# Stability Determination of One-Piece Ceramic Implants Using the Periotest Device: Follow-up Study of Up to 12 Months

Dan Hagi, DDS[1]

***Purpose:*** The aim of this study was to determine whether the Periotest device could be used to reliably and reproducibly determine the prosthetic readiness of one-piece ceramic implants. ***Materials and Methods***: Periotest values were measured on one-piece ceramic implants from two manufacturers, CeraRoot and Straumann PURE. Measurements were taken at the time of placement and up to 9 months after placement. The survival of the implants was assessed up to 12 months following placement. Data were modeled on R software utilizing the Cox Proportional Hazards model and Generalized Additive Model (GAM) regression. ***Results:*** In all, stability testing was performed on 320 placed implants in 202 patients. The overall implant survival rate after 12 months of follow-up was 96.9%. The mean Periotest value (PTV) at the time of placement was –2.0 for the surviving implants, while it was only +0.6 for the failed implants. The PTV showed a gradual and steady increase leading up to 12 to 16 weeks. The mean PTV recorded at 12 weeks was –3.2. The Periotest device provided accurate and reproducible stability measurements following the prescribed protocol, thus helping to determine readiness for prosthetic loading. ***Conclusion:*** Within the limitation of this study, the preliminary findings suggest that the Periotest is an objective tool for stability assessment of one-piece ceramic implants. Further follow-up is needed to evaluate whether the Periotest can be suggested as a monitoring device of stability after the prosthetic phase of the implants is completed. *Int J Oral Maxillofac Implants 2021;36:738–744. doi: 10.11607/jomi.8681*

***Keywords:*** ceramic implants, implant stability, Periotest

Primary and secondary implant stability are important for both short- and long-term success of dental implant treatment.[1,2] Determination of stability and therefore verification of rigid fixation is necessary before subjecting the implant to a prosthetic load.[3,4] Historically, various methods have been employed to help determine the time to initiate prosthetic restoration. One of the most common methods used in private practice is a percussion test using the handle of a mouth mirror or any other instrument.[5] A clinical judgment on stability is made based on the sound heard; a ringing "crystal" sound indicates high stability, while a "dull" sound may indicate low or no stability.[6] This is a very subjective way of testing implant stability and has yielded inconsistent results. Other methods include the use of radiographic analysis and reverse torque, again both proven to be nonreliable, and in the case of reverse torque testing, potentially destructive.[2] Although the use of 2D radiography can be used to detect marginal bone loss and nonhealing, the use of radiographs alone has not been shown to be an indicator of the level of osseointegration or stability.[2] The most reliable method for determining the stability of an implant prior to restoration is the resonance frequency analysis (RFA); this has been validated in numerous clinical trials over the past 20 years.[1,7–9] This method uses magnetic frequencies between the transducer and resonance frequency analyzer. The RFA device has a transducer, a metallic rod with a magnet on top, which is screwed onto an implant. The requirement here is the ability to connect a calibrated peg to the implant and therefore may only be used in two-piece implants.

Another method of testing the stability of implants has been the Periotest, which is also known as the damping capacity test.[9,10] This unique device was originally designed to test the mobility of teeth.[11,12] Subsequently, it has been used to test implants as well.[13–15] The device has an electrically driven and electronically monitored tapping head that percusses the implant a total of 16 times. The instrument includes a tapping rod that impacts the given object. The rod is drawn by a propulsion coil toward the impacting surface and moves at a constant velocity from the moment it leaves the handpiece until it impacts the surface. This means that over a certain distance (approximately 4 mm), the tapping rod is moving at the same velocity and is designed to impact the surface at any time

[1]Private Practice, Toronto, Canada.

