Cukurova Medical Journal
ÇUKUROVA ÜNİVERSİTESİ TIP FAKÜLTESİ

Cukurova Med J 2025;50(2):443-448
DOI: 10.17826/cumj.1707930

RESEARCH

Evaluation of insertion torque and implant stability using the osstell device according to connection method and practitioner variability

Osstell cihazı kullanılarak yerleştirme torku ve implant stabilitesinin değerlendirilmesi: bağlantı yöntemi ve uygulayıcı değişkenliğinin etkileri

Fariz Selimli[1], Ahmet Can Haskan[1]

[1]Hatay Mustafa Kemal University, Antakya, Hatay, Türkiye

Abstract

Purpose: This study aimed to evaluate the effects of SmartPeg connection methods and practitioner-related variability on insertion torque and implant stability measurements using the Osstell device.
Materials and Methods: Four oral and maxillofacial surgeons each placed 40 implants into bovine femur bone blocks with D1 bone quality. The study was conducted at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Hatay Mustafa Kemal University (Hatay, Türkiye). SmartPeg insertion torque was measured using a digital torque wrench. Resonance Frequency Analysis (RFA) was performed immediately after SmartPeg placement. Data were analyzed using ANOVA and Intraclass Correlation Coefficient (ICC).
Results: The mean insertion torque values were 69.88 ± 2.11 Ncm for the group with lower applied torque, 81.66 ± 1.43 Ncm for the group with higher manual torque, and 80.88 ± 1.55 Ncm for the standardized angulated adapter group. Statistically significant differences were observed among the groups. The highest intergroup consistency was recorded between the manual high-torque group and the angulated adapter group (ICC = 0.655, 95% CI: 0.045–0.955, p = 0.026). Additionally, ISQ values showed a positive correlation with torque consistency, suggesting that uniform application methods may enhance measurement reliability.
Conclusion: Practitioner-related variability affects SmartPeg insertion torque and subsequent ISQ measurements. The use of a standardized connection method, such as an angulated adapter applying fixed torque, may improve the reliability and reproducibility of RFA-based implant stability assessments.
Keywords:. Implant stability, insertion torque, resonance frequency analysis, practitioner variability, SmartPeg

Öz

Amaç: Bu çalışma, SmartPeg bağlantı yöntemlerinin ve uygulayıcıya bağlı değişkenliğin, Osstell cihazı kullanılarak yapılan yerleştirme torku ve implant stabilitesi ölçümleri üzerindeki etkilerini değerlendirmeyi amaçlamaktadır.
Gereç ve Yöntem: Dört ağız, diş ve çene cerrahı, D1 kemik kalitesine sahip sığır femur kemik bloklarına, her biri 40 implant yerleştirmiştir. Çalışma, Hatay Mustafa Kemal Üniversitesi Diş Hekimliği Fakültesi, Ağız Diş ve Çene Cerrahisi Anabilim Dalı'nda yürütülmüştür. SmartPeg yerleştirme torku dijital tork anahtarıyla ölçülmüştür. SmartPeg bağlantısından hemen sonra rezonans frekans analizi (RFA) gerçekleştirilmiştir. Veriler, ANOVA ve iç sınıf korelasyon katsayısı (ICC) ile analiz edilmiştir.
Bulgular: Ortalama yerleştirme torku, düşük tork uygulayan grupta 69.88 ± 2.11 Ncm, yüksek tork uygulayan grupta 81.66 ± 1.43 Ncm, standart açı adaptörlü grupta ise 80.88 ± 1.55 Ncm olarak bulunmuştur. Gruplar arasında istatistiksel olarak anlamlı fark saptanmıştır. En yüksek grup içi tutarlılık, yüksek manuel tork grubu ile açı adaptörlü grup arasında kaydedilmiştir (ICC = 0.655, %95 GA: 0.045–0.955, p = 0.026). Ayrıca, ISQ değerlerinin tork tutarlılığı ile pozitif korelasyon gösterdiği gözlemlenmiştir; bu durum, standart bağlantı yöntemlerinin ölçüm güvenilirliğini artırabileceğini göstermektedir.
Sonuç: Uygulayıcı kaynaklı değişkenlik, SmartPeg yerleştirme torkunu ve buna bağlı olarak ISQ ölçümlerini etkileyebilmektedir. Sabit tork uygulayan açı adaptörü gibi standart bağlantı yöntemlerinin kullanımı, RFA temelli implant stabilite değerlendirmelerinde tekrarlanabilirlik ve güvenilirliği artırabilir.

