The Evaluation of the Reliability of Periotest for Implant Stability Measurements: An In Vitro Study

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Periotest (Medizintechnik Gulden, Modautal, Germany) is a widely accepted implant stability measurement method, although the reliability is not well known. The aim of this in vitro study was to investigate the reliability of the Periotest in implant stability measurements. Thirty implants were placed in 3 cow ribs. The stability of each implant was measured by insertion torque, resonance frequency analyses, and Periotest and then compared. The Periotest values (PTVs) were measured by 4 different examiners. The measurements were repeated twice in both the buccal and mesial directions, for each implant at 2-hour intervals and the intra- and interobserver reliability of Periotest was measured. Results showed that the intraobserver reliability of the Periotest was excellent for the buccal PTVs but fair to poor for the mesial PTVs. The interobserver reliability of the Periotest was excellent for the buccal PTVs but poor for the mesial PTVs. No significance was found between the PTVs and IT values ($P = .803$) and PTVs and ISQ values, whereas a 47.1% significant correlation was detected between the IT values and ISQ values ($P = .009$). The present study indicates that only Periotest measurements from buccal result in excellent intra- and interobserver reliability for the quantification of the implant stability.

Key Words: in vitro model, dental implant, statistics, Periotest, resonance frequency analysis, Osstell, insertion torque, implant stability

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INTRODUCTION

Implant stability, whether immediately following surgery (known as primary stability) or during and after the healing process (secondary stability) is an important parameter in evaluating the situation of osseointegrated implants as well as in the decision of timing of loading.[1–3] Acceptable primary stability is a key factor to consider before immediately loading the implants.[4] It is of great value to obtain reliable numerical data about the amount of stability since determination of objective information will directly influence the treatment outcome.[5–7] Objective data are necessary to decide about the loading protocols for immediate, early, or delayed loading. The method used for measuring implant stability is expected to be accurate, repeatable, and reliable.[8] Various measurement techniques exist for measuring dental implant stability.[9–12] Studies about correlation among these stability measurement techniques and relationship between bone quality and implant stability may be important in evaluating the prognosis of implants and achieving effective treatment planning. Except for the IT measurement, the two other methods for the evaluation of the clinical stability of implants—including the Periotest (Medizintechnik Gulden, Modautal, Germany) and resonance frequency analysis—can be accepted as noninvasive and not damaging for the implant-bone interface.[13]

Among these, the resonance frequency analysis (RFA) technique has been used extensively for about 10 years, but its use is controversial and a study stated that it is unreliable for the analysis of the prognosis of implant survival.[14]

As pointed out in a couple of studies,[2,15,16] implants showing unusual decreases in stability values should alert the clinicians and push them to take additional precautions, such as unloading until implant stability is regained and checking for trauma or infection. In a situation where the implants are already loaded and the stability should be measured, the removal of a cemented crown and tightened abutment for mounting of a SmartPeg (Osstell AB, Goteborg, Sweden) for a RFA measurement could create a challenging task. The Periotest has an important advantage against the others: it can be applied directly on the implant superstructure. The Periotest is a commonly used method,[17,18] but there is limited evidence on its reliability. It has been shown in a former study associated with specific model samples that the Periotest demonstrated a high degree of reliability and repeatability.[17,18] That said, Periotest values (PTV) showed variations when the measurements were made with gingiva formers or abutments in a more recent clinical study.[19] Accordingly, the confusion

