Primary Stability/Mobility of 1-Stage and 2-Stage Dental Implants: A Comparative *In Vitro* Study

Gülsah Gülay, DDS,* Neset Volkan Asar, DDS, PhD,† Ibrahim Tulunoglu, DDS, PhD,‡ Ilser Turkyilmaz, DDS, PhD,§ Hom-Lay Wang, DDS, MS, PhD,|| and Tolga F. Tözüm, DDS, PhD¶

Purpose: *To evaluate the primary stability of 1-stage (nonsubmerged) and 2-stage (submerged) implants via newest wireless resonance frequency (RF) analyzer and newer wireless mobility measuring (MM) device.*

Materials and Methods: *Six 1-stage dental implants with internal hex connection and six 2-stage dental implants, 4.1 mm in diameter and 11.5 mm in length, were inserted bilaterally into the first premolar, second premolar, and first molar regions of 6 standard mandibular transparent self-curing acrylic resin models. After that, the periimplant circular bone defects were created in millimeter increments ranging between 0 and 5 mm to the same extent on all implants.*

Results: *Implant stability quotient values significantly decreased at 1-stage and 2-stage implants when periimplant defects increased. Similar implant stability quotient values were found for both implant types; however, significantly lower MM values were noted for 2-stage implants. Irrespective of implant systems, the results indicated a significant association between wireless RF analyzer and wireless MM device.*

Conclusion: *Both wireless RF analyzer and wireless MM device were adequate in assessing implant stability. There was no difference between 2-stage and 1-stage implant systems, except lower MM values were noted for nonsubmerged implants. (Implant Dent 2012;21:461–466)*

Key Words: dental implants, transducers, alveolar bone loss, stability

Due to highly predictable outcomes, the selection of osseointegrated implants to restore missing teeth has been increased over the past decades.[1,2] The successful outcome of any implant treatment depends on factors such as implant stability, bone quality, and surgical procedures.[3–6] The primary dental implant stability has been considered as a key factor for clinical success by clinicians. Primary stability is principally the stiffness of the surrounding bone and the engagement of the implant within that bone. As the primary stability decreases, the possibility of the micromotion between the surface of dental implant and the bone increases, which may cause the implant failure.[7] Various methods are available to determine the primary and secondary stability of dental implants in a noninvasive manner (ie, insertion torque, resonance frequency [RF] analysis).[8,9] RF analysis is an objective, reliable, and easily predictable clinical method developed for dental implantology, where it quantifies the implant stability determined as implant stability quotient (ISQ) value ranging between 1 and 100 (the higher the ISQ, the more stable is the dental implant).[10–12] Both the previous electronic cable version (Osstell cable; Osstell AB, Gothenburg, Sweden) and the newer magnetic wireless version (Osstell Mentor; Osstell AB) of RF analyzers were used in various *in vitro*, animal, and clinical studies.[13–16] Another method is the mobility analysis performed with the mobility measuring (MM) device (Periotest; Medizintechnik Gulden e.K., Modautal, Germany), which evaluates the tooth mobility by measuring the dampening characteristics of the periodontal ligament. The previous MM version with cable (Periotest; Medizintechnik Gulden e.K) was designed and applied for few years to quantify natural teeth,[17] where a newer wireless electromechanical

*PhD Student, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.
†Clinical Instructor, Department of Prosthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey.
‡Professor, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.
§Assistant Professor, Dental School Implant Clinic, Department of Comprehensive Dentistry, The University of Texas Health Science Center, San Antonio, TX.
||Professor and Director, Graduate Periodontics, Department of Periodontics and Oral Medicine, School of Dentistry, The University of Michigan, Ann Arbor, MI.
¶Associate Professor, Department of Periodontology, Faculty of Dentistry, Hacettepe, University, Ankara, Turkey.

Reprint request and correspondence: Tolga F. Tözüm, DDS, PhD. Department of Periodontology, Faculty of Dentistry, 3rd Floor, Hacettepe University, Sihhiye, 06100 Ankara, Turkey, Phone: +90 312 305 2237, Fax: +90-312-310-4440, E-mail: ttozum@hacettepe.edu.tr

ISSN 1056-6163/12/02106-461
Implant Dentistry
Volume 21 • Number 6
Copyright © 2012 by Lippincott Williams & Wilkins
DOI: 10.1097/ID.0b013e3182661615

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

MM device (Periotest M; Medizintechnik Gulden e.K) was developed for the mobility measurement of both natural teeth and dental implants. It was invented to measure the stability of implants by generating a value ranging between 8 and 50.[17,18] The evaluation of marginal bone loss around dental implants is an important parameter as the loss of surrounding bone may result in the loss of stability and eventually implant failure.[6,15,19] Some studies[12,20,21] performed to understand the relationship between periimplant bone loss and stability values demonstrated a linear correlation between the exposed implant height and the corresponding ISQ value. The level of the marginal bone surrounding a dental implant is crucial because the lower ISQ values were observed when the distance between implant abutment junction and the first bone-implant contact increased.[6,11,22] Marginal bone level measurements in intraoral radiographs are commonly used to evaluate the clinical performance of dental implants.[23] Because noninvasive methods (RF analysis and mobility measurement) are sensitive enough to detect changes in the marginal bone level, they may be used as a complementary technique to radiography.[24]

