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The behavior of polyetheretherketone healing abutments when measuring implant stability with electronic percussive testing

Çağatay Dayan PhD, DDS[1] | Canan Bural PhD, DDS[2] | Onur Geçkili PhD, DDS[2]

[1]Program of Dental Technicians, Istanbul Cerrahpasa University, Istanbul, Turkey

[2]Department of Prosthodontics, Faculty of Dentistry, Istanbul University, Istanbul, Turkey

Correspondence
Onur Geckili, Department of Prosthodontics, Faculty of Dentistry, University of Istanbul, 2nd Floor, 34093 - Capa, Istanbul, Turkey.
Email: geckili@istanbul.edu.tr

Abstract

Background: It is unknown whether it is possible to measure implant stability with polyetheretherketone (PEEK) healing abutments using electronic percussive testing (EPT).

Purpose: To investigate the reliability of the percussive test values (PTVs) measured with PEEK healing abutments and to compare them with the PTVs measured with titanium healing abutments.

Material and Methods: Thirty dental implants were inserted into the fresh pelvis belonging to a cow. Titanium healing abutments (2 and 5 mm), PEEK healing abutments (5 mm), and prepable standard titanium abutments (5 mm) were screwed to the implants, respectively, and PTVs were measured by two examiners using a wireless EPT device. Differences in PTVs between different dental implant components were evaluated using Friedman's test with post hoc Wilcoxon signed-rank test and Bonferroni correction. Inter and intra-observer reliabilities were detected using interclass correlation coefficients (ICCs)

Results: The mean PTVs obtained using the PEEK healing abutments were significantly higher than the mean PTVs obtained using the other abutments for both examiners ($P < .01$). The ICCs for intra-observer reliability were detected as poor for PEEK healing abutments; and excellent for the other abutment types for both examiners. The ICCs for the inter-observer reliability between the two examiners were poor (0.25) for PEEK healing abutments, and excellent for the 2 and 5 mm titanium healing abutments and for standard abutments (0.82, 0.84 and 0.93, respectively).

Conclusion: Within the limitations of this in vitro study, it may be concluded that EPT measurements should be avoided using PEEK healing abutments because of the poor reliability.

KEYWORDS

implant, implant stability, implantology

1 | INTRODUCTION

Several methods have been developed and proposed for objective measurement of dental implant stability at the bone-implant interface. Characteristics of ideal measurement procedures and tools include feasibility and ease of use in daily practice, rapid generation and reproducibility of results, and noninvasiveness.[1] Implant stability can be measured by numerous methods. Methods like push-out/pull-out or removal torque tests are destructive and preferred only studies with in vitro or ex vivo settings. Non-destructive methods which are frequently used include insertion torque, resonance frequency analysis (RFA), or electronic percussive testing (EPT).[2,3] Among these, insertion torque measurements can only be used to measure primary stability of an implant at the surgery. However, RFA and EPT have been proposed to measure both primary and secondary stability of an implant.[2] As it is impractical to radiographically evaluate bone structure changes associated with dental implantation especially after loading, it is much better to monitor the integration of an implant with

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these methods. Moreover, it has been shown that implants showing unusual reductions in stability values should aware the clinicians to take supplementary precautions such as unloading the implants till adequate stability is regained, check and correct the occlusal discrepancies or start treating the peri-implant tissues in case of infection or peri-implantitis.[4,5] However, assessment of implant stability after the delivery of superstructures is particularly challenging.[6] For monitoring the stability of an implant after loading, the removal of a cement or screw retained crown and unscrewing the tightened abutment thereafter for mounting of a smartpeg for a RFA measurement could create a real challenging task both for the patient and the clinician.[7] But, EPT can be used at all stages of implant therapy; for instance, for measuring primary stability during surgery, after healing to determine if enough osseointegration has taken place to allow for the application of force to the implant, and following loading of the final prosthesis to ensure the diagnosis of adverse developments at early or later stages.

