Measurement of Dental Implant Stability by Resonance Frequency Analysis and Damping Capacity Assessment: Comparison of Both Techniques in a Clinical Trial

Jürgen Zix, MD, DMD[1]/Stefan Hug, MD, DMD[2]/Gerda Kessler-Liechti, DMD[2]/
Regina Mericske-Stern, DMD, PhD[3]

Purpose: *Two noninvasive methods to measure dental implant stability are damping capacity assessment (Periotest) and resonance frequency analysis (Osstell). The objective of the present study was to assess the correlation of these 2 techniques in clinical use.* ***Materials and Methods:*** *Implant stability of 213 clinically stable loaded and unloaded 1-stage implants in 65 patients was measured in triplicate by means of resonance frequency analysis and Periotest. Descriptive statistics as well as Pearson's, Spearman's, and intraclass correlation coefficients were calculated with SPSS 11.0.2.* ***Results:*** *The mean values were 57.66 ± 8.19 implant stability quotient for the resonance frequency analysis and −5.08 ± 2.02 for the Periotest. The correlation of both measuring techniques was −0.64 (Pearson) and −0.65 (Spearman). The single-measure intraclass correlation coefficients for the ISQ and Periotest values were 0.99 and 0.88, respectively (95% CI). No significant correlation of implant length with either resonance frequency analysis or Periotest could be found. However, a significant correlation of implant diameter with both techniques was found (*$P < .005$*). The correlation of both measuring systems is moderate to good. It seems that the Periotest is more susceptible to clinical measurement variables than the Osstell device. The intraclass correlation indicated lower measurement precision for the Periotest technique. Additionally, the Periotest values differed more from the normal (Gaussian) curve of distribution than the ISQs. Both measurement techniques show a significant correlation to the implant diameter.* ***Conclusion:*** *Resonance frequency analysis appeared to be the more precise technique.* Int J Oral Maxillofac Implants 2008;23:525–530

Key words: *damping capacity assessment, implant stability, osseointegration, resonance frequency analysis*

Treatment success of dental implants is mainly dependent on the stability of the implant-bone interface. The success criteria proposed by Buser et al[1] and Cochran et al[2] include *(1)* absence of clinically detectable implant mobility, *(2)* absence of pain or any subjective sensation, *(3)* absence of recurrent peri-implant infection, and *(4)* absence of continuous radiolucency around the implant after 3, 6, and 12 months of loading. However, none of the currently used assessment methods is able to predict treatment outcomes.[3] It is documented that clinical as well as radiologic examination are of limited value in predicting treatment outcome of implants, such as implant survival and maintenance of osseointegration.[4,5] Although there is insufficient evidence to demonstrate that quantitative measurement techniques have a reliable prognostic value in predicting loss of implant stability, the damping capacity assessment (Periotest) and the resonance frequency analysis (RFA; Osstell) are currently—apart from radiographs—objective methods to monitor the state of osseointegration.[3]

[1]Resident, Department of Cranio-Maxillofacial Surgery, University of Bern, Switzerland.
[2]Resident, Department of Prosthodontics, School of Dental Medicine, University of Bern, Switzerland.
[3]Professor and Chair, Department of Prosthodontics, School of Dental Medicine, University of Bern, Switzerland.

Correspondence to: Prof Dr R. Mericske-Stern, Department of Prosthodontics, School of Dental Medicine, University of Bern, Freiburgstr 7, CH-3010 Bern, Switzerland. Fax: +41 31 632 49 33. E-mail: regina.mericske@zmk.unibe.ch.