**Correspondence to:** Dr Dan Hagi, DH Smile Center 7900 Bathurst St. Suite 8, Thornhill, Ontario, Canada L4J0J9. Email: dr.dh@dhsmilecenter.com

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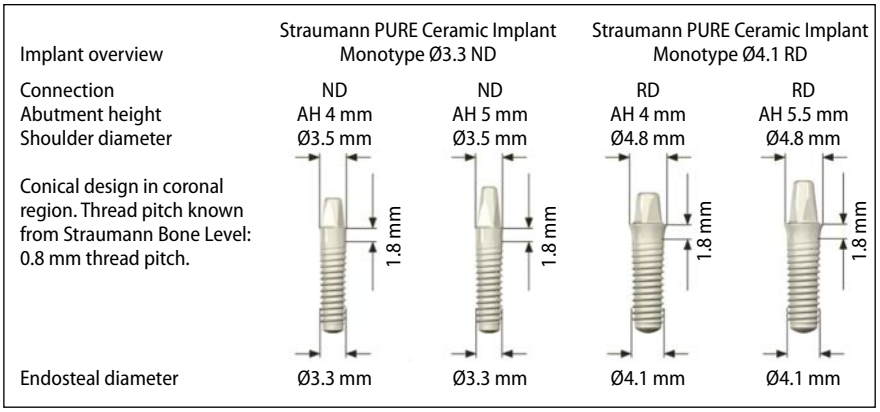


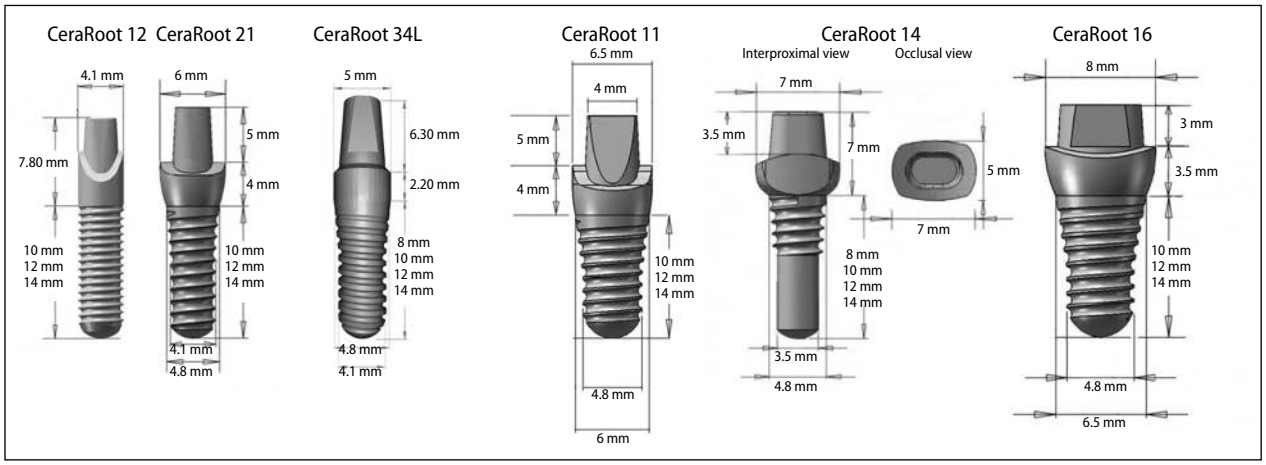




**Fig 1** Shapes and sizes of implant brands used. Straumann *(left),* CeraRoot *(below).*

during this constant velocity travel. The end of the rod inside the handpiece is rigidly connected to an accelerometer, which produces an output proportional to its acceleration. The Periotest value (PTV) readings are from −8 to +50, with −8 being the highest stability value.[16] Prior Periotest studies with titanium implants have concluded that damping capacity assessment is a reliable method to monitor implant mobility and consequently changes at the implant-bone interface and therefore suitable for implant stability assessment.[4,11,13,14] The main issue with the Periotest device has been inconsistent values due to varied device positioning. The scale of the Periotest device is also unusual and is not correlated with the value of micromotion as seen with the implant stability quotient (ISQ) values obtained from RFA devices.[17] There is also no consensus on how to interpret PTVs and how to use the PTVs, with ceramic implants, to guide assessment of stability and readiness for prosthetic rehabilitation.