Anahtar kelimeler: İmplant stabilitesi, yerleştirme torku, rezonans frekansı analizi, uygulayıcı farklılığı, SmartPeg

Address for Correspondence: Dr. Fariz Selimli, Faculty of Dentistry, Hatay Mustafa Kemal UniversityAddress Department of Oral and Maxillofacial Surgery, Antakya, Hatay, Türkiye E-mail: dr_selimli@hotmail.com
Received: 28.05.2025 Accepted: 24.06.2025

INTRODUCTION

Implant therapy has become a widely accepted and predictable solution for edentulism[1]. One of the most critical factors affecting implant success is stability, which is essential for achieving osseointegration and determining the appropriate timing for prosthetic loading[2]. Implant stability is typically categorized into two types: primary and secondary[3]. Primary stability refers to the mechanical engagement of the implant with bone immediately after placement, whereas secondary stability results from biological processes such as bone remodeling and healing over time[3]. The interplay between these two types of stability determines the clinical outcome of the implant. Therefore, reliable and objective methods for assessing implant stability are of great importance in both research and clinical practice[4].

Several techniques have been developed to evaluate implant stability, including percussion, periotest, and resonance frequency analysis (RFA)[5]. Among them, RFA is a widely accepted and non-invasive method for assessing the stiffness of the implant–bone interface by transmitting vibrations through a device called a SmartPeg[6]. The SmartPeg is connected to the implant, and the device measures the resonance frequency, which is then converted into an Implant Stability Quotient (ISQ) value ranging from 1 to 100[6]. Higher ISQ values indicate stronger bone-implant integration. The accuracy of this method, however, depends on various factors, including the bone quality, implant design, and critically, the consistency of SmartPeg attachment[7]. In comparative studies, magnetic RFA devices have been shown to produce different stability readings depending on the connection method, suggesting the need for standardization in transducer placement[8].

Although the Osstell device provides reliable data for clinical decision-making, inconsistencies in ISQ measurements have been reported due to variations in the torque applied during SmartPeg placement[9]. Previous studies have shown that both under- and over-tightening can lead to deviations in ISQ values, potentially affecting clinical interpretations[10]. Additionally, factors such as practitioner technique, fatigue, and hand dominance may influence the torque applied during manual SmartPeg attachment[11]. Despite its widespread use, there is still a lack of standardization in the SmartPeg connection process, and little is known about the impact of practitioner-related variability on ISQ values. Therefore, it is essential to evaluate whether the use of a standardized connection method such as an angulated adapter with predefined torque can minimize these discrepancies and improve measurement reliability.

This study aimed to evaluate the effects of SmartPeg connection methods and practitioner-related variability on ISQ measurements obtained using the Osstell device. The torque values resulting from manual SmartPeg placement by four practitioners with equal clinical experience were compared with those obtained using an angulated adapter that applied a standardized torque of 10 Ncm. The goal was to determine whether the standardized connection technique could reduce inter-operator variability and enhance the consistency of RFA-based implant stability assessments.

MATERİALS AND METHODS

Study design and sample

This in vitro experimental study was conducted to evaluate the effects of SmartPeg connection methods and practitioner-related variability on implant stability measurements. This study was conducted at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Hatay Mustafa Kemal University (Hatay, Türkiye). Fresh bovine femur bones with D1 bone quality were used, and each of the four practitioners placed 40 implants. The bones were stored in a refrigerated environment until the procedure.