Both techniques are stability measurements using a controlled force to detect lateral movement, but they differ substantially in their technical aspect. The Periotest consists of a small computer connected to a handpiece with an 8-g tapping rod inside. Using an electromagnetic accelerator, the tapping rod strikes a tooth or implant 16 times in 4 seconds at a velocity of 0.2 m/s. The contact time between the tapping rod and the implant is measured and converted by the computer into Periotest values.[6] Periotest values range from 8 for maximum stability to +50 for clinical mobility. The device was initially designed for the measurement of tooth mobility, but it is also used for the stability assessment of implants. Several authors have concluded that the Periotest is a reliable method to monitor changes in the implant-bone complex and is therefore an adequate tool in assessing the stability status of an implant.[6–10] However, the sensitivity and specificity of the Periotest still need to be determined. A recent study[11] evaluated the prognostic value of the Periotest for early implant failure. With a cutoff Periotest value of –2, the authors found a sensitivity of 84% and a specificity of 39% for determining implant failure. These values show the problem of detecting implant failure at an early stage. Other authors point out the limitations of this method due to several sources of error in clinical application.[12] Unlike the Periotest, which generates forces mechanically, the RFA method uses the piezo effect to produce a deflection of the implant. The transducer, which is attached either directly onto the implant or to the abutment, contains 2 piezoceramic elements. The first piezo element generates an excitation signal (a sinusoidal wave varying in frequency from 5 to 15 kHz), which leads to a vibration of the whole transducer-implant-tissue complex. The subsequent response oscillation is measured by the second piezo element. This signal is then amplified, analyzed, and finally displayed graphically as well as numerically in a unit called the implant stability quotient (ISQ).[13] ISQs range from 1 (mobility) to 100 (maximum stability).[13] Nedir et al[14] found a sensitivity of 100% and a specificity of 97% for the Osstell device (Integration Diagnostics) with a cutoff ISQ of 47 for determination of implant stability.

Multiple studies have investigated the commercially available measuring devices Osstell and Periotest for the measurement of dental implant stability and confirmed the usefulness of both methods for this purpose.[4–10,13,15–17] The objective of the present study was to evaluate the presumed correlation of the RFA technique and the damping capacity assessment of the Periotest in a clinical trial.

MATERIALS AND METHODS

Patients

The study was conducted from June 2004 to April 2005 at the Department of Prosthodontics, School of Dental Medicine, University of Bern, Switzerland. Edentulous patients with maxillary and mandibular implants and removable prostheses were eligible if they had participated regularly in a maintenance care program after completion of implant-prosthodontic treatment. Their records and radiographs confirmed that the implants had been clinically successful for the entire time before the measurements took place. In the context of the present study, the measurements of the loaded implants were obtained when the patients were recalled by the dental hygienist. The program is based on recall appointments with a 6- to 12-month frequency. During this maintenance visit, the bar was removed and the measurements could easily be made. Unloaded implants were measured in patients who underwent the surgical procedure of maxillary and mandibular implant placement during the same time period. All patients gave their written consent to undergo the measurements.

Implants

The implants measured were solid-screw Straumann implants (Straumann, Waldenburg, Switzerland). Only implants that were stable and showed no clinical signs of peri-implant tissue loss or infection were included in the study. All implants were placed at the Department of Prosthodontics during a period of 6 years using a nonsubmerged, single-stage technique according to a standard surgical procedure.[18] All prostheses were connected to the implants by means of an octa-abutment.

RFA

Implant stability was measured in triplicate for each patient by a single experienced dentist using the RFA technique with the Osstell I instrument (Integration Diagnostics). From previous studies the examiner had experience using this device.

In 20 patients the measurements with RFA and Periotest were carried out immediately after implant surgery, ie, on unloaded implants. In the remaining patients, the implants were measured after a loading period of up to 6 years (minimum, 1 year). In cases of loaded implants, the screw-retained prostheses were removed and the transducer (type A11) was screwed onto the octa-abutment. Unloaded implants were directly connected with the standard and wide-neck transducer (type F4). The ISQs were recorded and analyzed by personal computer (MS Excel 9.0; Microsoft, Redmond, WA).

Table 1 Implant Length in mm

Length	Frequency	Percentage
6	3	1.4
8	15	7
10	65	30.5
12	123	57.7
14	7	3.3
Total	213	100.0

Table 2 Implant Diameter in mm

Diameter	Frequency	Percentage
3.3	68	31.9
4.1	142	66.7
4.8	3	1.4
Total	213	100.0

Periotest

The Periotest measurements (Siemens Gulden-Medizintechnik, Bensheim, Germany) were performed in triplicate for each implant by an experienced clinician according to the manufacturer's manual. From several previous studies, the examiner had experience using this device.

The Periotest was repeated when there was a difference of ≥ 8 between 1 or more measurements. The results were documented and analyzed using the same method described for ISQs.