It has been shown that the quantitative and reproducible features and the ease of use of EPT permit an objective clinical follow-up of bone-implant interface stability, and the decision of successful integration.[8] Furthermore there exists studies showing direct correlation between stability values obtained by EPT and the degree of osseointegration and the prognosis of early implant loss.[9,10]

EPT devices which were originally developed to measure tooth mobility work on a principle of impacting the test surfaces 16 times in 4 second intervals. The stability of the test surfaces is measured by the accelerometer mounted in the percussion rod and the percussive test values (PTVs) are displayed on the digital screen of the instrument. PTVs range from −8 (high stability) to +50 (low stability). According to the classification of Fleiss,[11] good to excellent results have been reported for the intraobserver and interobserver reliability values of EPT measurements in previously reported ex vivo models.[7,12–14] However, it should be underlined that the EPT measurements from these reported studies were performed only using healing abutments, which had varying heights (3-4 mm).

There is no strict approval for which abutment should be used for EPT. In most studies, titanium healing abutments have been used for EPT measurements. More recently healing abutments made of polymers such as polyetheretherketone (PEEK) which have been used in orthopedic surgery for over 20 years are introduced because of esthetic reasons and maintaining the health of peri-implant soft tissues during healing. Although titanium healing abutments have been the gold standard in dental implant care for many years,[15] it has been shown that PEEK may be preferred for the trans-mucosal portion of the implant-abutment complex during healing for esthetic or technical reasons.[16] Several studies[15–17] have confirmed the positive healing outcomes of PEEK healing abutments. PEEK healing abutments can be chosen instead of titanium healing abutments because of their inert chemical properties, white color, and biocompatibility.[16] Moreover these healing abutments can be easily shaped and modified chairside for the particular soft tissue of an implant to ensure optimized emergence profile.

Publications reporting on the influence of implant abutments on EPT measurements are scarce.[18,19] Gomez-Roman and Lukas[18] compared the PTVs when EPT was measured over healing abutments, standard abutments, and single crowns and they concluded that lowest PTVs were detected on healing abutments and stated that PTVs decrease with height. To date, there exists no study on the effect of abutment material on EPT measurements in the literature. Hence, this study was conducted to investigate the reliability of the PTVs measured over PEEK healing abutments which include very limited information in scientific community and to compare them with PTVs over titanium healing abutments and over titanium standard abutments. The null hypothesis was that there would be no difference in the PTVs measured with PEEK and titanium healing abutments.

2 | MATERIALS AND METHODS

2.1 | Implant placement

Fresh pelvis belonging to a cow was selected for the experimental procedures and collected from a butcher's shop. The soft tissues covering the bones were completely dissected to expose the bony surface with lancets and periosteal elevators. According to the Lekholm and Zarb classification,[20] the pelvis was similar to type I-quality bone and type II-quality bone.

Thirty tapered implants belonging to the same manufacturer (Neoss System, Neoss Ltd, Harrogate, UK) were chosen for the experiments. Implant locations were marked on the bones at safe distance intervals. All osteotomies were performed by the same oral and maxillofacial surgeon who was blinded to the study protocol and the implants were inserted following the surgical drilling protocols recommended by the manufacturer.

2.2 | EPT measurements

Titanium healing abutments with 2 and 5 mm heights; 5 mm PEEK healing abutments and 5 mm prepable standard titanium abutments were screwed to the implants, respectively, (Figure 1) and PTVs were measured by two experienced clinicians who were blinded to the study protocol using a wireless EPT device (Periotest M, Medizintechnik Gulden, Modaustal, Germany). The device was accurately calibrated before the study. PTV measurements were made by holding the handpiece of the device perpendicular to the abutment in the buccal direction by each examiner (Figure 2). After impact on the implants by the percussion rods, the microcomputer recorded the PTVs in the form of a digital display. At least two

