A Prospective Study to Assess Osseointegration of Dental Endosseous Implants with the Periotest Instrument

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Long-term studies have documented the successful treatment of edentulous and partially edentulous patients with titanium implants. However, the inability to identify some non-osseointegrated implants before occlusal loading is costly to practitioners and patients. This study followed all patients (n = 40) who had implants placed over a 6-month period. The Periotest instrument was used at Stage II surgery, final impression, prosthesis placement, and 6 and 12 months after occlusal loading to quantify mobility/lack of mobility of implants with conventional 1-piece temporary healing abutments in place. The positive predictive value was 64%. The Periotest instrument was able to identify non-integrated implants only when measured at Stage II surgery and 12 months after occlusal loading, 64% of the time. However, Periotest values recorded at Stage II surgery are not valid predictors of non-osseointegrated implants 12 months post-occlusal loading. (INT J ORAL MAXILLOFAC IMPLANTS 2000;15:389–395)

Key words: *dental prosthesis, endosseous dental implantation, osseointegration, sensitivity and specificity*

Long-term studies have documented the successful treatment of edentulous and partially edentulous patients with endosseous titanium implants.[1–4] Success rates between 81% and 93% have been reported.[1–3] Successful treatment with endosseous implants is dependent upon a complex relationship of numerous factors[4]: *(1)* biocompatibility of the implant, *(2)* macroscopic and microscopic nature of the implant surface, *(3)* quality and quantity of bone at the implant site, *(4)* surgical technique, *(5)* healing and the presence/absence of systemic disease, and *(6)* design, fit, and long-term loading of the restoration.

Osseointegration has recently been defined as "a process whereby clinically asymptomatic rigid fixation of alloplastic materials is achieved and maintained in bone during functional loading."[5] Clinically, mobility of dental implants can be measured in macroscopic units, similar to the determination of natural tooth mobility. Tooth mobility has been graded clinically by placing a tooth between 2 metallic instrument handles and moving the tooth in as many directions as possible.[6] Mobility can be recorded as follows: Normal; Grade I: slightly more than normal; Grade II: moderately more than normal; and Grade III: severe mobility buccolingually and vertical displacement. These are qualitative assessments of mobility. Standardized measurements in recording the mobility of natural teeth are beneficial to clinicians, since mobility can be a quantitative measure of periodontal disease.

Soft tissue changes associated with lack of implant osseointegration and/or mechanical failures can also be evaluated but are not easily quantified. Reproducible, quantitative measurements of implant mobility would be valuable to clinicians and researchers in assessing osseointegration. A simple, predictable, noninvasive test to quantify implant stability and osseointegration is highly desirable. Adell[1] originally believed that osseointegration of implants could be assessed by tapping an implant

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Table 1 No. of Immobile (Mobile) Implants by Quadrant, Arch, and Gender

	Anterior maxilla	Posterior maxilla	Anterior mandible	Posterior mandible
Female	14 (4)	12 (5)	34 (0)	7 (1)
Male	7 (0)	7 (0)	15 (0)	7 (0)
Totals	21 (4)	19 (5)	49 (0)	14 (1)

Table 2 Percentage of Immobile Implants by Quadrant and Gender

	Anterior maxilla	Posterior maxilla	Anterior mandible	Posterior mandible
Female	73.7	70.6	100.0	87.5
Male	100.0	100.0	100.0	100.0
All patients	80.8	79.2	100.0	93.3

and/or abutment with a metal instrument and assessing the nature of the sound. This has proven to be unsuccessful due to the inability of humans to consistently discriminate sound in terms of specific, sensitive criteria.[7]

The clinical presence of mobility in endosseous implants has been one of the parameters used to assess a lack of osseointegration.[7–10] However, detection of mobility cannot be made until gross macroscopic movement is visualized. A microscopic, quantitative method of detecting early, minute mobility of implants would be helpful in assessing the presence or absence of osseointegration. If a clinician could detect implant mobility early in the course of treatment, expenses related to fabrication of a restoration could be saved if the implant is not osseointegrated.

An instrument that quantifies mobility of teeth has been developed (Periotest, Siemens AG, Bensheim, Germany). It was originally designed to measure tooth movement in quantitative units. The manufacturer suggests that tooth mobility can be quantitatively ascertained with a high degree of precision in the absence of pathologic radiographic findings.[11]

The Periotest instrument has been used to measure implant mobility.[12–16] Olivé and Aparicio described Periotest values (PTVs) for commercially pure titanium implants of –5 to +5.[16] Osseointegrated implants are considered to be ankylosed. This phenomenon translates into negative or low positive readings (ie, less than 5) on the Periotest value scale. Truhlar et al[13] reported in a study involving over 2,000 osseointegrated implants that the range of mean PTVs was less than 2 PTVs for implants placed into bone with a range of 1 to 4 in bone quality. However, the assessment of bone quality remains qualitative.