Only fresh bovine femur bones with D1 bone quality, free of fractures, deformities, or prior manipulations, were included in the study. Specimens with visible surface damage or any irregularities in cortical structure were excluded. To eliminate variability due to operator experience, only oral and maxillofacial surgeons with equal levels of clinical training and experience participated in the procedures.

Practitioner standardization and sequence

The procedures were performed by four oral and maxillofacial surgeons, consisting of two female and two male practitioners, all with equal clinical experience. The practitioners performed implant placement and SmartPeg connection in a rotating sequence to minimize fatigue and standardize conditions. At the beginning of each cycle, the first female practitioner started the procedure on 10 implants, followed by the first male, the second female, and the second male practitioner, each performing 10 implants in turn. This cycle continued until each practitioner had completed 40 implants. During the process, practitioners had resting periods until their turn resumed, ensuring equal workload and minimizing physical strain. The entire procedure was completed simultaneously in a controlled laboratory setting.

Implant placement procedure

Titanium dental implants with a diameter of 3.4 mm and a length of 11 mm (MGM Dental Implant Systems, Beaswiller, Germany) were used throughout the study. The implants were inserted into fresh bovine femur bones with D1 bone quality under controlled laboratory conditions. Each implant site was prepared using a sequential drilling protocol as recommended by the manufacturer. To ensure parallel and reproducible placement, a custom surgical guide was utilized during implant insertion. All implant placements were performed manually without the use of a torque device, and insertion torque values were not recorded at this stage to prevent interference with subsequent stability measurements.

Figure 1. View of the MGM implants placed into the bovine femur specimens in a standardized linear alignment.

SmartPeg connection and torque measurement

Following implant placement, SmartPeg devices compatible with the Osstell ISQ system were connected to each implant. The SmartPeg was attached manually by the same operator who placed the implant. A manual torque wrench was used to quantify the applied connection torque. The torque value used for each connection was recorded in Newton-centimeters (Ncm). Variability in torque values among practitioners constituted one of the main variables of the study. All measurements were performed under the same environmental conditions to minimize external influences.

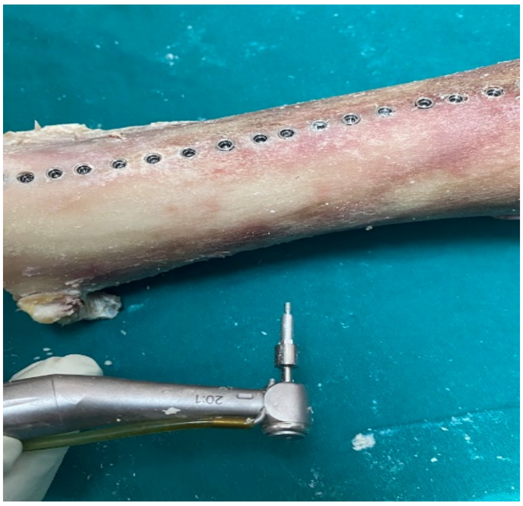


Figure 2. Placement of the smartpeg driver with an angulated adapter.

Implant stability measurement (RFA)

Implant stability was assessed using resonance frequency analysis (RFA) with the Osstell ISQ device. For each implant, measurements were taken in two perpendicular directions: mesiodistal and buccolingual. The ISQ values obtained from these directions were recorded separately. The mean ISQ value of the two measurements was calculated for each implant and used as the final stability score. All measurements were performed immediately after SmartPeg connection, without any delay, under consistent laboratory conditions.

