävedalen, Sweden), obtaining ISQ units (implant stability quotient).

Meredith et al. (8) developed the resonance frequency analysis in 1997 with the Osstell device. Since then, a significant number of studies have appeared in the literature, proving that this non-invasive technique is clinically useful for studying the initial stability of the dental implants, and has been shown to be better than other techniques for measuring the stability on the spot during implant placement. It has been used with different implant surfaces, types and designs for studying and comparing different implant and implant-prosthesis designs and surfaces; for studying and comparing different techniques for seating the implant, of milling and immediate or early loading; for studying and evaluating the factors that influence the implant stability over time, length and diameter of the implants, type of bone, etc.; or to study the relationship of the implant stability compared to the use of grafts or various other bone substitutes. Such studies have been carried out on experimental models *in vitro*, on cadavers and in vivo.

It is generally accepted that the primary stability of a dental implant, along with a correct osseointegration, are two of the most important factors affecting the success of an implant. Although the sequence of osteotomes used in our study was not exactly that recommended by the manufacturer (a difference of 0.1 mm in the diameter by having to use the material available at the Department), we think that this minimal discrepancy should not influence the results.

Many other factors such as the height, width and/or density of the alveolar bone are widely documented, as well as the influence of the macroscopic design of the implant. Results that coincide with those obtained in this study, where we find that higher values of osseointegration are obtained in a type IV bone with the tapered Swiss Plus implant design. Therefore, it is clear that different implant surfaces may result in varying initial torques of the implant. In our case, the surface of the Swiss Plus implant, the MTX™ microtextured titanium shows excellent histomorphometric results as well as clinical results. In a recent study, the MTX surface achieves an excellent bone-implant contact and osteoconductive capacity (18) and the surface of the Mk III, TiUnite® have been shown to improve the bone response compared with other implant surfaces (19). Good results are presented with both surfaces, which lead us to believe that it is not a key factor, comparing these two types of implants, for their primary stability. However, this hypothesis is still being studied.

As far as the morphology of the different types of implants used and their relationship to the primary stability, we have not found anything beyond the verification of our initial hypothesis, leading us to conclude that the conical or tapered shape offers greater primary stability to the implant. As for the analysis of the pre-implant stress at the level of the alveolar crest, Cruz et al. (20) found a similar distribution of the model (analysis of finite elements) for cylindrical and conical shapes.

The validity of our results has been the subject of a solid statistical study, the results of which support our initial hypothesis. However, we must not forget that this has been an experimental study carried out on an animal model, which involves a series of limitations, such as considering the quality of bone in an area other than the oral cavity, as well as lackin vascularization.

Conclusions

In the study carried out *in vitro* and in type IV bone, it is observed that the initial hypothesis coincides with the results obtained: an adequate primary stability is achieved, despite not having a complete sequence of osteotomes, and it is also predictable with respect to the macroscopic structure of the implant, observing that the primary stability increases when we use conical implants.

According to our initial hypothesis, our ISQ results for the two types of implants show statistically significant differences ($p=0.042$). Slightly higher values were observed for the Swiss Plus implant, which supports the results that we anticipated, that is, that the tapered or conical form offers more primary stability to the implant.

The results of this study suggest that the implants seated using the shortest sequence of osteotomes showed a greater stability than with the complete sequence of osteotomes.

Finally, the results of our study reveal the need to prepare new or additional lines of research in order to answer the possible questions that arise as a result of our discussion, mainly due to the lack of studies in our same line of research. The most recent research and publications show the trend towards associating the primary stability of the implants with the new surfaces instead of the macroscopic shape of the implants.

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