The purpose of this study was to quantitatively measure the mobility of endosseous titanium implants at the time of second-stage surgery in humans using the Periotest instrument. Measurements of the implants were also made at various times after the implants were uncovered, including 1 year after occlusal loading of the implants. Analyses were performed to determine whether certain Periotest values made at the time of implant exposure (second-stage surgery) could be reliable predictors of long-term osseointegration.

MATERIALS AND METHODS

The patient population consisted of patients treated by the author. Implants were placed by 4 oral and maxillofacial surgeons at the Gundersen Clinic, La Crosse, Wisconsin. All of the surgeons had been placing implants for at least 5 years. The numbers of implants previously placed by the surgeons ranged from 60 to 500. The study included all patients (n = 40; 14 male, 26 female) who elected to have implants placed over a 6-month period (Tables 1 and 2). Seventy-seven implants were placed into 26 female patients (35 maxillae, 42 mandibles), and 36 implants were placed into 14 male patients (14 maxillae, 22 mandibles). The range of patient ages was 18 to 76 years. The study was approved by the Institutional Review Board of the Gundersen Medical Foundation. The protocol for placement of the endosseous titanium implants (3i, Palm Beach Gardens, Florida) was established by Brånemark.[17] One hundred thirteen implants were placed. All implants were at least 10 mm in length, and no implant exceeded 18 mm in length. Implants were either 3.75 or 4.0 mm in diameter. Twenty-five implants were placed into anterior maxillae, 24 into posterior maxillae, 49 into anterior mandibles, and 15 into posterior mandibles. The anterior maxilla was defined as corresponding to tooth locations canine to canine. The anterior mandible was defined as the bone volume available between the mental foramina.

At least 4 months of healing occurred for mandibular implants and 6 months for maxillary implants before the implants were uncovered. Implants were used to provide retention and support for implant-retained crowns, bars/overdentures, or fixed hybrid prostheses in both arches.

Periotest values were obtained at the time the implants were uncovered. The Periotest instrument was used to measure the mobility of in vivo endosseous titanium implants by percussing temporary healing abutments (THAs) placed on dental implants, just above the gingival margin of the tissues surrounding the THAs. The electronically controlled rod of the Periotest instrument percussed the THAs 4 times per second. The rod decelerated when it hit the THAs. A rigid bone/implant attachment (osseointegration) caused a more rapid deceleration of the rod than a less rigid bone/implant attachment (not osseointegrated). Quantitative values were recorded for statistical analysis.

After the rod hit the THA it recoiled. By design, the contact time per impact between a rod and a natural tooth is approximately 1 ms. This, according to the manufacturer, represents the measuring parameter for the instrument.[12] Thus, in a period of 4 seconds, 16 defined and reproducible impacts were made between the rod and the THA. A miniature accelerometer at the tip of the rod sends a signal to the microcomputer in the Periotest instrument. The computer then calculates the braking time. The PTV is indicated digitally with a range of –8 to +50. The values are the result of a complex formula.[18] In this investigation, all measurements were made by attaching 6-mm THAs (THA64, 3i) to the implants. The measurement protocol developed by the manufacturer for the Periotest instrument was followed. The patient's head was positioned against the headrest and oriented so that the implants were vertical. The Periotest handpiece was held parallel to the horizon, with the start button on the top of the handpiece. The handpiece was held within 4 mm of the THA. The rod hit the THA within 1 mm of the gingival margin, perpendicular to the THA and implant (Fig 1). All measurements were made by the author. During the measurements, an audible signal was emitted to indicate correct or incorrect handpiece position, since deviations in the horizontal plane can influence the measurements.

Additional PTV measurements were made at the time of final impressions and prosthesis placement. Measurements were also made at 6 and 12 months after the implants were occlusally loaded. For these measurements, the restorations and abutments were removed, and 1-piece THAs (6 mm tall, 4 mm wide) were placed onto the implants and tightened by hand before PTVs were recorded.

Statistical analyses were performed with the data for specificity, sensitivity, and positive-negative predictor values.