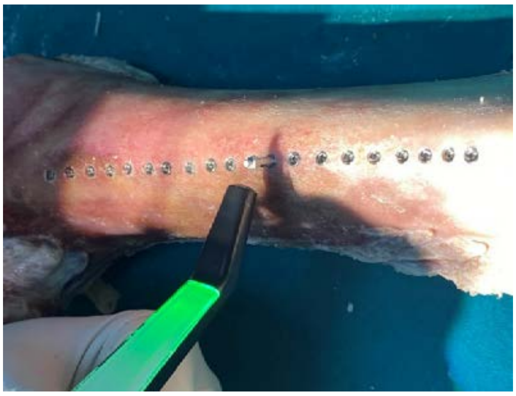


Figure 3. Resonance frequency analysis performed using the Osstell device following smartpeg placement.

Statistical analysis

Statistical analysis was performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess the normality of data distribution. For normally distributed data, the independent samples t-test was used to compare differences between practitioner groups. One-way ANOVA and Tukey's HSD post-hoc tests were used for comparisons among more than two independent groups. The intraclass correlation coefficient (ICC) based on a two-way random-effects model was used to evaluate inter-practitioner reliability of placement torque values among female, male, and angulated placement groups. ICC scores were interpreted as follows: <0: no agreement; 0–0.20: slight; 0.21–0.40: fair; 0.41–0.60: moderate; 0.61–0.80: substantial; and 0.81–1.00: almost perfect agreement. Descriptive statistics were expressed as mean ± standard deviation (SD), minimum–maximum for numerical variables, and number (%) for categorical variables. A p-value < 0.05 was considered statistically significant.

Ethical Approval Statement

This study was conducted using bovine femur bone specimens and did not involve human participants or live animals. Nevertheless, ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Hatay Mustafa Kemal University (Meeting Date: 01.04.2024, Meeting No: 03, Decision No: 25). The study was reviewed and approved unanimously by the committee, confirming compliance with ethical and scientific standards.

RESULTS

To investigate the effects of practitioner-related variability and the use of an angulated adapter on insertion torque and implant stability values, 40 implants placed by each of the four practitioners were evaluated. Both intra- and inter-practitioner reliability were assessed. The results of the comparative analyses performed between different practitioners and connection methods are presented in the following tables.

Table 1. Comparison of ISQ measurements between two practitioners for male and female groups, with intra-practitioner reliability analysis.

Gender	Practitioner	n	Mean ± SD	Min–Max	Difference (95% CI)	p (paired t-test)	ICC (95% CI)	p (ICC F-test)
Female	Practitioner 1	40	69.80 ± 2.48	63.25–73.5	0.16 (-1.02, 0.69)	0.702	0.602 (0.247–0.789)	0.002
Female	Practitioner 2	40	69.96 ± 2.52	62.25–75.75				
Male	Practitioner 1	40	81.43 ± 2.11	77.75–85.50	0.22 (-0.72, 1.14)	0.633	0.006 (-0.870–0.473)	0.492
Male	Practitioner 2	40	81.22 ± 1.93	77.75–86.25				

*mean: average value; SD: standard deviation; min: minimum; max: maximum; ICC: intraclass correlation coefficient; ISQ: implant stability quotient; p-value: probability value; CI: confidence interval

Table 2. Differences and concordance analyses of placement torque measurements in women, men, and angulated adapter groups

Group	Female (n=40)	Male (n=40)	Angulated Adapter (n=40)	p-value
Torque Measurements	69.88±2.11 (62.75–73.5)	81.66±1.43 (78.38–85)	80.88±1.55 (78–83.5)	<0.001
ICC (%95 CI)	0.655 (0.045–0.955)			0.026

*mean: average value; SD: standard deviation; min: minimum; max: maximum; ICC: intraclass correlation coefficient; p-value: probability value; CI: confidence interval.

In the analysis of 40 implants, a statistically significant difference was found between the mean insertion torque values of the female, male, and angulated adapter groups ($p<0.001$) (Table 2). The insertion torque values of the male surgeons were found to be similar to those of the angulated adapter group, while the insertion torque values of the female surgeons were statistically significantly lower ($p<0.05$) (Figure 1). The Intraclass Correlation Coefficient (ICC) between the female, male, and angulated adapter groups was assessed, revealing substantial agreement (ICC = 0.655, 95% CI: 0.045–0.955, p = 0.026). This indicates significant consistency across the three groups, with the measurements being highly reliable.

