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In vitro evaluation of the influence of the cortical bone on the primary stability of two implant systems

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Abstract

Aims: Immediate loading has become a predictable option for treatment, while one of the main requirements for its implementation is obtaining appropriate primary stability in implants. With that aim, conical implants are commercially available, since, according to specialized literature, they provide greater stability. One of the methods to measure implant stability which has evolved to further stages is resonance frequency analysis (RFA). In the present paper we attempt to evaluate the influence of the cortical bone on the primary stability of two implants of similar diameter and length.

Study design: 15 fresh cow ribs were selected and six different implant beds were prepared in each. These preparations corresponded to two different implant systems: A Swiss Plus from Zimmer Dental® and an Mk IV from Nobel Biocare®. Two drilling protocols were used for soft bone, hard bone and bone without cortical. After preparing the beds, the implants were placed and implant primary stability was measured with the Osstell® mentor.

Results: Higher ISQ (Implant Stability Quotient) values were observed for both implant systems when the cortical bone is maintained than when it is eliminated, the difference being statistically significant in the case of Mk IV implants.

Conclusions: The results from this study show the importance of preserving cortical bone during drilling in order to obtain greater primary stability.

Key words: *Primary stability, cortical bone, ISQ.*

Introduction

The process of implant osseointegration involves a series of physiological processes of bone resorption and apposition, in which bone formation around the implant takes place, allowing better bone-implant joint.

In order to make this process take place, it is necessary to achieve appropriate initial implant stability and control loadings acting on the implant with the aim of avoiding failure. Such stability is known as primary stability, is defined as the implant's initial mechanical subjection after placement and is mainly determined by initial bone-implant contact (1,2).

Primary stability is one of the most important factors in the osseointegration process, especially when immediate loading has been planned (3-5). This stability depends on several factors which may be classified as:

— Implant-related factors: morphology, length, diameter, kind of surface or distance between spires

— Surgical procedure-related factors: insertion technique (non-homogeneous drilling, axiality loss during drilling, etc.), congruence between implant and bone preparation, bicortical anchorage, etc.

— Biological factors: bone quality and quantity, presence of cortical bone (6,7)

The importance of preserving the cortical bone during implant bed preparation becomes especially important in regions of cancellous bone, such as the posterior region in the upper jawbone.

In these situations of soft bone, the cortical bone will play an important role to provide the implant with greater stability. This may be achieved by placing the implant shoulder slightly juxtaosseously or even burying it completely. The increase of implant diameter in such region seems to increase implant primary stability (8,9).

Studies show that cortical bone is up to 10 times more rigid than cancellous bone, thus explaining why implant length does not play a much relevant role (10).

The use of anatomical implants —where implant diameter is reduced from coronal to apical— and implants with wider platform allows better implant settlement on the cortical bone. Besides, shorter thread helps compact cancellous bone, thus increasing the contact between bone and implant, and therefore also primary stability (11).

Until very recently, quantitative measurement of primary stability was carried out with invasive methods. For instance, with implant traction, in order to get to know its removal torque. This biometrical and destructive test is limited to in-vitro studies or animal models, since it is not suitable for clinical use (12).

Within the group of non-invasive techniques, measurement of implant insertion torque has been used, being —unlike the previous one— a clinical and one-stage method. These values range between 5 and 50 N/cm, but the torque necessary to achieve appropriate primary stability is not known with accuracy; however, it is thought that such stability should be at least 30 N/cm (13,14).

Implant insertion torque has been related to bone mineral density, where values lower than 30 N/cm indicate low mineral density, while medium density ranges between 30 and 40 N/cm and would be the stability necessary for implant insertion; over 40 N/cm it would be considered as high bone mineral density (15,16).

In the last decade, Meredith (6) developed an easy, non-invasive and reproducible method to measure implant stability which can be used immediately after implant placement and during the osseointegration process, offering the possibility to get to know implant stability at any time during the cicatrisation process. This method is known as resonance frequency analysis (RFA). This measurement is carried out with a machine connected through a specific transducer to each model of implant, obtaining a numerical value known as implant stability quotient (ISQ) whose range oscillates between 1 and 100 (17).

Different Osstell® models have been developed since the first model, which appeared at the end of the 90s; this first model operated electrically and the transducer connection was through a cable. The last model, that which it is used nowadays, is magnetic and does not involve any cable (cordless). In the electrical system, a piezoelectric crystal in the vertical portion of the probe is used to stimulate the complex transducer-implant; another piezoelectric crystal at the opposite side of the probe is used as receptor of response impulse.

