



# The Relationship Between Resonance Frequency Analysis (RFA) and Insertion Torque of Dental Implants: an in Vitro Study

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## Abstract

**Purpose:** The aims of the present study are to correlate the ISQ values, registered by the Osstell ISQ system, with the insertion torque during the placement of the implant, and to assess the influence of the thread initiator on the ISQ values and on the insertion torque.

**Materials and methods:** 140 rough surface implants screw-shaped implants, placed in 10 bovine ribs, were assigned to Group A (using the thread initiator before the insertion of the implant) or Group B (thread initiator was not used). The implants were implanted using a manual torque wrench so insertion torque was registered. Once the implants were in place, primary stability was measured by means of RFA with the Osstell ISQ.

**Results:** When the thread initiator was used (group A), the mean insertion torque was  $24,36 \pm 14,88$  N and when the thread initiator was not used (group B) the mean insertion torque was  $35,30 \pm 10,51$  N. The mean ISQ of the thread initiator group was  $69,14 \pm 8,39$  and of the non thread initiator group was  $72,17 \pm 5,76$ . Pearson's correlation coefficient was 0,587 ( $p < 0,05$ ) for group A and 0,193 ( $p < 0,11$ ) for group B.

**Conclusions:** It seems that the fact of using or not the thread initiator have no influence in the ISQ values. However, the IT decreased when the thread initiator is employed.

**Keywords:** Implant stability, Insertion torque, ISQ, Osstell, osseointegration

## Introduction

Implant stability depends directly on the mechanical connection between the implant surface and the surrounding bone. Initial stability, a consequence of an immediate mechanical adaption between the implant and the bone site, depends on the density of the bone tissue (the bone quantity and quality), the surgical technique used and the congruity of the site and macrostructure of the implant [1-6]. Secondary stability is the result after the formation of woven and lamellar bone around the dental implant surface as a secondary bone contact [2,3]. Primary stability was always considered a fundamental prerequisite to acquiring osteointegration [3,7] and it is now even more

important, whenever clinicians want to use immediate loading protocols [8,9]. Extensive micromotion during healing and functional loading is one likely reason for implant failure as this may result in non-physiological conditions for bone formation and remodelling [10]. The greater the primary stability, the smaller the micromotions are between implant and bone. The micromotion promotes the formation of a soft tissue capsule around the implant, and as a result implant failure may occur [11,12].

Various non-invasive stability measurement techniques (i.e. methods of percussion, radiography, resonance frequency

analysis, placement resistance, reverse torque and vibration in the sonic and ultrasonic ranges) were used to measure the stability of endosseous dental implants [2,3,5,13]. One of the quantitative methods is the insertion torque (IT) [3]. The IT, was described by Johansson and Strid [14,15], is the moment of force necessary to seat the implant into the osteotomy site, and it furnishes worthy information about the quality of the local bone [1- 5,16]. The determination of the IT is done by a torque gauge incorporated within the drilling unit or with a torque wrench during the insertion of the implant [8,9]. It is an easy method, but it can be measured only once, at the time of the insertion of the implant. It is not used to monitor the stability over time.

Resonance frequency analysis (RFA) was introduced by Meredith in 1996 [6,17]. It is a non-invasive, reliable, and objective method where the device measures the degree of implant stability at any time during the course of implant treatment and loading [3, 5,18,19]. The technique has been demonstrated to evaluate implant stability as a function of interface stiffness [6,15,20]. Although there is some controversy about it, a recent study has demonstrated a correlation between bone density and ISQ and displacement measurements. Thus, clinical measurements of implant micromotion would be one way to identify implants at risk of failure [21]. The implant/bone interface is measured from RFA as a reaction to oscillations exerted onto the implant / bone contact, where the unit of measurement is recorded as implant stability quotient (ISQ). RFA is assessed by the instrument Osstell (Osstell AB, Göteborg, Sweden). Osstell gives the ISQ on a scale from 1 to 100. The higher the ISQ number, the higher the stability [22,23].