Yttria-stabilized zirconia polycrystal (YTZP) was used as a dental implant material for the first time with the SIGMA implant system introduced to dental implantology by Sandhaus and Pasche in 1984.[18] Over the years, surface modifications followed the same pattern as titanium surface modifications, to increase osseointegration and decrease healing times.[19] From a macroscopic standpoint, most ceramic implants were and continue to be monobloc, one-piece implants. Like with any implanted device, dental implants are expected to fulfill their function of tooth replacement devices, and the only way this is possible is for the implant to remain in a clinically undetectable micromovement range. The gold standard of implant stability testing is the RFA. With the exception of three recently commercially available two-piece ceramic implants, RFA cannot be used with one-piece ceramic implants, and thus, it is the author's aim in this publication to determine if the Periotest device is a reliable, reproducible method for determining the stability of one-piece dental implants and objectively optimizing the time of prosthetic loading.

## MATERIALS AND METHODS

The investigation involved two implant systems, namely, CeraRoot (CeraRoot) and Straumann PURE (Straumann). Implant diameters were between 3.3 and 6.5 mm, and implant lengths ranged from 8 to 14 mm (Fig 1).

All implant procedures were performed by the same dental surgeon between 2012 and 2019 in one surgical center. Informed consent was obtained from each of the subjects.

**Fig 2** Positioning of the Periotest device on the shoulder of the implant.

Implants were placed according to manufacturer recommendations in either healed sites or immediately after extraction. Osteotomies in preparation for implant insertion were done according to the manufacturer's guidelines. Implants were inserted at slow speed (15 to 30 rpm), and in the case of the CeraRoot system, some of the implants (CeraRoot 14) were press-fit into the osteotomy. Since all the implants were one-piece, in some instances, adjustment had to be made to the implant abutments in order to avoid premature loading; this was done using superfine diamond burs with profuse irrigation.

Placement of implants was combined with minor grafting or guided bone regeneration procedures, if bone volumes were deficient. In some instances, provisional restorations were fabricated chairside and provisionally cemented with temporary cement (TempBond Clear, Kerr Dental). In the event that multiple implants were surgically placed and splinted with a provisional restoration, a definitive cement was used to securely lute the restoration and prevent uncementation during the healing phase; in these cases, a dual-curing self-adhesive resin cement was used (G-CEM LinkAce, GC America). Following the initial healing phase, the implants were restored with all-ceramic crowns or all-ceramic fixed partial dentures (FPDs) and definitively cemented using GI Cement (FujiCEM II, GC America). Cementation was carried out with careful attention to meticulously cleaning all excess cement.

The stability of the implants was measured using the Periotest method[20] starting immediately after implant placement and up to 9 months after implant placement. The average PTV was as follows:

- At insertion: –1.9
- At 8 weeks: –2.0
- At 10 weeks: –3.5
- At 12 weeks: –3.2
- At 16 weeks: –2.2
- At 20 weeks: –0.2
- At 24 weeks: –3.3

Each time, the device was placed perpendicularly to the abutment, parallel to the horizon, and lying on the buccal portion of the prosthetic shoulder of the implant to make sure the placement vertically was consistent between readings (Fig 2). Three consecutive measurements were taken, and the mean reading for each implant was recorded. If an immediate provisional was placed and implant stability was to be tested, the provisional prosthesis was carefully removed or cut off the abutment (if definitive cement was used), and testing was carried out.

To determine whether PTV at placement predicted implant success, failure rates were analyzed as a function of initial PTV, placement site, implant size, and grafting during implant placement. A Cox Proportional Hazards model was used to investigate the association between the survival of the implants and the predictor variables, as it could be safely assumed that time-independent hazard ratios between implants and covariate effects would only potentially exert an effect at placement time.

Healing and therefore stability is nonlinear over time, so the regression approach used was a Generalized Additive Model (GAM). This fits a series of functions and optimizes a smoother that characterizes the temporal trend, without adding too many parameters. Additionally, individual implant variability could be included as a stratum to generate an estimate of the general "shape" of PTVs across time.

To estimate inflection points corresponding to stability plateaus or peaks on the GAM curve, the first-order derivatives of the fitted GAM line were calculated and used to estimate turning points. A positive derivative indicates an increase, whereas a negative value represents a decrease. Zero values correspond with a slope of zero. A peak would be indicated by a transition from increasing to decreasing slopes, reflecting the rise and dip of the measure. Confidence intervals of the slope derivatives were generated from 10,000 sample draws from the posterior distribution of the model coefficients.