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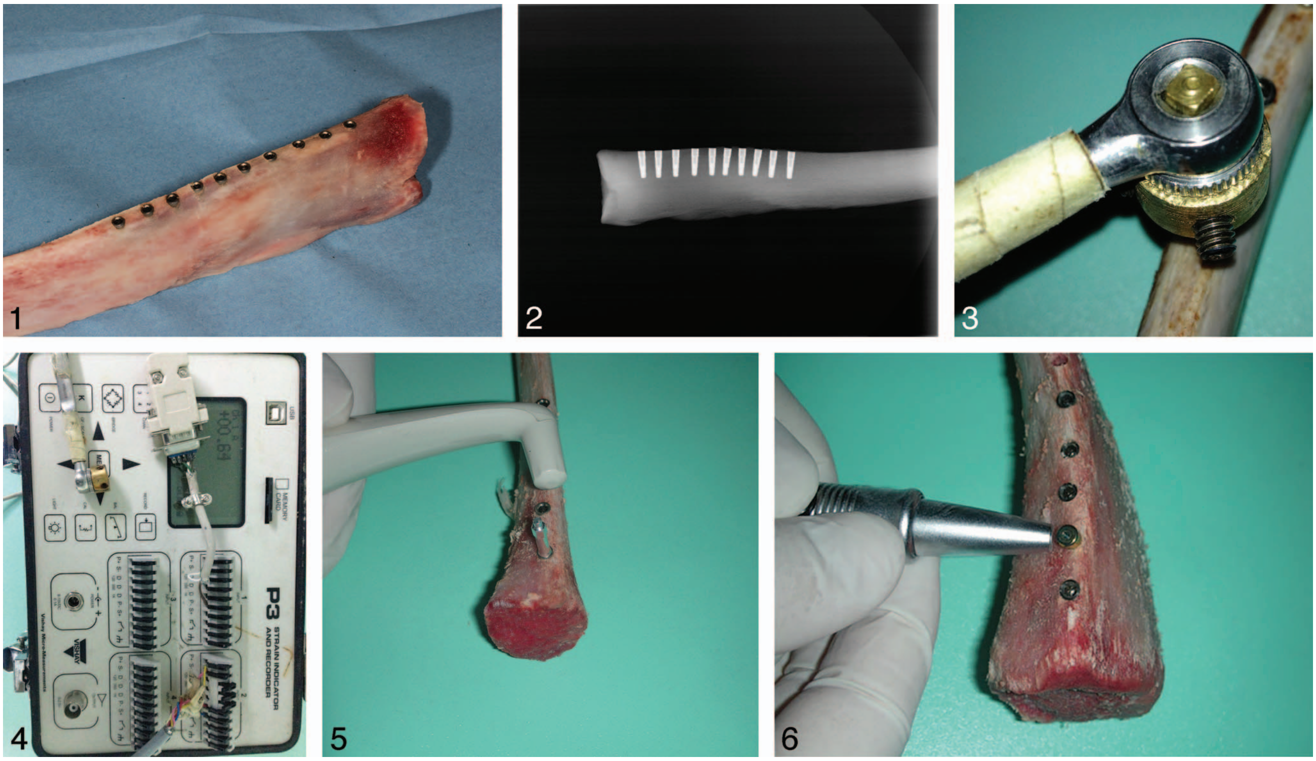
DOI: 10.1563/AAID-JOI-D-13-00303



Figures 1-6. Figure 1. The view of one of the ribs with the inserted 10 implants. **Figure 2.** The hand wrist radiograph taken from the rib to see the exact positions of the implants. **Figure 3.** The measurement of insertion torque using the custom-made device. **Figure 4.** The strain gauge measurement system. **Figure 5.** The measurement of RFA using Osstell Mentor (Integration Diagnostics, Savedalen, Sweden). **Figure 6.** The measurement of PTVs using the Periotest (Medizintechnik Gulden).

about the reliability of the Periotest still exists, and further evaluation within the clinical environment is necessary.

The purpose of this in vitro study was to test the reliability of Periotest in measuring the implant stability in fresh cow bone (demonstrating the human jawbone instead of artificial models) and additionally to evaluate the relationship between the 3 known objective methods that have been clinically used, primarily for the evaluation of implant stability.

Material and Methods

In vitro specimen preparation

Three fresh cow ribs belonging to the same animal, obtained from a butcher shop, were selected for the experimental procedures. The ribs served as a model of human edentulous jawbone owing to the macroscopic composition of cortical and medullar bone.[20] The ribs had a minor portion of cortical bone and a greater proportion of medullar bone,[8] similar to a type 3 quality bone according to the classification of Lekholm and Zarb.[21,22] Ten implants were inserted into each rib (Figure 1), with a safe distance from each other, for a total of 30 implants. The implants were all 3.8 mm wide and 13 mm long and from the same manufacturer (Trias Implant System, Servo-Dental GmbH & Co, Hagen, Germany) to maintain a standard test condition. The implant beds were prepared following the standard drilling protocol recommended by the manufacturer. Hand wrist radiographs were taken from the ribs to see the exact positions of the implants using Orthophos XG5 Sirona digital machine (Sirona Dental Company, Bensheim, Germany) with an exposure parameter of 64 kvp, 9s, 16 mA (Figure 2).

Measurements

The insertion torque (IT), RFA, and PTV of each implant was measured by the researcher having placed the implants. The PTVs were then additionally measured by 3 different examiners. The Periotest measurements were repeated twice in both the buccal and mesial directions for each implant at 2-hour intervals, and the averages of registered PTVs were recorded as the buccal PTV and the mesial PTV for every implant. The registered ISQs were recorded as the buccal ISQ value for the frontal and mesial ISQ for the lateral measurements for each implant.