Clinically, ISQ values have been correlated with changes in implant stability during osseous healing. Thus, IT and ISQ values are thought to have a positive correlation. However, the correlation of higher IT torque translating into higher primary stability may not always be true because the quantity and quality of bone varies significantly among patients [4].

The aims of the present study are to correlate the ISQ values, registered by the Osstell ISQ system, with the insertion torque during the placement of the implant and to assess the influence of the thread initiator on the ISQ values and on the insertion torque.

### Material and Method

140 rough surface implants (Shot Blasting®: alumina particle sandblasting and acid passivation) screw-shaped implants (Essential® Cone, Klockner Implant System, SOADCO, Andorra) were used. All implants had a diameter of 4mm (diameter at platform level is 4,5mm), a length of 10mm and a mechanized collar height of 1,5mm. The implants were assigned to one of the following groups:

**a) Group A:** complete drilling sequence, following the manufacturer's protocol and using the thread initiator before the insertion of the implant.

**b) Group B:** complete drilling sequence without using the thread initiator.

The implants were placed in 10 bovine ribs (bone quality type II, according to Leckholm & Zarb [24], by an experienced clinician (user and knower of the Klockner Implant System for more than 2 years), following the manufacturer's protocol. 14 implants were placed in each rib. The osteotomy was performed under abundant irrigation with sterile saline solution at 800 rpm. The implants were inserted using a manual torque wrench so that the rough/smooth interface was placed at bone crest level. The distance between the implants had to be at least 10mm in between of the centre of the implants. As the implants were placed with manual torque wrench, the exact insertion torque was registered.

Once the implants were in place, primary stability was measured by means of RFA with the Osstell ISQ, by a second experienced clinician in the use of the ISQ device. The ISQ was measured over the Smartpeg screwed directly to the implant by the specific plastic hand-screwdriver. One Smartpeg is used every 5 implants (so 10 measurements were made with each transducer). The ISQ was registered perpendicular to the Smartpeg in 2 different positions:

- 1) The ISQ is registered from the front of the rib; and
- 2) The stability is registered from the right of the rib (90° from the first measurement). At each position, the ISQ was registered once.

SPSS 19.0 software (SPSS, Chicago, IL) was used for the statistical analysis. Mean values and standard deviations and the Pearson Correlation Coefficient were calculated. The normal distribution of the values and the homogeneity of the variances were tested through a Kolmogorov-Smirnov test. The differences between the mean values were compared with the non-parametric Mann-Whitney test. Then, all the values were grouped according to the ISQ and IT registrations and the differences were compared with the non-parametric Kruskal-Wallis test. When significant differences were obtained, 95% confidence intervals were found for average and mean differences ( $p < 0.05$ ).

### Results

When the thread initiator was used (group A), the mean insertion torque was  $24,36 \pm 14,88$ N and when the thread initiator was not used (group B) the mean insertion torque was  $35,30 \pm 10,51$ N. The mean ISQ of the thread initiator group was  $69,14 \pm 8,39$  and of the non thread initiator group was  $72,17 \pm 5,76$ . Pearson's correlation coefficient was 0,587 ( $p < 0,05$ ) for group A and 0,193 ( $p < 0,11$ ) for group B.

The mean insertion torque values according to the ISQ was studied in Table 1. Statistically significant differences were found between group A when the ISQ was  $< 60$  and  $\geq 60$ ; between group A when the ISQ was  $< 60$  and group B when the ISQ was  $\geq 60$  and between group A and B when the ISQ was  $< 60$  and when

the ISQ was  $\geq 60$  (shown in Table as a, b, c and d). In Table 2 the insertion torque related to the ISQ divided in three groups (low, medium and high ISQ values) was showed.

**Table 1:** Insertion torque values according to Osstell measurements. (Means having different letter in the column have statistically significance differences, a:  $p < 0,004$ ; b:  $p < 0,0005$ ; c:  $p < 0,001$ ; d:  $p < 0,003$ ). I = n° of implants in each group.