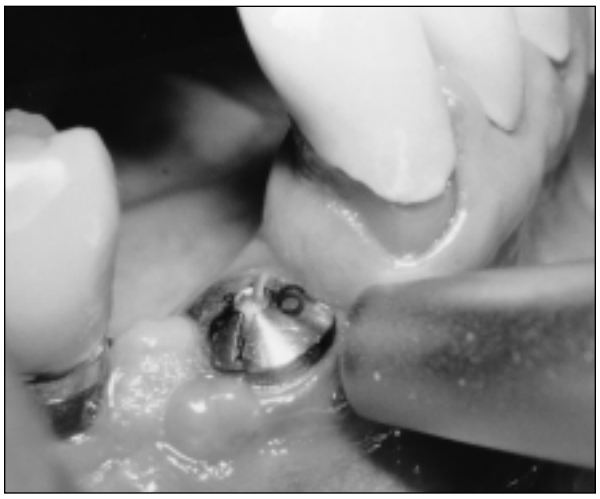

Fig 1 Clinical view of 1-piece temporary healing abutment in place on endosseous implant. The handpiece of the Periotest instrument is placed within 4 mm of the temporary healing abutment.

RESULTS

A total of 113 dental implants was placed into the arches of 26 female and 14 male patients. Ten implants failed to osseointegrate. The overall osseointegration rate was 91%. The percentages of osseointegrated implants per quadrant are reported in Table 2. (Osseointegration was defined as no implant mobility with application of buccolingual pressures on temporary healing abutments between 2 metallic instrument handles.)

Sensitivity of a test measures the ability of the diagnostic test to correctly identify those patients with true disease (implants that have not osseointegrated). The results are also known as true positives. A formula has been established as follows[19]:

$$\text{Sensitivity} = \frac{\text{True positive results}}{\text{True positive results} + \text{false negative results}}$$

Specificity of a test measures the ability of a diagnostic test to correctly identify the absence of disease (osseointegrated implants). These results are also known as true negatives. The formula establishes specificity as follows:

$$\text{Specificity} = \frac{\text{True negative results}}{\text{False positive results} + \text{true negative results}}$$

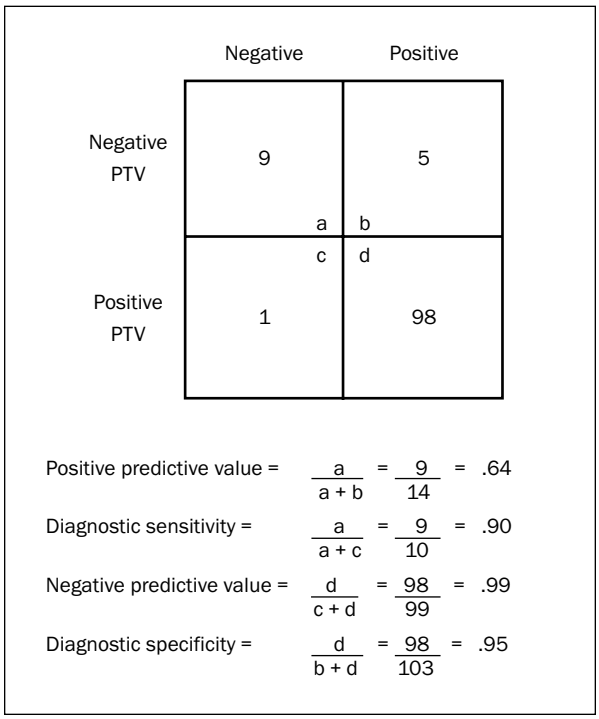

Fig 2 Sensitivity, specificity, and predictive values (n = 113) of implants 1 year post-occlusal loading. Assumptions: osseointegration rate is 95%, sensitivity of Periotest instrument is 90%, and specificity of Periotest instrument is 95%.

Sensitivity and specificity may seem adequate in determining the validity of a diagnostic test; however, 2 additional measures are perhaps more important in describing the effects of misclassification errors. The usefulness of a diagnostic test also depends on the true prevalence of the condition in the population being studied. The positive predictive value (diagnostic value) is the proportion of true cases among all those with a positive test result. This relates to what a clinician sees—those individuals with positive tests (ie, nonintegrated implants). Positive predictive values (PPV) are identified as:

$$\text{PPV} = \frac{\text{True positive results}}{\text{True positive results} + \text{false positive results}}$$

The negative predictive value (false negative rate) for a diagnostic test equals the proportion of false negatives among those with negative results. Negative predictive values (NPV) are identified as:

$$\text{NPV} = \frac{\text{True negative results}}{\text{False negative results} + \text{true negative results}}$$

The PPV for using the Periotest instrument as described in this study was 64%; that is, the Periotest instrument can successfully predict nonintegration of implants 64% of the time. The NPV for using the Periotest instrument as described in this study was 99%; that is, the Periotest instrument could correctly identify 99% of integrated implants. Figure 2 identifies the values recorded for this study.