IT Measurements

After completing the implant bed preparation, each implant was inserted until the rough area was completely covered and the highest final IT value was recorded in Ncm by using a custom-made device (Figure 3). An individual tip suitable for the fixation of drivers of all implant systems was manufactured and positioned in a hand wrench of the Zimmer Dental Implant System (Zimmer Dental, Carlsbad, Calif) that carried two strain gauges (Micro Measurements Division Type EA-06-125MW-120, Measurements Group Inc, Raleigh, NC) connected to a strain

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gauge measurement system (Strain Indicator and Recorder, Model P3, Serial 159606, Vishay Micro-Measurements, Raleigh, NC, Figure 4).

The RFA measurements were made by using the Osstell Mentor device (Osstell AB). A magnetic peg calibrated for Trias implants was inserted by means of a plastic screwdriver (Smartpeg type 6; Osstell AB) and hand-tightened by the main examiner on each implant. The probe of the analyzer was held 1 mm from the peg at a 90° angle (Figure 5). After a few seconds, the RFA value was registered as an ISQ value on the digital screen of the instrument. The averages of registered ISQs were held as buccal ISQ value for the frontal and mesial ISQ for the lateral measurements for each implant.

Periotest Measurements

This electronic instrument can measure quantitatively the mobility and the results are represented as PTVs, from −8 (lowest mobility) to +50 (highest mobility). To guarantee a good direct contact of the Periotest tip on the implant, a gingivaformer was screwed on each implant, hand tightened, and the PTVs were measured (Figure 6). To test the interobserver reliability of the method, Periotest measurements were carried out additionally by three other prosthodontists, blinded to the study protocol, using the Periotest Classic device. All examiners repeated the measurements after 2 hours of waiting period to test the intraobserver reliability and to gain time for disremembering the position of the Periotest in the previous measurement.[20] At the end, all values were evaluated then for inter- as well as intraobserver reliability.

Statistical analysis

For the statistical analysis of the results, Statistical Package for Social Sciences software (SPSS Inc, Release 15.0 for Windows, Chicago, Ill) was used. The relevance of the parameters to the normal distribution was analyzed by using Kolmogorov-Smirnov test. Comparison between the means of the first and the second measurements for each observer was analyzed by using Wilcoxon sign test.

Interobserver and intraobserver reliability was measured by the interclass correlation coefficient (ICC). The difference within the measurements of each observer was evaluated by using analysis of variance test, and Bonferroni's test was used for post hoc comparisons. The difference between the measurements of the observer was analyzed by using Friedman test. The ICCs were qualified as recommended previously,[20,23–25] ICC < 0.4 is poor reliability; ICC between 0.4–0.7 is fair-to-good reliability, and ICC > 0.7 is excellent reliability. The level of significance was set at 95% ($P < .05$).

Results

Intraobserver reliability

The PTVs obtained from the buccal and mesial measurements of the examiners are shown in Table 1. The ICC values for the intraobserver reliability were 0.985 in examiner 1 (95% IC; 0.913; 0.978), 0.983 in examiner 2 (95% IC 0.964; 0.992), 0.972 in examiner 3 (95% IC 0.942; 0.986) and 0.992 (95% IC 0.984; 0.996) in examiner 4 for the buccal PTVs. All the ICC values for the buccal measurements were evaluated as excellent. For the mesial PTVs, the ICC values for the intraobserver reliability were 0.668 in examiner 1 (95% IC 0.567; −0.752), 0.159 in examiner 2 (95% IC −0.208; 0.487), 0.382 in examiner 3 (95% IC 0.031; 0.649), and 0.243 in examiner 4 (95% IC −0.23; 0.550). The ICC values for the mesial measurements were evaluated as fair in examiner 1 but poor in the other examiners. The mean of the PTVs measured by all of the examiners are shown in Table 2.

Interobserver reliability

For the buccal PTVs, the ICC values for the interobserver reliability were 0.970 in the first measurements (95% IC 0.948; 0.984) and 0.986 in the second measurements (95% IC 0.976; 0.993) of the 4 examiners. All the ICC values for the buccal measurements were evaluated as excellent.

For the mesial PTVs, the ICC values for the interobserver reliability were 0.253 in the first measurements (95% IC 0.080; 0.467) and 0.391 in the second measurements (95% IC 0.207; 0.593) of the 4 examiners. All the ICC values for the mesial measurements were evaluated as poor.