Statistical Analysis

Descriptive statistical analysis was applied for distribution of RFA and Periotest values. Pearson's, Spearman's, and intraclass correlation coefficients were calculated. Linear regression analysis was performed for both test values with length and diameter of implants as independent parameters. The quantile-quantile plot was used to evaluate whether the 2 datasets (RFA and Periotest) had a common distribution. This graphic data analysis techique for comparing the distribution of 2 datasets has 2 components: *(1)* the quantile points themselves and *(2)* a 45-degree reference line. If the 2 datasets come from a population with the same distribution, the points should fall approximately along this line. The level of statistical significance was set at $P < .05$. All statistics were performed with SPSS 11.0.2 (SPSS, Chicago, IL).

RESULTS

Altogether 65 edentulous patients with a mean age of 63.1 years were included in the study. In 45 cases, the implants were loaded; 20 patients' implants were measured immediately after surgery.

One hundred five implants (49%) were located in the maxilla and 108 (51%) in the mandible. Forty-seven percent of all implants were placed in female patients. Implant lengths ranged from 6 to 14 mm, and diameters of 3.3, 4.1, and, in a few cases, 4.8 mm were used (Tables 1 and 2).

Altogether the triplicate measurements exhibited values close to each other for the 2 techniques. The overall mean ISQ value was 57.66 ± 8.19 (range, 23 to 73) for RFA. Periotest values ranged from + 5 to –7.67 with a mean value of –5.08 and a standard deviation of 2.02.

The correlations of both measuring techniques were –0.64 (Pearson) and –0.65 (Spearman). A scatterplot of Periotest versus RFA measurements is diagrammed in Fig 1. The single-measure intraclass correlation coefficients for the ISQ and Periotest values were 0.99 and 0.88, respectively (95% CI). Significant correlation of implant stability with implant length could be found for neither Periotest nor RFA (Figs 2 and 3). The correlation of RFA and Periotest values with implant diameter was statistically significant (Figs 4 and 5). *P* values are given in Table 3.

The quantile-quantile plots (Figs 6 and 7) show that the distribution of RFA values was almost linear to the normal distribution. Fig 7 clearly shows that the Periotest values differed more from the normal distribution than the RFA values.

DISCUSSION

The first reports of stability measurements of dental implants with the Periotest device and the RFA technique were published in 1990 and 1996, respectively.[16,17] Only recently, 2 studies came out that compared both measuring methods in an in vitro experiment.[19,20] Up to now, no direct comparison of both techniques in a clinical setting has been conducted.

The laboratory experiments with the Osstell and the Periotest instrument showed a statistically linear association between measurements, with high statistical correlation coefficients of –0.9 and –0.8.[19,20] Compared to these results, the correlation of both methods in this clinical trial is clearly less pronounced. In clinical use, the examiner is limited by access, space, and patient compliance, unlike in a laboratory experiment, where a standardized measuring

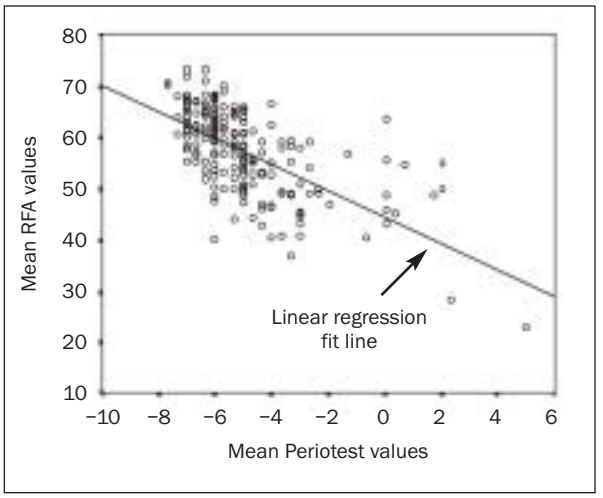

Fig 1 Scatterplot of Periotest values versus ISQs.