DISCUSSION

The percentage of implants that became osseointegrated in this study is consistent with percentages reported by others[1–4] (90% to 95% in the mandible and 85% to 90% in the maxilla).

Sensitivity and specificity testing are not usually independent. With any particular diagnostic test, as one increases, the other is likely to decrease.[20] The sensitivity of the Periotest instrument has been defined as 90%, and the specificity has been defined as 95% (personal communication, D. Rosema, Siemens Periotest, Bioresearch, 1992). The specificity would have increased to 100% if the cut-off PTV was raised to 10. However, those criteria would have little predictive value for assessing integration/nonintegration of implants for clinicians because macroscopic movement of nonintegrated implants can be visualized at that value. Olivé and Aparicio did not specify a cut-off PTV to define osseointegration or nonosseointegration.[16]

The reality of assessing integration/nonintegration of dental implants is not always clear. There will always be a gray area of uncertainty, and this should be allowed for in the decision-making process. The sensitivity and specificity of a diagnostic test can be altered by the inclusion of more than one test to determine the presence or absence of osseointegration.

The PPV using the Periotest instrument at Stage II surgery and successful osseointegration 1 year after occlusal loading was 64%. However, the negative predictive value was 99%. Since 1% of integrated implants may be identified as being nonintegrated, clinicians probably should not use the PTV as their only parameter for determining osseointegration of dental implants at the time the implants are uncovered. It is significant that a PTV greater than 5 at Stage II surgery is highly predictive of an implant that will not be successful 1 year after occlusal loading. In this study, 64% of the nonintegrated implants were correctly identified as being nonintegrated at the time the implants were uncovered. The NPV indicates the proportion of patients correctly identified as not having the disease

(integrated implants). In this study, 99% of the integrated implants were correctly identified by the Periotest instrument as integrated.

Accuracy is defined as the proportion of results that agrees with the gold standard of known osseointegration rates. Osseointegration is known to be dependent on the quality of the bone into which implants have been placed.[3] Bone quality varies, at least in part, according to the anatomic location involved. This study did not have adequate numbers of implants in all anatomic locations; therefore, conclusions relative to bone quality and the presence/absence of osseointegration cannot be made. In this case, the Periotest instrument was accurate in its assessment of integrated implants 99% of the time. Prevalence is defined as the proportion of subjects who have the disease. In this study, the Periotest instrument identified 8.8% of all implants as nonintegrated.

The Periotest instrument was originally designed to objectively measure movement of a tooth within the periodontal ligament. Braking times for the rod of the Periotest instrument range from 0.3 to 2.3 milliseconds, which correspond to PTVs of –8 to +50.[14] Teerlinck et al[14] have determined that the peak value of the force delivered by the rod varies between 18 N and 12 N for PTVs of –4 to +2, respectively. They have correlated tapping an implant with a metallic instrument to elicit a clear metallic sound with approximately this level of force. The PTV constitutes a reproducible, quantitative measurement unit and closely correlates with tooth mobility. To facilitate use of the Periotest instrument in clinical practice, the manufacturer converted the contact time in milliseconds to a numerical scale of –8 to +50.[13,18] The manufacturer has suggested the following ranges for natural teeth[18]: Firm = –8 to +9; Palpable mobility = 10 to 19; Visible mobility = 20 to 29; and Mobility in response to tongue and lip pressure = 30 to 50. These PTV ranges were developed to describe healthy teeth in male and female adults. Females have somewhat higher PTVs than males, and maxillary teeth exhibit higher PTVs than mandibular teeth.

Periotest values in the lower negative range indicate increasing or existing ankylosis of natural teeth, or, perhaps, osseointegration of endosseous implants.[18] An area of critical importance in implant dentistry involves situations in which implants may not be osseointegrated but are not clinically mobile. The manufacturer of the Periotest instrument considers this situation to be possible in the PTV range of +4 to +9.[18] Clinical studies have suggested that PTVs of 5 or greater may indicate a potential problem and lack of osseointegration.[16,21,22] In this study, PTVs equal to or greater than 5 were considered to indicate nonintegrated implants.

Olivé and Aparicio[16] reported that Periotest measurements taken after Stage II surgery can be a very useful clinical parameter to identify implants that are clinically immobile but are not stable enough for clinical loading. They speculate that leaving such implants temporarily unloaded or subloaded could allow the formation of a mature bone-implant interface for later use. There are other variables to consider when recording PTVs for use in determining osseointegration of dental implants:

1. Length of implant: Generally, the longer the implant, the more surface area that is in contact with the bone and the lower the PTV.
2. Diameter of the implant: Generally, larger diameters mean greater surface area in contact with bone and thus a lower PTV (± 2 to 3 units).
3. Anatomic location: Areas with greater amounts of Type I bone will give lower PTVs than areas of Type IV bone (± 3 to 4 units).
4. Abutment lengths: Generally, if a measurement is made on the longer abutment (farther from the abutment-implant interface), the PTV will be higher than if the measurement was made closer to the abutment-implant interface (± 3 to 4 units).