Notwithstanding, no significance was found between the PTVs and IT values ($P = .803$), but a 47.1% significant correlation was detected between the IT values and ISQ values ($P = .009$). Additionally, a 30.3% negative correlation was found between PTVs and ISQ values but this correlation was not significant ($P = .104$).

Discussion

Methods for the evaluation of the clinical stability of implants involve quantitative assessments that are noninvasive, do not damage the implant-bone interface, and are expected to be objective.[13] Several methods such as Periotest, IT, or the RFA have been introduced for the measurement of the implant stability in bone and obtaining objective values. The main purpose of this study was to evaluate the reliability of Periotest measurements in the determination of implant stability in bone. Periotest is an electronic instrument developed to quantitatively measure the damping characteristic of the periodontal ligament of teeth and evaluate their mobility.[26] Although this method was developed for teeth, it is also being used to assess the stability of implants.[12] However, this method is reported to have a few limitations, such as the narrow range of values, from approximately −5 to +5 for measuring implant mobility. The sensitivity of this method has been reported not to be sufficient[27,28] and to be affected by a variety of factors, such as the striking position, the location of implants, as well as the handpiece angulation.[29] The above-mentioned factors could be the reason for the dissonant intra- as well as the interobserver measurement values for the mesial PTVs. It should be noted that between the measurements from the mesial side, performed by the same investigator 2 hours apart, fair to poor ICC values were obtained. Except the incongruence observed in the mesial measurements, the intra- and interobserver reliability of buccal measurements in this study was excellent, which is in accordance with the results of Manz et al.[17,18] The main reason for such diverse measurement results

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Table 1

PTVs obtained from the buccal and mesial measurements of the examiners

	Examiner 1				Examiner 2				Examiner 3				Examiner 4			
	1st Measurement		2nd Measurement		1st Measurement		2nd Measurement		1st Measurement		2nd Measurement		1st Measurement		2nd Measurement	
Implants	Buccal	Mesial	Buccal	Mesial	Buccal	Mesial	Buccal	Mesial	Buccal	Mesial	Buccal	Mesial	Buccal	Mesial	Buccal	Mesial
1	−5	−6	−5	−5	−5	−6	−5	−7	−6	−6	−6	−6	−5	−6	−5	−6
2	−6	−6	−5	−6	−5	−7	−6	−7	−6	−7	−6	−6	−6	−7	−6	−7
3	−6	−7	−5	−6	−5	−7	−6	−7	−6	−6	−6	−7	−6	−7	−6	−6
4	−6	−7	−6	−7	−6	−8	−6	−8	−7	−7	−7	−8	−6	−8	−6	−8
5	−5	−7	−4	−6	−6	−7	−5	−7	−5	−6	−6	−7	−5	−7	−5	−6
6	−6	−7	−6	−7	−7	−8	−6	−8	−7	−7	−6	−8	−6	−7	−6	−7
7	−7	−7	−7	−7	−7	−8	−6	−7	−8	−7	−7	−8	−6	−8	−7	−8
8	−7	−7	−7	−7	−8	−8	−7	−7	−3	−8	−7	−7	−7	−7	−7	−7
9	−7	−7	−7	−7	−7	−8	−7	−7	−8	−8	−7	−7	−7	−7	−6	−7
10	18	−6	20	−6	20	−8	20	−8	21	−8	17	1	17	−6	16	−6
11	−7	−7	−7	−7	−7	−7	−7	−7	−7	−7	−8	−8	−7	−8	−7	−7
12	−7	−7	−7	−7	−7	−7	−7	−7	−7	−8	−7	−8	−7	−7	−7	−8
13	−7	−8	−8	−7	−7	−7	−6	−7	−7	−8	−8	−8	−7	−8	−7	−8
14	−6	−7	−7	−8	−7	−7	−7	−7	−7	−8	−7	−8	−7	−6	−7	−7
15	−7	−8	−8	−8	−7	−7	−7	−8	−8	−8	−8	−8	−7	−8	−8	−8
16	−7	−8	−8	−8	−7	−8	−7	−8	−8	−8	−8	−8	−7	−8	−8	−8
17	−7	−7	−7	−7	−7	−7	−7	−7	−8	−8	−7	−8	−7	−8	−7	−8
18	−6	−7	−7	−7	−7	−8	−7	−7	−6	−7	−7	−8	−7	−8	−7	−8
19	−7	−7	−7	−7	−3	−3	−6	−7	−5	−6	−6	−8	−7	−8	−7	−7
20	−6	−7	−6	−7	−4	−5	−6	−8	−6	−8	−7	−7	−5	−3	−7	−8
21	−5	−7	−7	−8	−5	−7	−7	−8	−8	−8	−8	−8	−7	−7	−7	−7
22	−6	−7	−7	−7	−7	−7	−7	−7	−8	−7	−8	−8	−7	−7	−7	−7
23	−7	−8	−7	−8	−7	−7	−7	−7	−7	−8	−8	−8	−7	−7	−7	−7
24	−7	−7	−7	−7	−7	−7	−8	−7	−8	−8	−8	−8	−7	−8	−7	−7
25	−6	−8	−7	−8	−7	−7	−7	−7	−8	−8	−8	−7	−7	−8	−7	−7
26	−7	−8	−8	−8	−7	−7	−7	−7	−7	−8	−8	−8	−7	−8	−7	−8
27	−8	−8	−8	−8	−7	−8	−7	−7	−8	−8	−8	−8	−7	−8	−7	−8
28	−8	−8	−7	−7	−7	−8	−7	−8	−8	−8	−8	−8	−7	−8	−7	−7
29	−8	−8	−8	−8	−7	−6	−8	−7	−8	−8	−8	−8	−7	−8	−7	−7
30	−8	−8	−8	−8	−8	−8	−8	−8	−8	−8	−8	−8	−8	−8	−8	−8

