Influence of Transducer Orientation on Osstell™ Stability Measurements of Osseointegrated Implants

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ABSTRACT

Background: Resonance frequency (RF) analysis is frequently used to monitor implant stability in patients. The influence of transducer orientation on RF of implants placed in jawbone has not been evaluated.

Purpose: The aim of this study was to evaluate to what extent transducer orientation influences RF. The second aim was to evaluate if measurements taken with any particular orientation would best relate to marginal bone levels.

Materials and Methods: Nine patients edentulous in the upper jaw received 55 implants 3 years before this study. They underwent clinical and radiographic evaluation. Using Osstell™ (Integration Diagnostics AB, Göteborg, Sweden), four RF measurements were made for each implant. Measurements were obtained with the transducer cantilever placed buccally (B), distally (D), palatally (P), and mesially (M).

Results: All implants were clinically stable. Significant differences resulted between the measurements perpendicular to the bony crest (B, P) and the parallel ones (M, D). A tendency of negative correlation was found between marginal bone levels and implant stability quotient (ISQ) measurements; however, this correlation was not statistically significant.

Conclusions: In conclusion, when measuring the RF of dental implants using the Osstell, it has to be taken into account that the transducer orientation influences the measurement. It seems therefore advisable to standardize the orientation. Moreover, although there was a tendency, any statistical significant correlation between ISQ values and marginal bone levels could not be established.

KEY WORDS: clinical study, dental implants, resonance frequency analysis, stability

Resonance frequency (RF) is a noninvasive, objective method to evaluate implant stability and it has been validated through in vitro and in vivo studies.[1–3] The technique is based on the measurement of the RF of a small piezoelectric transducer screwed to an implant or abutment.[1] The accordance between the clinical outcome of implants placed in different bone qualities,[4–6] cutting torque at surgery,[4,5] finite element model,[7] and RF analysis suggests that this technique is a valuable help in the evaluation of implant stability.[4–7] The access to the technique has increased greatly because it is commercially available as the Osstell™ equipment (Integration Diagnostics AB, Göteborg, Sweden). The Osstell converts the RF values into implant stability quotients (ISQs), which can be directly compared.

ISQ values are increasingly taken into account when evaluating the clinical performance of dental implants. Interestingly, in an extensive review assessing different types of dental implants,[8] Osstell values were regarded as a possible measure of the primary outcome of dental implants.

Because of the possible increasing use of the technique, it would seem important to evaluate all the factors that might influence measurements. It was demonstrated that the distance of the transducer from bone[1–3] and the implant stability[1–5] influence RF, also the repeatability of the technique was demonstrated.[1,9]

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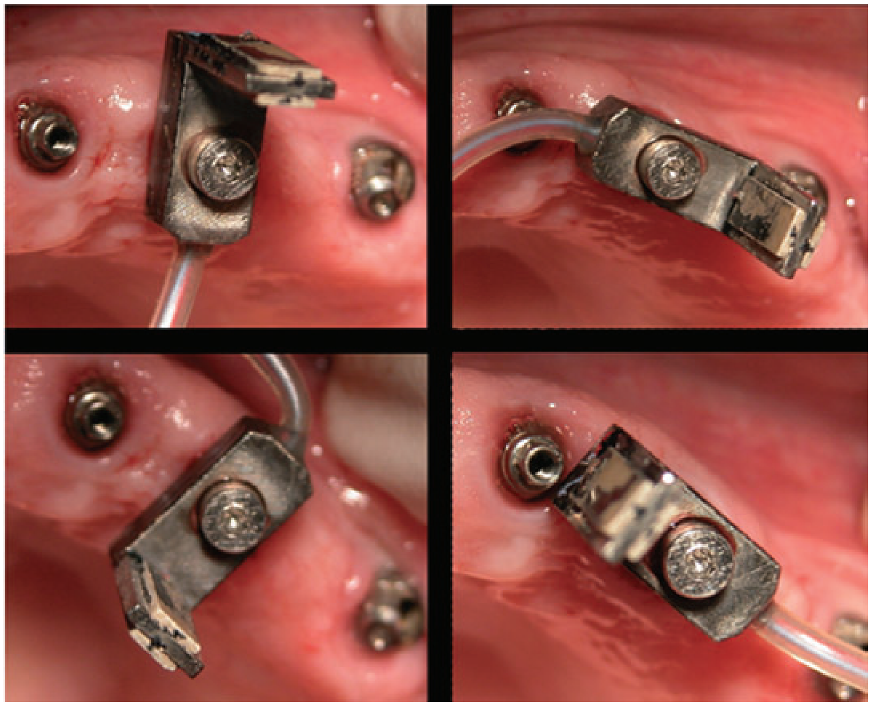

Figure 1 The different transducer orientations. Clockwise from top left corner: buccal, distal, palatal, and mesial.