## RESULTS

In all, 320 implants were followed in a total of 202 patients with ages ranging from 19 to 79 years. Overall, there were 77 male and 125 female patients. One hundred ninety-five implants were placed in the maxilla and 125 in the mandible. One hundred fifty implants were placed in healed sites and 170 immediately after extraction. Guided bone regeneration was combined with implant placement on 55 of the implants.

The distribution of implant types by brand and arch is shown in Table 1. Type, number, survival, and PTV at time of placement and prior to restoration of the

**Table 1 Distribution of Implants Used by Brand**

| System | Mandible | Maxilla | Total |
|---|---|---|---|
| Straumann PURE | 17 | 17 | 34 |
| CeraRoot | 105 | 181 | 286 |

**Table 3 Cox Proportional Hazards Model of Implant Failure Over Time**

| Source | Odds ratio | CI | z | Pr (>\|z\|) |
|---|---|---|---|---|
| Maxilla/mandible placement | 2.894 | (0.583, 14.376) | 1.300 | 0.194 |
| Grafting | 0.774 | (0.133, 4.524) | −0.284 | 0.776 |
| Immediate vs healed site | 0.885 | (0.219, 3.586) | 0.171 | 0.864 |
| Length | 1.044 | (0.483, 2.255) | 0.110 | 0.913 |
| Width | 1.901 | (0.794, 4.552) | 1.443 | 0.149 |
| PTV at placement | 1.116 | (0.988, 1.260) | 1.772 | 0.076 |

CI = confidence interval.

**Table 2 Distribution of Implant Types, Sizes, Failures, and Mean PTV at Time of Insertion and Prior to Restoration**

| System/ size/type | No. inserted | No. failed | Failure rate | Average PTV initial | Average PTV prior to restoration |
|---|---|---|---|---|---|
| **Straumann PURE** | | | | | |
| 3.3 mm | 2 | 0 | 0.0% | −1.7 | −2.3 |
| 4.1 mm | 32 | 0 | 0.0% | −2.5 | −3.6 |
| **CeraRoot** | | | | | |
| CR12 | 23 | 0 | 0.0% | 0.8 | −2.1 |
| CR21 | 33 | 0 | 0.0% | −0.9 | −2.6 |
| CR11 | 3 | 0 | 0.0% | −3.2 | −3.5 |
| CR14 (press-fit) | 82 | 6 | 7.3% | −0.7 | −3.2 |
| CR34 | 26 | 0 | 0.0% | −2.3 | −3.8 |
| CR16 | 119 | 4 | 3.3% | −3.3 | −4.3 |
| **Overall** | 320 | 10 | 3.1% | −1.9 | −3.2 |