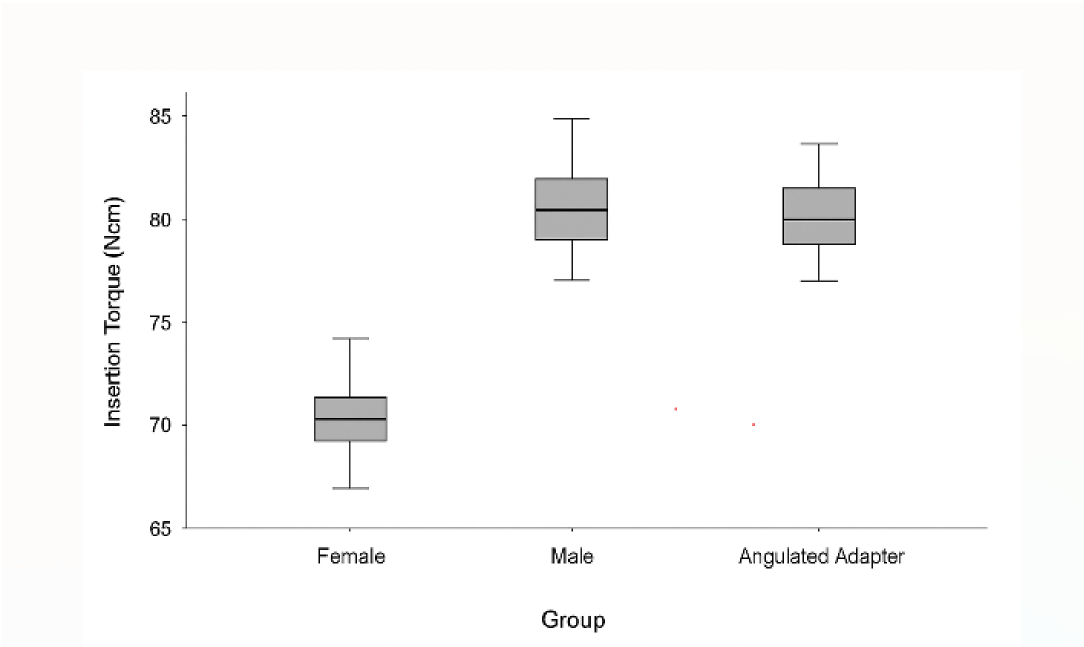
Table 3. Consistency analysis of insertion torque measurements between female, male, and angulated adapter groups

Group Comparison	ICC (95% CI)	p-value
Female - Angulated Adapter	-0.392 (-0.392 / 0.219)	0.723
Male - Angulated Adapter	-0.249 (-0.517 / 0.064)	0.944
Male – Female	0.008 (-0.011 / 0.042)	0.159

*ICC: intraclass correlation coefficient; p-value: probability value; CI: confidence interval

The consistency between group pairs was further examined through ICC values (Table 3). The comparisons revealed no significant agreement between any pair: female and angulated adapter (p = 0.723), male and angulated adapter (p = 0.944), or female and male practitioners (p = 0.159). All ICC values were close to zero or negative, indicating a lack of reliable consistency across these group comparisons.

As illustrated in Figure 1, the insertion torque values were found to be highest and most consistent in the male and angulated adapter groups. In contrast, the female group exhibited lower torque values with greater variability, indicating less uniform performance in implant placement.