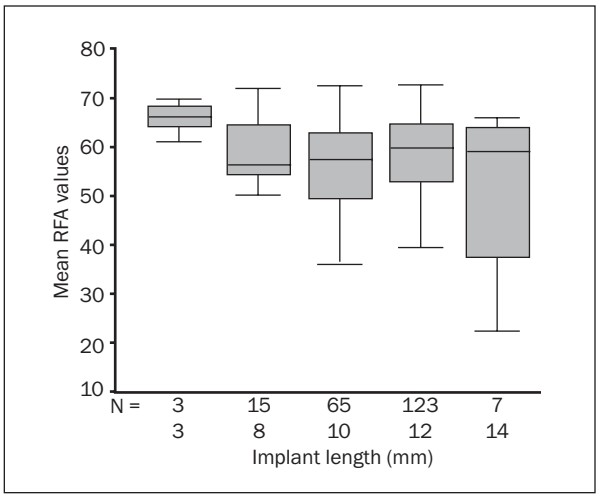

Fig 2 Boxplots of ISQs as a function of implant length.

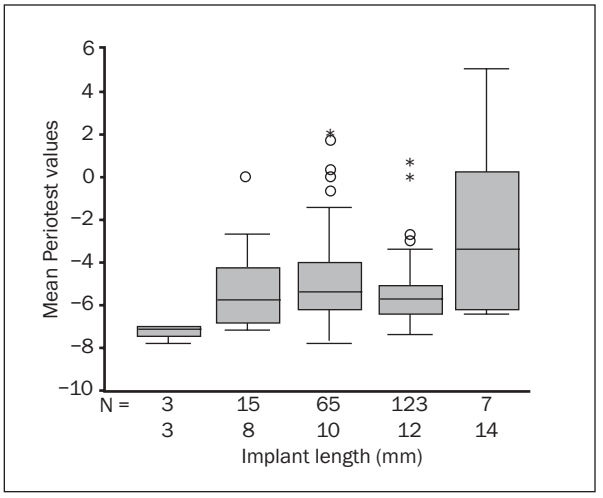

Fig 3 Boxplots of Periotest values as a function of implant length. (* represents extreme values; o represents outliers.)

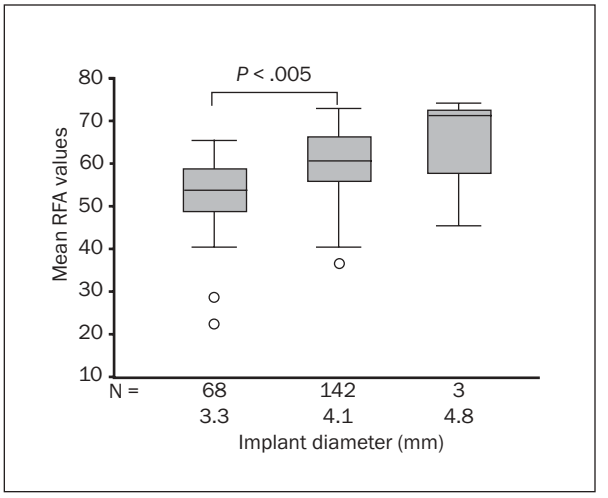

Fig 4 Boxplots of ISQs as a function of implant diameter.

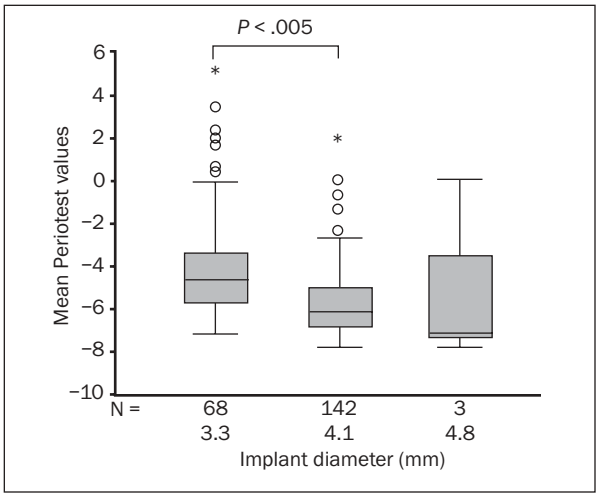

Table 3 *P* Values for Implant Diameter and Length

Implant	RFA	Periotest
Diameter	< .005	< .005
Length	.232	.594

Fig 5 Boxplots of Periotest values as a function of implant diameter. (* represents extreme values; o represents outliers.)