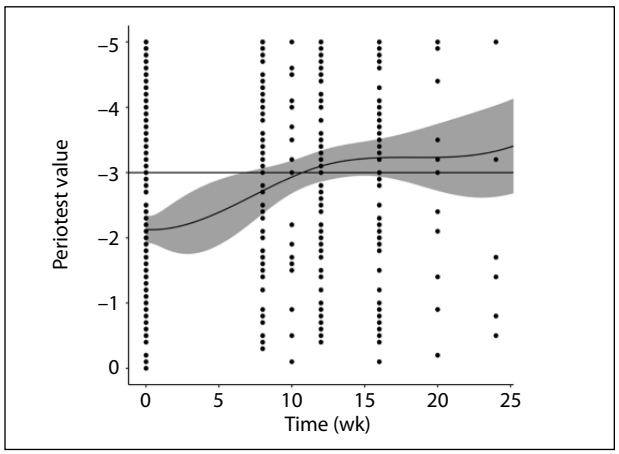



**Fig 3** PTV values across time reference line at PTV = −3.

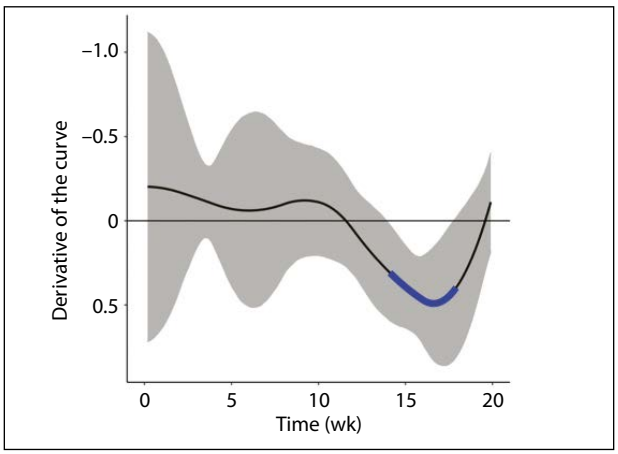



**Fig 4** GAM derivative curve of stability changes over time.

implants are summarized in Table 2. The data collected were analyzed to assess the possibility of any correlation between implant diameter, length, arch location, timing, and grafting procedure on the pattern of implant stability during the prerestorative phase.

Allowing for up to 12 months of follow-up of the 320 implants placed, 10 failed prior to prosthetic restoration, giving an overall 12-month survival rate of 96.9%. The Cox Proportional Hazards model of implant failure over time demonstrated that none of the factors that were followed could predict implant failure with statistical significance (Table 3).

The pattern of healing observed from plotting the PTV over time showed a decrease in PTV over time (Fig 3). PTV readings started to decrease (increased stability) and peak at 10 to 16 weeks. This apparent stability plateau was statistically supported by the analysis of the derivatives (Fig 4). The blue section of the derivative curve represents decreasing PTVs as stability plateaus. The lack of overlap of the shaded confidence intervals with the 0 line indicates that this feature was statistically significant. This plateau coincides with the 10- to 16-week mark, where stability plateaus and prosthetic stability are expected. At 20 weeks, stability began to increase again and gradually stabilize more.

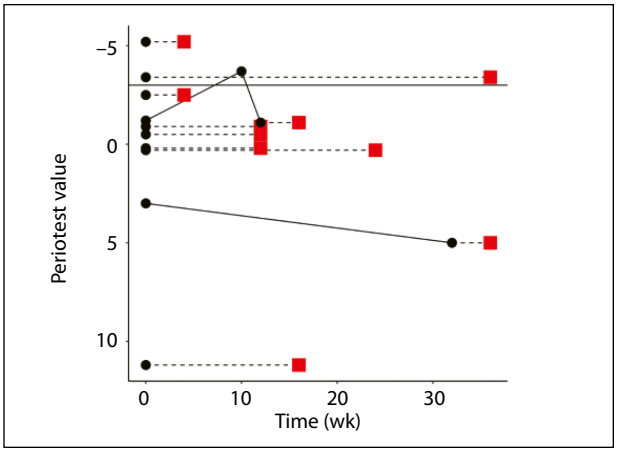



Fig 5 PTV over time for the failed implants.

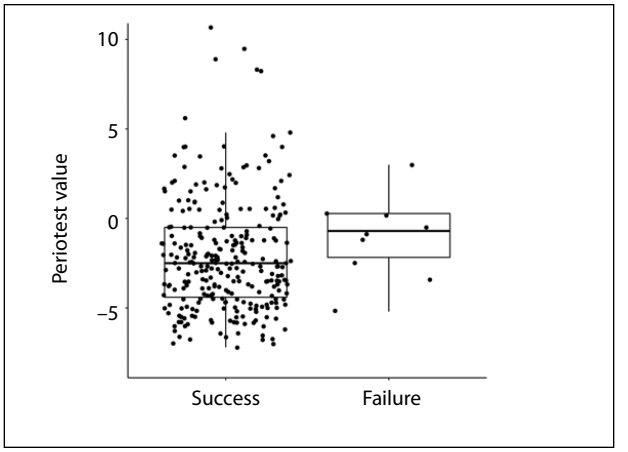
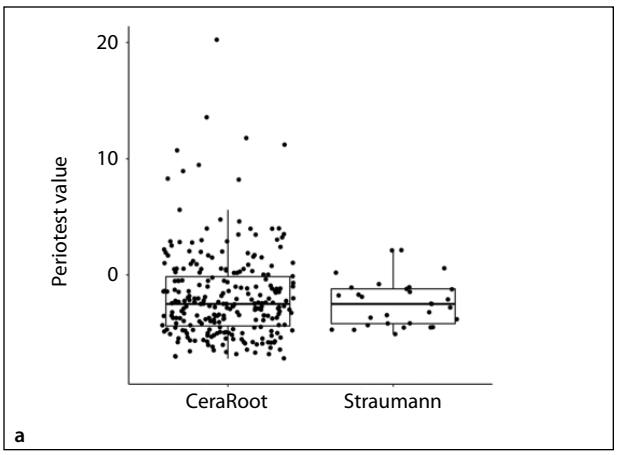