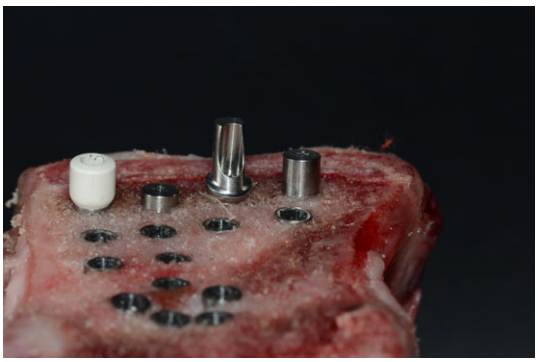


FIGURE 1 Compared implant abutments from left to right: 5 mm PEEK healing abutment, titanium healing abutment with 2 mm heights, 5 mm prepable standard titanium abutment, 5 mm titanium healing abutment

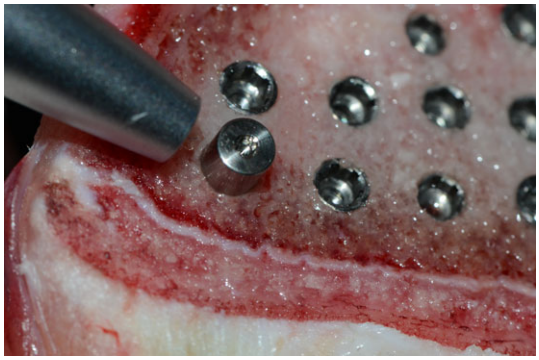


FIGURE 2 EPT measurements were made by holding the handpiece of the device perpendicular to the abutment in the buccal direction

measurements were made for each implant. If measured values were divergent, the measurement was continued until two subsequent values were identical. The measurements were repeated three times for each implant at 2-hour intervals to evaluate intraobserver and interobserver reliability according to abutment type.

2.3 | Statistical analysis

Statistical analyses were performed using SPSS (IBM Corp Released 2011. IBM SPSS Statistics for Windows, Version 20.0. IBM Corp, Armonk, New York) with the level of significance set at $P = .05$. The relevance of the parameters to the normal distribution was analyzed by using Kolmogorov-Smirnov test. Differences in PTVs between different dental implant components were evaluated using Friedman's test with post hoc Wilcoxon signed-rank test and Bonferroni correction. Inter-observer and intra-observer reliability were detected by using the interclass correlation coefficient (ICC). When the 2 examiner PTVs were compared, only significance was detected in PEEK healing abutments ($P < .05$; Table 1). The ICCs were qualified as recommended previously[1–3] when ICC < 0.4 poor reliability; when ICC is between 0.4 and 0.7 fair-to-good reliability, and when ICC > 0.7 excellent reliability.

3 | RESULTS

The mean PTVs obtained by the two examiners using the PEEK, titanium healing abutments, and prepable standard titanium abutments are shown in Table 1. Both examiners found significant differences between the different abutment types. The mean PTVs obtained using the PEEK healing abutments were statistically significantly higher than the mean PTVs obtained using the other abutments for both examiners ($P < .01$). PTVs measured with 2 mm titanium healing abutments were significantly lower than PTVs measured with other abutments for both examiners ($P < .05$). Additionally PTVs measured with 5 mm titanium healing abutments were significantly lower than the PTVs measured with standard abutments for both examiners ($P < .01$). The ICC values for intraobserver reliability were 0.35 for PEEK healing abutments; 0.88 and 0.95 for 2 and 5 mm titanium healing abutments, respectively, and 0.84 for standard abutments for examiner 1. For examiner 2 the ICC values for intraobserver reliability were 0.29 for PEEK healing abutments; 0.85 and 0.94 for 2 and 5 mm titanium healing abutments, respectively, and 0.81 for standard abutments. The ICC values for the interobserver reliability between the two examiners were 0.25 for PEEK healing abutments; 0.84 and 0.93 for 2 and 5 mm titanium healing abutments, respectively, and 0.82 for standard abutments.