may be the fact that—as pointed out in an article[30]—"if the perpendicular contact angle is larger than 20°, or if the parallel contact angle is larger than 4°, the measured value is invalid. Also, the rod and the test surface must maintain 0.6–2.0 mm distance and if the distance is over 5 mm, the measured value may be insignificant."[31] In the light of these results, it could be speculated that the Periotest method could lead to desultory measurement values especially in multicenter studies, where the observers have dissimilar conditions or measuring geometries.

Based on the results of a study comparing Periotest and RFA; it was reported that the RFA was more precise than the Periotest.[32] An animal study showed that both methods were comparably reliable, showing a strong association with each other in assessing implant stability.[33] In vitro studies had shown a significant linear association between the two above-mentioned methods.[34,35] In the present in vitro study, the results indicate that, considering implant stability measurements, the IT values were in harmony with RFA measurements, but the PTVs are not in correlation with either (Table 1). As a matter of fact, it had already been proven that RFA and Periotest measurements, implant IT values, as well as histomorphometric parameters (such as the bone mineral density) had no correlation with each other.[36] It had been stated that although negative PTVs indicate good implant stability and positive and high PTVs absence or loss of stability, the obtained values should not be regarded as prognostic values.[28] In a related study, it was even stated that in clinical application, a much greater measurement error than in in vitro experiments should be expected.[34] The PTV was reported to be sensitive to

Table 2

Mean of the PTVs measured by the examiners

	1st Measurement Mean ± SD	2nd Measurement Mean ± SD
Buccal PTVs		
Examiner 1	−5.80 ± 4.57	−5.93 ± 5.00
Examiner 2	−5.60 ± 4.97	−5.80 ± 4.93
Examiner 3	−6.07 ± 5.25	−6.47 ± 4.50
Examiner 4	−5.87 ± 4.38	−6.03 ± 4.22
Mesial PTVs		
Examiner 1	−7.23 ± 6.27	−7.13 ± 0.78
Examiner 2	−7.10 ± 1.06	−7.30 ± 0.47
Examiner 3	−7.50 ± 0.73	−7.67 ± 0.60
Examiner 4	−7.30 ± 1.05	−7.27 ± 0.69

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abutment length differences over the marginal bone, to differing superstructures used to tap against and their attachment mode.[19] The PTVs may be expected to increase by 1.5 units for each millimeter extension away from the marginal bone.[37] There are too many factors influencing the accuracy of the PTV measurements. In the light of this study's findings, it is advisable that the PTV measurements be performed from buccal.

Conclusions

Within the limitations of the present in vitro study, it can be concluded that PTVs do not have a strong correlation with ISQ values of RFA measurements or with IT values. To achieve good intra- and interobserver reliability, it is recommended that the measurements be performed from buccal. For the quantification of the implant stability for scientific purposes, a second method could be chosen for strengthening the results.

Abbreviations

ICC: interclass correlation coefficient
ISQ: instability quotient
IT: insertion torque
PTV: Periotest value
RFA: resonance frequency analysis

Acknowledgment

The authors would like to thank Emrah Cabukusta, Turkish distributer of the Trias Implant System, for providing the implants and the SmartPegs (Osstell AB) for this in vitro study.

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