Fig 6 PTV at time of placement of the successful vs failed implants.



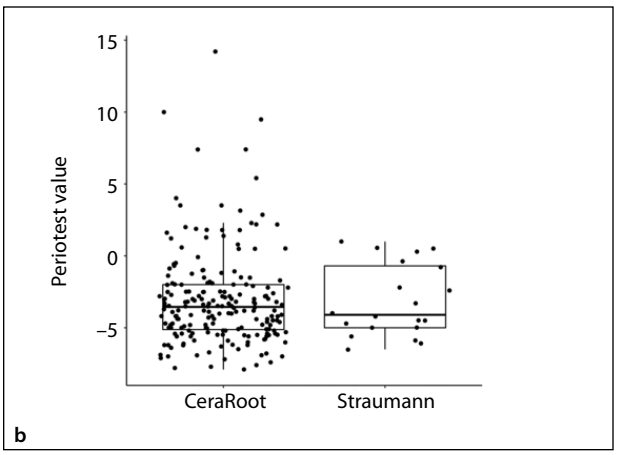




Fig 7 PTV *(a)* at placement and *(b)* at 12 to 16 weeks by brand.

Of the 10 implants that failed, 6 were CeraRoot 14 (press-fit) and 4 were CeraRoot 16 implants. There was no correlation between implant type, size, or placement parameters. However, there is a higher rate of failure (7.3%) with the press-fit implants. Figure 5 shows the PTV values over time for the failed implants.

There was no statistical difference in PTVs between implants; however, the average PTV at placement was higher (lower stability) for the press-fit implants as well as the narrower implants. This initial PTV got better over time (Fig 3) and reached on average approximately –3.0 (Table 2) for all types of implants that survived. The initial PTV for the failed implants averaged 0.6, which differed from the mean of the surviving implants whose initial PTV averaged –2.0 (Fig 6). There was also a difference in the initial PTV reading of implants in the maxilla, –1.0, and the mandible, –3.2. Though the difference was not statistically significant, it can be explained by the differing bone types in the maxilla and mandible. PTV readings prior to restoration in the maxilla and mandible of –2.0 and –5.2, respectively, were again not statistically significant; however, these readings were supported by what was expected with relation to differences in bone types between the arches.

There were no mechanical failures of the zirconia implants during the follow-up period and no statistically significant difference between the PTVs before and after abutment reduction. About one in seven implants (15.9%) required abutment preparation. If abutment reduction was necessary, an initial PTV was recorded, then another immediately after abutment reduction; no difference in PTV was ever noted.

When the two brands of implants used were compared, there was no statistical difference of PTV at 12 to 16 weeks postinsertion. Straumann implants did demonstrate a lower PTV compared with CeraRoot, though the difference was not statistically significant (Fig 7).

The stability of an oral implant is essential for its success and optimal function. Primary implant stability at the time of placement is prognostic of positive outcome.[23] Based on the present data, the implant length and diameter had no effect on the PTVs, even when the abutments had to be reduced for occlusal clearance.

## DISCUSSION

Methods for the evaluation of the clinical stability of implants involve quantitative assessments that ought to be objective, noninvasive, do not damage the implant-bone, and are reproducible.[8] RFA satisfies all requirements for assessment of the stability of implants and is proven to be the gold standard. In the last years, ceramic implants have gained market share, giving patients and practitioners a novel way to replace missing teeth. It has been difficult to assess their primary stability and determine the ideal time for restoration because of the inability to connect a peg to one-piece implants that would enable the use of RFA.