.**Figure 4. Boxplot of insertion torque measurements across female, male, and angulated adapter groups**

DISCUSSION

Resonance Frequency Analysis (RFA) measurements conducted during or after the osseointegration process can be affected by multiple variables, each exerting a significant influence on Implant Stability Quotient (ISQ) values[1-6]. Among these, implant diameter and length have been consistently shown to affect both primary and secondary stability, thereby impacting ISQ measurements[2,3]. Moreover, variations in implant surface characteristics, thread design, and dimensional specifications across different implant systems further contribute to ISQ variability[4,12].

The practitioner's technique, experience, and applied insertion torque also play a crucial role in implant stability outcomes[10]. Although all operators in our study had equal years of experience, differences in ISQ readings suggest that subtle variations in handling techniques may still affect outcomes. A previous study reported significant ISQ differences even among experienced surgeons, highlighting operator-related variability as a potential confounding factor[13,14].

Furthermore, the method of SmartPeg connection can significantly influence the reliability and repeatability of RFA measurements[7,15]. A hand-tightened connection may introduce inconsistent torque levels, while a calibrated torque-controlled method ensures standardization[9,16]. In comparative studies, magnetic RFA devices have been shown to produce different stability readings depending on the connection method, suggesting the need for standardization in transducer placement[8].

Several reports emphasize that SmartPeg tightening torque significantly impacts ISQ values[16]. Excessive torque may damage internal threads or components, while insufficient torque might result in movement during measurement, reducing accuracy. For this reason, it is recommended to apply consistent force during transducer connection to achieve reliable outcomes[17].

Lastly, our results support the literature in suggesting that although ISQ provides valuable information about implant stability, its accuracy can be influenced by technical variables, including connection method and operator differences[18,19]. Therefore, interpreting ISQ values should always consider these methodological factors to avoid misinterpretation of stability outcomes.

In conclusion, the findings of this study demonstrate that inconsistencies in manually applied SmartPeg insertion torque may affect the reliability of resonance frequency analysis. Consistent torque application was associated with more reliable ISQ values. The use of a standardized connection method such as an angulated adapter applying fixed torque can reduce operator-related variation. This emphasizes the importance of standardizing transducer connection techniques to ensure reproducible and objective implant stability measurements.

This study has several limitations. Firstly, the research was conducted in a controlled ex vivo setting, which may not fully replicate the complexities of clinical conditions. Although the bovine femur model structurally approximates the human jawbone, it does not reflect all biological and physiological variables present in vivo. Additionally, the use of a single implant system and a uniform bone quality (D1) limits the generalizability of the findings to other clinical scenarios. Although gender-related differences in hand strength were discussed, individual grip strength was not objectively measured, which may have influenced the torque application. Despite these limitations, the study provides meaningful insights into operator-related variability in implant stability measurements. Future investigations should incorporate in vivo models, multiple implant systems, and diverse bone densities to enhance clinical applicability.

Author Contributions: Concept/Design : FS, ACH; Data acquisition: FS, ACH; Data analysis and interpretation: FS, ACH; Drafting manuscript: FS, ACH; Critical revision of manuscript: FS, ACH; Final approval and accountability: FS, ACH; Technical or material support: FS, ACH; Supervision: FS, ACH; Securing funding (if available): n/a.
Ethical Approval: Ethical approval was obtained from the Ethics Committee of Non-Interventional Clinical Research of Hatay Mustafa Kemal University with the decision dated 01.04.2024 and numbered 03-25/10.
Peer-review: Externally peer-reviewed.
Conflict of Interest: The authors declare no conflict of interest.
Financial Disclosure: The study received no external funding.