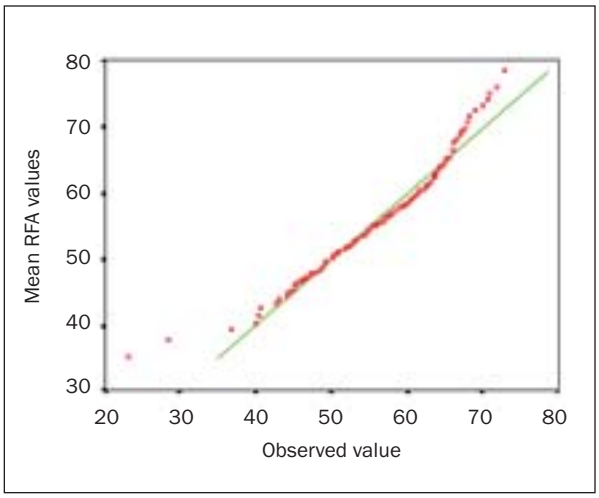

Fig 6 Quantile-quantile plots of ISQs.

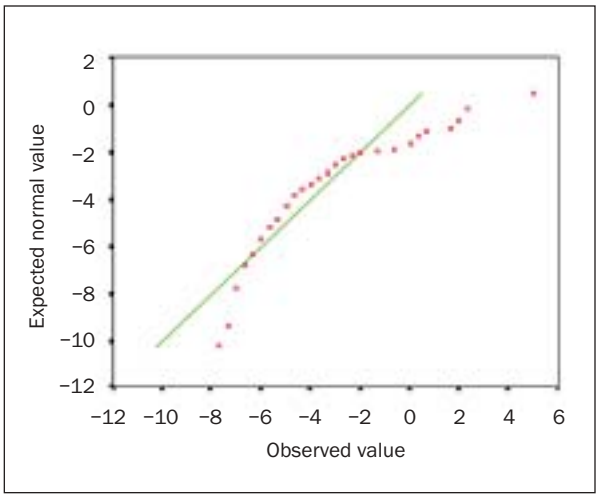

Fig 7 Quantile-quantile plots of Periotest values.

set-up permits constant conditions. Thus, the in vivo testing has additional sources of error, which result in reduced measurement accuracy. Both measurement devices are sensitive to changes in the abutment length above the marginal bone crest and to soft tissue contact with either the implant or the measuring unit.[12,15] However, in the case of the Periotest, other influencing variables may adulterate the measured value. These factors, notably the angulation of the handpiece, the vertical measuring point on the implant abutment, and the horizontal distance of the handpiece from the implant,[12] can be well controlled in a standardized measuring set-up but not in in vivo testing. As indicated by the lower intraclass correlation coefficient, the Periotest instrument showed a poorer reproducibility than the Osstell device. Also, the quantile-quantile plot (Figs 6 and 7), which visualizes whether a data sample follows a normal distribution, shows that the Periotest values were distributed further from the Gaussian curve. In contrast, the ISQs were between 40 and 70, which seems to be the range of stable ITI implants,[21] and they followed the normal distribution well. Moreover, the lower intraclass correlation coefficient supports the assumption that the Periotest is more susceptible to clinical measurement variables than the Osstell device. Intraclass correlation coefficients assess the consistency between 2 methods of measurement. In the present study, both measurement devices showed a significant correlation with the implant diameter ($P < .005$) but not with the implant length.

Although in this study the time needed to measure with either system was not recorded, it is obvious that from the clinician's point of view, the Periotest system is more user-friendly and time- as well as cost-efficient because unsplinted suprastructures need not be removed, and the measuring unit has unlimited functioning. In addition, the use of the Osstell device is limited by the fact that RFA transducers are not available for all implant systems.

The present study considered correlation between the RFA and Periotest techniques at a given time point. It is well known from the literature that single measurements are of limited value in assessing and predicting the stability of an implant because of the interindividual variability of values. Hence, future studies should investigate the correlation of both techniques in a dynamic, longitudinal study by conducting measurements on the same set of implants over time. Such studies might further help to evaluate accuracy and precision of both methods.

CONCLUSION

Both measuring techniques are applicable in the assessment of implant stability. The Osstell instrument seemed to be more precise than the Periotest, which exhibited a broader standard deviation and resulted in a lower interclass correlation coefficient. Periotest values appear to be more susceptible to clinical conditions.

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