The Periotest is an instrument developed to quantitatively measure the damping characteristic of the periodontal ligament of teeth and assess tooth mobility.[21] Although developed for teeth, it has also been used to assess the stability of implants.[16] This method was reported to have a few limitations, as it is affected by a variety of factors, such as the striking position as well as the handpiece angulation.[21] To obtain reproducible results, it is important to make sure the vertical position of the Periotest and the striking angle are consistent between readings. In this study, the striking position was maintained constant by positioning the device at the prosthetic margin, perpendicular to the abutment, and the device held parallel to the horizon. Previously, with two-piece implants, this was always challenging, as a consistent vertical landmark was absent. The ability to rest the instrument on the restorative platform of a one-piece implant gives a reproducible vertical position.

A particular PTV does not in itself have any prognostic value, though initial PTVs that are better than –2.0 PTV are associated with better outcomes. In this study, subjects were observed who had initial high PTV values (low primary stability) and with time gained stability and were successful. It is important, as it is with ISQ measurements, that implants with low initial stability readings (higher PTV) should be protected from premature loading for an extended period of time to ensure that the biologic stability and bone remodeling occurs without the interposition of soft tissues. The expectation is that primary stability goes down as secondary stability starts to increase. As long as PTVs see a downward trend, then it is known that the stability of the implant is increasing. Once the stability starts to exceed initial stability, new bone is being formed around the implant, and prosthetic rehabilitation may commence. The data demonstrated that there were statistically insignificant differences in PTVs between the maxilla and mandible. The mean PTV at the time of placement was –1.0 in the maxilla and –3.2 in the mandible. Prior to restoration, the mean PTV in the maxilla averaged –2.0, while in the mandible, it was –5.2. This can be expected due to what is known about the bone characteristics in the maxilla and mandible. As such, at the time of prosthetic rehabilitation, the PTV should reach a level that is lower than the initial PTV or lower than –2.0 in the maxilla or –3.0 in the mandible (allowing for cases where initial PTV was higher due to type II or III bone in the mandible). If at 12 to 16 weeks, the PTV does not meet this standard, then further time is needed for more osseous healing and maturation and retesting until the required PTVs are reached. The observed average rate of change after the initial 12 weeks of healing is –1.0 PTV per 4-week period.

It is important to note that the narrower-diameter implants had a higher initial PTV, as they could not be torqued into position with more than 30 Ncm. This meant that their initial PTV was higher, but they achieved an adequate level of stability over the 12 to 16 weeks.

An interesting observation was made with respect to the press-fit CeraRoot 14 implant. This implant more often achieved a lower initial PTV and was more likely to suffer early failure. Initial PTV for the press-fit design was –0.7, while for the threaded design, it was –2.3. Final PTV prior to restoration was –3.2 for the press-fit design and –3.3 for the threaded implants. While press-fit implants show lower initial stability, they integrate and reach similar stability to threaded implants at the time of prosthetic readiness. This was likely from the fact that it was more difficult to obtain primary stabilization with the press-fit design. Care needs to be taken to make sure that osteotomy preparation yields good initial stability and the implant is protected from premature loading.

The long-term measurement of implant stability is something that is missing in the literature. After prosthetic rehabilitation has been completed, a clinician is unable to connect a peg for RFA and generally relies on percussion and radiographic determination. The Periotest device can be used as the restored implant is struck in a calibrated area, ie, coronal to the implant-crown interface (gingival margin), once the luting agent has completely set. This is a baseline reading of stability to which subsequent readings are compared over time. Any increase in PTV may mean loss of stability and signs of an issue.

## CONCLUSIONS

The results over the observation period of 12 months after implant insertion reflect the already well-documented pattern of osseointegration of implants. The Periotest device is proving to be a reliable and reproducible way of determining one-piece implant stability and monitoring it over time. When placing one-piece

ceramic implants, the aim should be for a high level of primary stability and a PTV of approximately –2.0; lower PTVs mean that immediate temporization is achievable, while higher PTV readings necessitate protection from premature loading. An implant that is ready to be restored should have a PTV less than the initial measurement and less than –2.0 and –3.0 in the maxilla and mandible, respectively, ensuring that secondary biologic stability has been established.

## ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

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