Furthermore, it was found that, above a modest threshold, variations in the tightening torque of the transducer do not affect the measurements significantly.[1,10] On the other hand, less information has been reported regarding the influence of the transducer position with respect to bony anatomy. According to Meredith and colleagues,[2] the response of the transducer is directional, and therefore, it could be anticipated that, because of bone anatomy, different ISQ values are to be obtained in different directions. In a rabbit model, it was found that more sensible measures of bone quality changes at the implant interface were obtained if the transducer was placed perpendicular to the rabbit tibia.[2] Accordingly, the Osstell manufacturer recommends that the transducer is positioned perpendicular to the jaw with the cable in a buccal direction. However, no studies evaluated the influence of the transducer orientation when measuring the ISQ in human edentulous jaws using the Osstell apparatus. The aim of this study was to evaluate to what extent different orientation of the transducer would influence the ISQ of Brånemark System® implants (Nobel Biocare AB, Göteborg, Sweden) placed in fully edentulous maxillae and that reached the steady state. The second aim was to find out if ISQ obtained with any particular transducer position would best relate with bone levels.

MATERIALS AND METHODS

Patients

Nine patients, 7 females and 2 males (mean age: 63 years, range: 46–68 years), edentulous in the upper jaw, were included in the study. They had received a total of 55 implants (Brånemark System) supporting fixed cantilevered bridges. The patients had their prostheses in function for 3 years before the present study.

Implant Stability Measurement

All the bridgeworks were removed and implants checked manually for mobility. RF was then measured using the Osstell equipment. Transducers were hand screwed to the abutments and care was taken to avoid soft tissue contact. Abutment lengths were programmed in the Osstell computer, which automatically compensates for these. Whenever the graph associated with the ISQ measure showed flat or double peaks, screw tightening was checked and the measurement was repeated. For each implant, four measurements were made, each one with a different transducer position as shown in Figure 1. The first measure (B) was taken with the transducer perpendicular to the bone crest and the cantilever beam placed buccally. The second measure (D) was taken with the transducer parallel to the bone crest and the cantilever in a distal position. The third (P) was taken with the transducer perpendicular to the crest and the cantilever placed palatally. The fourth (M) was taken with the transducer parallel to the crest and the cantilever oriented mesially. All the ISQ values were then transferred to an electronic spreadsheet.

Radiographic Examination

Intraoral radiographs were taken using a parallel technique with the bridgework in place. Radiographs were thereafter digitized and analyzed using ImageJ, a freeware software (NIH, USA http://rsb.info.nih.gov/ij/). Bone levels were obtained by measuring the vertical distance of the implant/abutment connection from the bone contact. Measurements, taken to the closest 0.5 mm, were made on the distal and mesial side of each implant and then a mean value was calculated.

Statistical Analysis

Nonparametric Kruskal-Wallis test and post hoc Tukey test were used to identify statistically significant differences between the ISQ values obtained with different transducer positions (B, D, P, M). In addition, a correlation between bone levels and the different ISQ values (B, D, P, M) were evaluated using a Spearman's test. Statistical significance was set at .05.

RESULTS

All the implants were clinically stable and free from symptoms. The mean ISQ values for the four different transducer orientations are reported on Figure 2. A significant difference ($H = 85.9$; $p < .05$) resulted and paired comparisons revealed significant differences between the measurements made perpendicular to the bony crest (B, P) and the parallel ones (M, D). The mean marginal bone level was 1.5 mm (SD 0.6 mm) from the reference point. The frequency distribution of the bone levels measured is illustrated in Figure 3. A slightly negative correlation was found when plotting bone levels and the ISQ values measured along the different directions; however, for none of the positions, this correlation was statistically significant ($p > .05$).

DISCUSSION

The present results, as expected and in accordance with previous observations,[2] show that the RF, measured using the Osstell equipment, is influenced by transducer position. Significant differences resulted when the transducer cantilever was oriented perpendicular or parallel to the bony crest. Conversely, no difference was seen when rotating the cantilever along the same axis, in fact no significance resulted between the buccopalatal positions and between the mesiodistal ones. According to the present results, when measuring the RF perpendicular to the bony crest ISQ values may be up to 8 to 10 units lower compared to parallel orientations. Nevertheless, irrespective of transducer orientation, the mean stability values for each group were consistent with the range of ISQ levels already presented as descriptive of osseointegrated implants.[11] However, in order to monitor the stability of an implant over time correctly, it seems important that the same transducer orientation is kept during the different measurements. A second implication of the present data is that a standardized transducer