4 | DISCUSSION

In the present study, the behavior of PEEK healing abutments during implant stability measurements with EPT was assessed. The null hypothesis that there would be no difference between the PTVs measured with PEEK and titanium healing abutments was rejected. PTVs measured with PEEK healing abutments showed increased PTVs compared to other implant abutment types. Titanium and its alloys have significantly higher elastic moduli than bone, but it has been shown that PEEK has a low modulus of elasticity similar to human bone.[21,22] EPT is an electromechanical method, and the tapping head of the Periotest device has a pressure-sensitive tip that records the duration of contact with the implant. The lower elasticity modulus of the PEEK material may have affected the duration of contact and this may be the reason of the higher PTVs obtained with PEEK in our study.

Previous research has shown that the EPT devices show excellent reliability in measuring dental implant stability.[7,8,13,23] However, PTVs were measured with just titanium healing abutments in these studies. Today, many manufacturers fabricate PEEK healing abutments as an alternative to titanium healing abutments because of their superior properties such as white color, biocompatibility, and ability to be shaped and modified.[16] However no study exists evaluating the reliability of EPT devices when the PEEK healing abutments are used. The resulting excellent intraobserver and interobserver reliabilities of EPT with titanium healing abutments detected in the present study are in congruence with the results of previously made studies.[7,8,13,23] However, our results showed poor inter and intraobserver reliability of the EPT system when the PEEK healing abutments were used. This result is important and together with the 7-8 units higher PTVs; it can be advised not to use PEEK abutments when measuring implant stability with EPT.

Since incongruences have been observed in the mesial measurements with EPT in previous research,[13,24] EPT was performed only from buccal in the present study.

TABLE 1 Mean PTVs Obtained by the 2 Examiners

	Abutment types				
	PEEK healing abutment	Standard abutment	2 mm healing abutment	5 mm healing abutment	P^*
Examiner 1	2.08 ± 1.53	0.38 ± 1.44	−6.88 ± 1.37	−5.14 ± 0.74	.001
Examiner 2	1.08 ± 1.89	0.28 ± 1.54	−6.76 ± 1.49	−5.23 ± 1.09	.001

P values are from Friedman test ($P < .05$).

Since EPT measurements can be performed after prosthetic loading, it is important to measure its reliability not only with the healing abutments. Therefore in the present study the reliability of EPT was tested additionally with standard titanium abutments and the results showed excellent intra and interobserver reliability. However, PTVs with titanium standard abutments were detected significantly higher than the PTVs with titanium healing abutments in the present study. Additionally significantly higher PTVs were detected with 5 mm titanium healing abutments as compared to 2 mm titanium healing abutments. These results are not surprising and in accordance with the previous studies[6,8] showing that PTVs increase with abutment height. As stated previously,[6] when the engaging point of the abutment with the EPT device nears the bone margin, the PTVs be susceptible to decrease because of the diminishing length of the leverage arm. It was reported that striking position, implant location, and handpiece angulation can affect PTVs.[25] In addition to these factors, our findings show that the implant abutment type that is used to perform EPT can affect PTVs. Therefore, clinicians should be aware that the PTVs may vary depending on the implant abutment types and lengths as suggested previously[6,8] and by the results of the present study.

It is important to point out that the present in vitro results are qualitative in nature and their clinical significance should be tested in clinical studies. However, compared to in vitro studies, clinical studies are more difficult to perform and it is not possible to achieve standardization with clinical studies using the methods applied in the present study. Even though dental stability measurements made in in vitro methods may not be as accurate or valid as those obtained through in vivo methods, they can provide useful guidance for clinical applications.

Owing to the results of this ex vivo study, it may be concluded that EPT measurements should not be performed using PEEK healing abutments. Additionally, if possible, PTVs should be derived from the same type of implant abutments with the same heights during all prosthetic stages.

CONFLICT OF INTEREST

The authors report no conflict of interest.

ORCID

Onur Geçkili https://orcid.org/0000-0002-7852-3915

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