Osstell < 60 ISQ		Osstell $\geq 60$ ISQ	
Group A	Group B	Group A	Group B
12,00 $\pm$ 2,33 N a, b, c	46,33 $\pm$ 18,00 N c	25,95 $\pm$ 10,08 N a, d	34,81 $\pm$ 14,69 N b, d
8 I (11,43%)	3 I (4,29%)	62 I (88,57%)	67 I (95,71%)

**Table 2:** Insertion torque values according to Osstell measurements divided in three groups: low (0 - 33,33), medium (33,33 - 66,66) and high (66,66 - 100) ISQ values. I = n° of implants in each group.

Low Osstell		Medium Osstell		High Osstell	
Group A	Group B	Group A	Group B	Group A	Group B
18,45 $\pm$ 7,32 N	31,88 $\pm$ 12,42 N	28,28 $\pm$ 14,22 N	30,91 $\pm$ 12,36 N	29,71 $\pm$ 5,50 N	45,50 $\pm$ 16,22 N
31 I (44,29%)	16 I (22,86%)	18 I (25,71%)	34 I (48,57%)	21 I (30%)	20 I (28,57%)

**Table 3:** ISQ values according to the insertion torque measurements. (Means having different letter in the column have statistically significance differences, a:  $p < 0,0008$ ; b:  $p < 0,0005$ ). I = n° of implants in each group.

TI < 30		TI $\geq 30$ ISQ	
Group A	Group B	Group A	Group B
66,97 $\pm$ 8,41 ISQ a, b	71,09 $\pm$ 4,08 ISQ	74,97 $\pm$ 4,91 ISQ b	73,07 $\pm$ 6,80 ISQ a
51 I (72,86%)	32 I (45,71%)	19 I (27,14%)	38 I (54,29%)

The mean ISQ values related to the insertion torque are given in Table 3. Statistically significant differences were only found between group A when the IT was  $< 30$  N and  $\geq 30$  N and between group A when the IT was  $< 30$  N and group B when the IT was  $\geq 30$  N (shown in table as a, b). In Table 4 the ISQ values according to the insertion torque divided in three groups (low, medium and high IT) was showed.

**Table 4:** ISQ measurements according to insertion torque values divided in three groups (low, medium and high insertion torque values). I = n° of implants in each group.

Low IT		Medium IT		High IT	
Group A	Group B	Group A	Group B	Group A	Group B
64,72 $\pm$ 8,84 ISQ	71 $\pm$ 3,88 ISQ	72,05 $\pm$ 5,04 ISQ	72,1 $\pm$ 4,32 ISQ	75,79 $\pm$ 4,26 ISQ	72,77 $\pm$ 7,34 ISQ
36 I (51,43%)	15 I (21,43%)	22 I (31,43%)	24 I (34,29%)	12 I (17,14%)	31 I (44,29%)

## Discussion

This study was conducted to evaluate the correlation between the IT and the ISQ values obtained from the RFA. The bone in which the implants are place is type II, according to Leckholm & Zarb's [24] classification. The mean ISQ in our study was  $69,14 \pm 8,39$  for the thread initiator group and  $72,7 \pm 5,76$  for the non thread initiator group. These results are similar to those of other trials examining the ISQ in cow ribs (also bone quality type II). In 2009, Andrés-García et al. [25] found a mean ISQ of  $70,86 \pm 3,4$  and  $70 \pm 3,8$  when placing two different implants (3,7 x 10mm Zimmer® Dental and 4x 10 mm Nobel Biocare®) in cow ribs with bone quality type II-III. In 2014, Romanos et al. [26] analysed the ISQ of three types of implants (two types of straight-screw type implants -one with polished collar and the other one without- and one tapered-screw type implant) placed in cow ribs, bone quality type III. The implants were Straumann, length 10 mm and diameter 3,3 mm. The mean ISQ values were  $75,02 \pm 3,65$ ,  $75,98 \pm 3,00$  and  $79,83 \pm 1,85$ , respectively. The slight differences between the results of those trials and the present one could be due to the different macro design of the implants used. The literature agrees that the most appropriate design is endosseous screw-shaped implants.