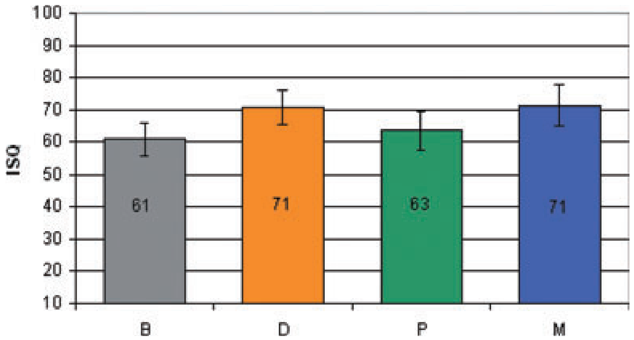

Figure 2 Mean implant stability quotient values for the different transducer orientations ($n = 55$; $H = 83.9$; $p < .05$). Paired comparison: M versus B ($Q = 13.4$), $p < .05$; M versus P ($Q = 10.4$), $p < .05$; M versus D ($Q = 0.65$), $p > .05$; D versus B ($Q = 12.8$), $p < .05$; D versus P ($Q = 9.8$), $p < .05$; P versus B ($Q = 3$), $p > .05$.

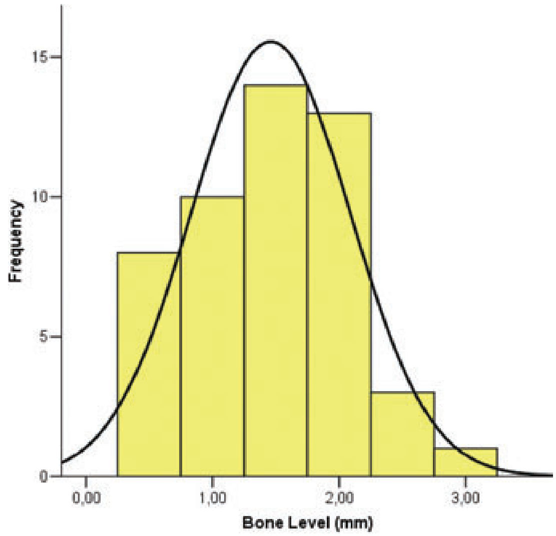

Figure 3 Diagram of frequency distribution of bone levels.

orientation is advisable whenever the Osstell is used to report the outcome of different implant systems.

The second finding of the study was the lack of correlation between ISQ values and bone levels. According to previous in vitro and in vivo studies, a strong negative correlation exists between ISQ and bone levels,[2,3] in fact greater distances of the transducer from the bone significantly lower the ISQ values. This was not the case in the present study and similarly, Balleri and colleagues[11] reported no significant correlation when measuring the ISQ values of maxillary and mandibular implants after 1 year of loading. In the same way, Bischof and colleagues[6] did not find any difference when comparing the ISQ of ITI implants placed 1 mm deeper into bone because of aesthetic considerations and implants placed in normal relation to the bony crest. Interestingly, for implants placed in gypsum blocks, Huang and colleagues[12] reported the same lack of correlation between resonance frequencies and boundary heights when the height of the gypsum was less than 3 mm from the neck of the implant. In contrast, a strong correlation was found if boundary height was more than 3 mm; it was therefore concluded that RF becomes more sensible to bone losses when those exceed 3 mm. However, it has to be pointed out that in Huang and colleague's study,[12] RF was measured using a transient method which is slightly different from the static method applied in the Osstell. When considering previous in vivo data by Meredith and colleagues[3] regarding the static method, a correlation resulted between RF and bone levels; however, the exposed implant lengths were higher than in the present study. In fact, the experimental equipment for RF analysis could not compensate for abutment length, and as a consequence, the RF values were plotted versus exposed implant lengths which included abutment heights. In another in vitro study by Meredith and colleagues,[1] the RF of implants embedded in metallic blocks and luted with resin was measured. Implants were exposed for 5, 4, 3, 2, 1 mm or were completely embedded, and although some scatter of the data was noted for 0 and 1 mm levels, a strong correlation resulted between RF and exposed implant length. Even though these results seem controversial, a possible explanation for the lack of correlation resulted between RF and bone levels of the present study could be because of the fact that the distance of the first bone contact from the transducer was minimal. This explanation seems to be supported by the present data where the majority of the implants had similar bone levels (in the range of 1.5 or 2 mm below the implant-abutment connection) and no great variation in bone levels resulted. In fact, the possibility that a high stiffness of the bone implant interface could overshadow the influences of small bone losses that eventually occurred at implants should be considered. On the other hand, Sennerby and colleagues[13] showed in an animal model that RF was sensitive to detect changes in stability caused by the initiation and resolution of an experimental peri-implantitis. In that study, RF values appeared to be linearly related to continuous bone resorption as measured radiographically. Contrary to Sennerby and colleague's[13] investigation, in the present study RF was measured only once, therefore it is likely that repeated measurements would have been significantly related to the bone losses that eventually occurred.

In conclusion, when measuring the RF of dental implants using the Osstell it has to be taken into account that the transducer orientation influences the measurement. It seems therefore advisable to standardize the orientation. Moreover, although there was a tendency, any statistical significant correlation between ISQ values and marginal bone levels could not be established.

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