REFERENCES

1. Bafijari D, Pirayesh R, Memari Y, Nezafati S, Jafari M. Influence of resonance frequency analysis (RFA) measurements for successful osseointegration of dental implants during the healing period and its

impact on implant assessed by Osstell Mentor device. Open Access Maced J Med Sci. 2019;7:4110–5.
2. Herrero-Climent M, Falcao A, Tondela J. Relevant aspects of the dental implant design on the insertion torque, resonance frequency analysis (RFA) and micromobility: an in vitro study. J Clin Med. 2023;12:1–12.
3. Dos Santos MV, Elias CN, Cavalcanti Lima JH. The effects of superficial roughness and design on the primary stability of dental implants. Clin Implant Dent Relat Res. 2011;13:215–23.
4. Petersson A, Sennerby L. On standard calibration of ISQ transducer pegs: prerequisites for accurate and comparable RFA measurements. Integr Diagn Updat. 2016;1:1–3.
5. Monje A, Ortega-Oller I, Galindo-Moreno P, Catena A, Monje F, O'Valle F et al. Sensitivity of resonance frequency analysis for detecting early implant failure: a case-control study. Int J Oral Maxillofac Implants. 2014;29:456–61.
6. Meredith N, Alleyne D, Cawley P. Quantitative determination of the stability of the implant-tissue interface using resonance frequency analysis. Clin Oral Implants Res. 1996;7:261–7.
7. Kästel I, Hüttig F, Wegner B, Kirchner E, Heinemann F. Does the manual insertion torque of smartpegs affect the outcome of implant stability quotients (ISQ) during resonance frequency analysis (RFA)? Int J Implant Dent. 2019;5:1–7.
8. Geckili O, Bilhan H, Cilingir A, Mumcu E, Bural C. A comparative in vitro evaluation of two different magnetic devices detecting the stability of osseointegrated implants. J Periodontal Res. 2012;47:508–13.
9. Salatti DB, Pelegrine AA, Gehrke S, Teixeira ML, Moshaverinia A, Moy PK. Is there a need for standardization of tightening force used to connect the transducer for resonance frequency analysis in determining implant stability? Int J Oral Maxillofac Implants. 2019. doi:10.11607/jomi.7361
10. Al-Otaibi HN, Almutairi A, Alfarraj J, Algesadi W. The effect of torque application technique on screw preload of implant-supported prostheses. Int J Oral Maxillofac Implants. 2017;32:259–63.
11. Leyk D, Gorges W, Ridder D, Wunderlich M, Rüther T, Sievert A et al. Hand-grip strength of young men, women and highly trained female athletes. Eur J Appl Physiol. 2007;99:415–21.
12. Petersson A, Sennerby L. On standard calibration of ISQ transducer pegs: prerequisites for accurate and comparable RFA measurements. Integr Diagn Updat. 2016;1:1–3.
13. Balleri P, Cozzolino A, Ghelli L, Momicchioli G, Varriale A. Stability measurements of osseointegrated implants using Osstell in partially edentulous jaws after 1 year of loading: a pilot study. Clin Implant Dent Relat Res. 2002;4:128–32.
14. Scarano A, Inchingolo F, Quaranta M, Piattelli A. A 5-year follow-up of osseointegrated implants inserted without flap surgery. Clin Implant Dent Relat Res. 2010;12:1–6.
15. Huang HM, Pan YH, Lin DJ, Lee SY. Effects of various tightening torques of the smartpeg on resonance frequency measurements. Clin Oral Implants Res. 2006;17:346–50.
16. Rasmusson L, Meredith N, Kahnberg KE. Stability assessments and histology of titanium implants placed simultaneously with autogenous onlay bone in the rabbit tibia. Int J Oral Maxillofac Surg. 1998;27:229–35.
17. Bornstein MM, Hart CN, Halbritter SA, Morton D, Buser D. Early loading of nonsubmerged titanium implants with a sandblasted and acid-etched (SLA) surface: 3-year results of a prospective study in partially edentulous patients. Int J Oral Maxillofac Implants. 2009;24:887–93.
18. Sim CP, Lang NP. Factors influencing resonance frequency analysis assessed by Osstell mentor during implant healing: a systematic review. Clin Oral Implants Res. 2010;21:598–607.
19. Atsumi M, Park SH, Wang HL. Methods used to assess implant stability: current status. Int J Oral Maxillofac Implants. 2007;22:743–54.