Can the Periotest instrument give different values for the same phenomenon measured at different times? There have been numerous studies that have documented a high degree of precision and reproducibility in in vivo and in vitro situations.[14,23–25] The findings of this study are consistent with a case report in which decreasing PTVs were recorded for 2 maxillary incisor Brånemark System implants, from Stage I surgical placement to Stage II surgical uncovering to 3 months after occlusal loading.[26]

Reliable early determination of osseointegration can be beneficial to clinicians, since it could decrease costs associated with implant treatment by identifying implants that are not integrated before the cost of the restorations is incurred. It would also reduce treatment time if nonintegrated implants are removed as soon as they are detected. However, clinicians should use other clinical parameters in addition to PTVs. The ideal method would provide for a quantitative measurement of implants at the time they were placed (Stage I surgery). These values could be compared with values of osseointegrated implants. Implants that had values that were inconsistent with osseointegration could be removed and replaced with larger implants, or the implant sites could be prepared for implant placement with bone grafting or other procedures.

There were several limitations with this study, which can be changed to perhaps improve the reliability of results in future studies. The sample size in this study was small in terms of patients, anatomic locations, and numbers of implants placed. Larger sample sizes are needed to make stronger conclusions that would be more applicable in clinical practice. Implants that vary in diameter should also be used in an attempt to quantify differences in PTVs of implants with different diameters.

One-piece temporary healing abutments were used for the measurements. They were tightened by hand using a conventional driver. More consistent PTVs could probably be obtained by using 2-piece THAs where the abutment screws would be torqued with a known preload of 20 Ncm by means of a torque driver. This would permit consistent screw tightening, which may have a bearing on increased PTVs. If the THA/implant interface was not secure, PTVs would increase. In this case, the PTVs would not be measuring the relative ankylosis of osseointegration; instead, the PTVs would reflect the relative tightness of the THA/implant connection. Olivé and Aparicio partially addressed this concern, but only in regard to the differences in hardness between gold alloy screws and commercially pure titanium abutments.[16]

Periotest values could also be influenced by the location of the rod/THA contact in a vertical direction. Meredith et al[27] have demonstrated that angulation, striking point, and abutment length may influence Periotest values. In this study, measurements were made approximately 1 mm above the gingival margin. However, since the height of the THAs varied according to different clinical situations, the measurements occurred at varying distances occlusal to the THA/implant interfaces. A refinement could include using one consistent height for the 2-piece temporary healing abutments so that the measurements would occur at a consistent height relative to the implants.

Periotest values may be susceptible to changes in the direction of force applied to the implant components. Ichikawa et al[28] recorded a PTV of 5 when testing one particular implant in a mesiobuccal to distolingual direction. When force was applied in a distobuccal to mesiolingual direction on the same implant, they recorded a PTV of 0. They also suggested that the PTVs of osseointegrated implants remain constant or become more negative with time. They felt that PTVs of 0 or greater result in an unfavorable prognosis for a given implant.

A greater sample size would also be beneficial, especially relative to the known differences in bone quality in the 4 quadrants of edentulous arches.[17] Periotest values may vary depending on the quality of bone (Types 1 to 4), and sufficient numbers of implants need to be placed in all types of bone and statistical analysis performed to provide more clinical information.

CONCLUSIONS

In this study, 113 implants were placed and followed up to 1 year after loading. Ninety-one percent of all implants placed became osseointegrated. Osseointegration rates varied from 79% in the posterior maxilla to 100% in the anterior mandible. Periotest values were obtained using standard 1-piece temporary healing abutments on the implants. Initial PTVs were obtained at the time the implants were uncovered. Additional measurements were obtained at the time of final impressions, prosthesis placement, and 6 and 12 months after occlusal loading. The negative predictive values of implants with PTV greater than 5 at the time of Stage II surgery and failure to osseointegrate within 1 year of occlusal loading were not significant. Absolute Periotest values greater than 5 may not be beneficial to clinicians in predicting whether dental implants will fail to osseointegrate. Clinicians should continue to use all clinical parameters in assessing the osseointegration of implants. Predicting long-term stability of implants a the time of placement must still be considered faulty at best.

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