In the new magnetic system the transducer has a magnet at the end which is stimulated through a magnetic impulse from the wireless probe for a millisecond. After exciting the transducer, the pin vibrates, thus emitting electric voltage to the probe bovine. This voltage measurement reaches the resonance frequency analyser, which emits an ISQ value (18-21).

The higher the ISQ value is, the greater the implant anchorage to bone will be. Specialized literature describes ISQ values from 57 to 82 for correct osseointegration with an average of 69 after one year of loading (22,23) and indicates which values lower than 40 involve high-risk situations for the implant, while values higher than 55 are considered as favourable. The values recommendable for immediate loading are still to be established (24).

Some resonance frequency analyses demonstrate that implants with appropriate initial stability keep such stability from three to four months after their put into operation, while implants with low stability values undergo high failure risk after the first or second month of immediate loading (25).

Once we have analysed the importance of preserving the cortical bone during the drilling process, the main aim of the present study is to ascertain primary stability achieved by the different drilling protocols offered by two implant systems in an animal model with type II-III

bone quality, preserving the cortical bone and eliminating it subsequently.

Material and Methods

We selected 15 fresh cow ribs of similar anatomical characteristics. Each rib was selected in different blocks in order to obtain homogeneous areas to undertake implant preparation.

All ribs were obtained from a butcher's shop and came from the same animal, a cow of around two and a half years of age. These ribs served as a model of human edentulous jawbone due to their macroscopic composition of cortical and medullar bone. The most proximal region of the rib, of higher diameter, has a minor portion of cortical bone and greater medullar proportion, being similar to a type-III (or D3 to D4) quality, respectively (26,27). Bearing such premise in mind, we did without both rib extremes with the aim of obtaining a II-III intermediate-quality bone.

Six implant beds were prepared in each rib block, which correspond to the following drilling protocols:

a) Standard drilling protocol recommended by the manufacturer

b) Standard drilling protocol recommended by the manufacturer and elimination of the cortical bone by using a countersink

Each bed should have at least a perimeter of 5 millimetres of bone around and an inter-implant distance of 7 millimetres was maintained. Each preparation was carried out by following the drilling protocol recommended by the manufacturer.

Each rib block was firmly subjected to a table when carrying out preparations and measurements.

Locations were randomly assigned by tossing a coin. Preparations corresponded to two different implant systems: A conical Swiss Plus SPB of 3.7 x 10 mm (Zimmer® Dental) and an Mk IV of 4 x10 mm (Nobel Biocare®).

The drilling protocol recommended by the manufacturer for the placement of Swiss Plus implants was the following:

a) The milling process recommended by the manufacturer is composed of:

— Ball-end milling cutter; pilot milling cutter; 2.3-milling cutter; 2.8-milling cutter; and 3.4-milling cutter

b) The milling process recommended by the manufacturer and elimination of cortical bone:

— Ball-end milling cutter; pilot milling cutter; 2.3-milling cutter; 2.8-milling cutter; 3.4-milling cutter; and countersink

The milling process recommended by the manufacturer for the placement of Mk IV implants was the following:

a) The milling process recommended by the manufacturer is composed of:

— Ball-end milling cutter; pilot milling cutter; profile milling cutter; 3.15-milling cutter; and 3.35-milling cutter

b) Milling process recommended by the manufacturer and elimination of cortical bone:

— Ball-end milling cutter; pilot milling cutter; profile milling cutter; 3.15-milling cutter; 3.35-milling cutter; countersink

After completing the beds, each implant was placed until the rough area was completely covered and the corresponding transducer of each implant was also placed, tightening them by hand. Subsequently, we measured primary stability in each implant through the Osstell® mentor system, obtaining four figures for each implant. The probe was always positioned with a 90º angle regarding the position of the transducer. Of the four measures obtained for each implant, only the highest values were used in the study.

Results

Once the values for each milling sequence have been obtained, we proceeded to introduce the data obtained in a database drawn up with MS Access software (Microsoft Office 2000 version; SR-1 Pentium). Data analysis was carried out with SPSS 13.0 software for MS-Windows.

Firstly, we undertook the Shapiro-Wilk test to check the normality of the differences. In case that normality was fulfilled, we undertook T-student in normal groups to valuate the significance of the differences and the Wilcoxon test in non-normal groups.

In case that the Shapiro-test distribution is non-normal, we undertook Friedman's non-parametric test to valuate the significance of the differences. In case that any significance was detected, we researched where such discrepancies were to be found through the Holm-Bonferroni method.

Such detailed method was carried out for resonance frequency analysis for milling sequence group in each type of implant, first in an independent manner and subsequently by comparing the results of different implants.