Pearson's correlation coefficient showed that the correlation between the IT and the RFA is positive: 0,587 ( $p < 0,05$ ) for group A and 0,193 ( $p < 0,11$ ) for group B. The correlation for the group B is very low. This means that when the thread initiator was used there were more correlation in between the two variables and that when thread initiator is not used there was almost no correlation between them.

The data published about this theme is contradictory. Data presented by Turkyilmaz et al. [3] in 2006, is in contrast with the results of group B of the present study. They analysed 142 Brånemark implants and reported an Spearman correlation of 0,583 that is very far from 0,193 reported for group B, but is similar to the correlation reported for group A. The reason for this difference appears unclear, but it could be explained by the different design of the implants studied, as well as the smaller number of the sample. Kahraman et al. [2], in 2009, found a positive significant correlations between the IT and ISQ values at the surgery ( $r = 0,78$ ,  $p < 0,001$ ), and at the prosthesis delivery ( $r = 0,46$ ,  $p < 0,01$ ) when 16 Straumann Standard Plus Implants and 26 MIS Seven Implant were inserted in 13 patients. In 2010, Degidi et al. [8] also reported a positive but low correlation between IT and ISQ of 0,247 when 514 Xive Implants was inserted in 52 patients. Makari et al. [6] in 2012 showed a positive correlation between IT and ISQ at baseline ( $r = 0,313$ ,  $p < 0,049$ ), at 3 weeks ( $r = 0,472$ ,  $p < 0,002$ ), and at 6 weeks ( $r = 0,419$ ,  $p < 0,007$ ). In 2012, Degidi et al. [9] published another study in which IT and ISQ was evaluated in 4135 XiVE implants (Dentsply Friadent) inserted in 1045 patients. The correlation between the two variables in that study was  $r = 0,218$  ( $p < 0,0001$ ). Also in 2012 Park et al. [13], viewed a correlation between the ISQ value and the maximum

IT value at the initial implant surgery ( $p < 0,01$ ,  $r = 0,427$ ); when 81 implants (Branemark with the external connection and ITI implants with internal connection) were inserted in 41 patients. They also found that Implants in the mandible showed higher ISQ values than did those in the maxilla ( $p < 0,01$ ), and ISQ values were higher for the external type of implants compared to those of the internal type ( $p < 0,01$ ). As the implant diameter increased, the ISQ value also increased ( $p < 0,01$ ). Respect to the IT, they showed that Implants in the mandible showed higher maximum IT values than did those in the maxilla ( $p < 0,01$ ), while male patients exhibited higher maximum IT values than did females ( $p < 0,01$ ). Maximum IT values were higher with the external implant type compared to those of the internal type ( $p < 0,01$ ).

It is also suggested that ISQ and IT values are also dependent on the system used [27,28], and self-tapping tapered implant design brings higher initial stability than parallel wall cylindrical implant systems [29]. O'Sullivan et al. [27] presented that surface geometry had a great importance, in which the design of the implant had the ability to increase the interfacial stiffness at the implant / bone interface analysed by IT and RFA analysis.

When the IT and RFA are analysed by groups, our results are in agreement with those of Degidi et al. [8]. It seemed that ISQ values were generally high or medium, while low ISQ values were quite rare. On the other hand, the distribution of IT values was much more uniform between the groups. These data suggests that RFA and IT represent two different features of primary stability, with the first indicating the resistance to bending load and the latter indicating the resistance to shear forces [8,30].

### Conclusions

The fact of using or not the thread initiator has no influence in the ISQ values. However, the IT decreased when the thread initiator is employed.

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