The two kinds of milling protocols (preparations) established for each implant system are the following:

a) Milling process recommended by the manufacturer

b) Milling process recommended by the manufacturer and elimination of cortical bone

ISQ values obtained in preparations carried out for Swiss Plus implants ranged from 65 to 78 (protocol a) and from 65 to 75 (protocol b). The range of ISQ measurements for Mk IV implant was 65-75 (preparation a) and 62-71 (preparation b).

The mean of ISQ values obtained (together with standard deviations) for the Swiss Plus implant was 70.86 (±3.352) in preparation a, and 68.40 (± 3.157) in preparation b; lower values are reported in preparations in which the cortical bone had been eliminated.

Table 1. Average values and standard deviation after comparing preparations of bone layer following the recommendations of the manufacturer and after the elimination of the cortical bone, comparing both implant systems.

		Related differences				Sig. (bilateral)
		Average values	Typical deviation	95 % Confidence interval for the difference		
				Inferior	Superior	
Pair 1	Soft SP – Soft MK IV	0,86667	4,43793	-1,59098	3,32431	,462
Pair 2	Cortical SP – Cortical MK IV	1,80000	5,53173	-1,26337	4,86337	,228

The mean of ISQ values obtained (together with standard deviations) for the Mk IV implant was 70.00 (± 3.779) in preparation a, and 66.60 (± 3.924) in preparation b.

Analysing the means of the differences (paired data), it can be observed that they are quite close values (differences are small).

We observed statistically significant differences between standard preparations for the Mk IV implant in relation to the cases in which the cortical bone had been eliminated ($p = 0.01$).

However, the differences found between the two milling modalities for the Swiss Plus implant were not statistically significant ($p = 0.055$).

Table 1 shows the means of the results obtained when comparing both milling processes recommended by the manufacturer and the same milling process after eliminating the cortical bone, when comparing both implant systems. In this case, no statistically significant differences were found.

Discussion

According to what has been established in other experimental papers which used cow ribs as model of study, the most distal region of the rib —which is of lower diameter and contains greater cortical bone and lower proportion of medullar bone— would be similar to a type-II bone, according to the classification made by Leckholm & Zarb (1985) (25) or to a D2 or D3 bone according to the classification developed by Misch (1990) (26).

The fact of obtaining so similar results may be due to similarity in implant design, since both implants are of conical morphology: their diameter is very similar, since that of Swiss Plus is 3.7 mm and that of Mk IV is 4 mm, their length is also the same (10 mm) and preparations were carried out randomly in a similar rib block.

Lower ISQ values have been observed when the bone was instrumented to a greater level; that is, when the cortical bone was eliminated, which coincides with the strategy of different clinicians, who —in situations of more trabecular bone— do without the last milling cutters in order to preserve the cortical bone to a greater extent, so that it is the implant itself which ends up preparing the bed.

In spite of not finding statistically significant differences in preparations for the Swiss Plus implant, the level of significance obtained ($p = 0.055$) is close to what is considered as optimum in health sciences literature ($p = 0.05$). Encouraged by such finding and considering that it may be the result of a sample of reduced size, we decided to calculate the ideal sample size with the data obtained. Through the expression minimum sample to detect differences of 2.4 units between the standard preparation for the Swiss Plus implant and cortical preparation, assuming an alpha error of 0.05 and a contrast power of 80 % with a typical deviation of the estimated differences (considering our own study as a pilot study) of 4.6, we can conclude that ideal sample size should be 31.

However, statistically significant differences were found in Mk IV implant ($p = 0.01$). On the other hand, no statistically significant differences were found regarding primary stability obtained for both systems.

Another factor to be borne in mind is that transducer tightening to the corresponding implants was carried out manually, which may give rise to the alteration of some results. This is due to the inexistence of a dynamometric system for tightening.

Unlike the previous Osstell® models, the current Osstell® model is wireless, which facilitates its use and handling; however, when obtaining values, one faces the problem that —keeping the probe perpendicular to the transducer— different values are obtained according to the position on the horizontal plane in which its is placed. These differences in the values obtained are explained by the manufacturer as the values of "higher" or "lower" stability shown by the implant; terms not valued in literature. Therefore, we chose the higher value obtained in each batch of 4 lectures, each of them carried out at 90º degrees of separation between them and another one on the horizontal plane.

We may conclude the present paper stating that no statistically significant differences between both implants were found, probably due to the existing similarity between them, and that differences regarding implant stability were only to be found when the cortical bone was eliminated and when it was kept.

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