In addition to the importance of stability, mobility, and radiographic loss, the design of dental implants in terms of 1-stage (nonsubmerged) and 2-stage (submerged) dental implants has pivotal importance.[25] Buser et al[26] reported that 1-stage dental implant system with the implant shoulder located at the soft tissue level did not create microgap at the alveolar bone crest level, which could lead to less crestal bone resorption during healing and after initiation of functional loading compared to 2-stage implants. On contrary, Koczorowski and Surdacka[27] investigated the bone loss around 1-stage and 2-stage dental implants and concluded that the bone loss of the alveolar ridge at the 1-stage implants was greater than that at 2-stage implants. Although some studies investigated the relation between stability, mobility, and bone loss, to the best of our knowledge, there is a lack of evidence about the comparative analysis of primary stability and mobility of 1-stage (nonsubmerged) and 2-stage (submerged) dental implants. Thus, the aim of the present study was to determine the association between implant stability and marginal bone loss.

MATERIALS AND METHODS

Dental Implants and Procedure

Six tapered, screw-type, 1-stage dental implants with internal connection (Periotype X-Class; Periotype Implant, Zürich, Switzerland) and 6 tapered, screw-type, 2-stage dental implants with internal connection (Osstem US II Plus Fixture; Osstem Implant, Seoul, South Korea) were used in this study. All dental implants were 4.1 mm in diameter and 11.5 mm in length.

Six standard mandibular transparent self-curing acrylic resin models polymerized under pressure, which eliminates the trapped air bubbles in the models, were fabricated as previously described.[15,20,28,29] Each acrylic resin model received 6 implants. Three 1-stage dental implants were placed in the right side of mandible, whereas three 2-stage dental implants were placed in the left side. The implants were inserted into the first premolar, second premolar, and first molar regions bilaterally, and during placement, no periimplant defects were created. Each implant was used for 3 times, where a total of 18 insertions were performed for each implant system. All implants were inserted according to the manufacturer's instructions. After drilling, dental implants were placed into the implant sockets using a hand rachet.[30]

Circular vertical bone defects representing periimplant bone loss were created by removing the resin around each implant with trephine burs under saline irrigation.[21] Any material in contact with the implants was cut with a sharp scalpel. The periimplant circular bone defects were created in millimeter increments ranging between 0 and 5 mm to the same extent on all implants in each of the resin blocks. The horizontal dimension of the defects was all the same due to using a standard trephine bur, which created the periimplant horizontal clearance of 0.5 mm.[18]

In vitro drilling, dental implant placement, circular defect creation, RF, and mobility measurements were performed by calibrated practitioner, who had significant experience in implant dentistry.

RF Analysis and MM Device Measurements

At baseline, without defect preparation and after each defect preparation, RF and MM values were measured. The rigidity of the implant-acrylic interface was assessed by the recent version wireless RF analyzer (Osstell ISQ; Osstell AB) and the wireless MM device (Periotest M; Medizintechnik Gulden e.K). All measurements were taken from buccolingual direction. The wireless electromagnetic RF analysis device (Osstell ISQ, Osstell AB) analyzes the RF (range, 110–1000 Hz) of a smart peg (Osstell Smart Peg; Osstell AB) (type 4 for 1-stage implants and type 6 for 2-stage implants), which can be attached to the implant with the aid of a cylindrical plastic holder provided by the company, 4-5 N.cm torque was enough. The probe of the wireless RF analyzer was held buccolingually to the implant. The ISQ value is presented on the screen of the analyzer. The RF values are converted to ISQ by the analyzer automatically. ISQ values ranging between 1 and 100 demonstrated that the higher the ISQ, the more stable is the dental implant.

The wireless MM device (Periotest M; Medizintechnik Gulden e.K) was used to measure the assessment of stability of the dental implant by generating a value ranging between −8 and +50. An electrically driven and electronically monitored tapping head percusses the cover screw of the dental implant buccolingually. The values achieved are classified by the manufacturer as follows: −8 to 0: good osseointegration, indicating that the implant is well integrated and pressure can be applied to it; +1 to +9: a clinical examination is required, and the application of pressure on the implant is generally not possible; +10 to +50: osseointegration is insufficient and no pressure may be allowed to act on the implant.

Statistical Analysis

Statistical software (SPSS 11.0; SPSS, Inc, Chicago, IL) was used to perform the general analysis of the data.

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

Table 1. Descriptive and Comparative Statistical Analysis of ISQ and MM values for 1-Stage and 2-Stage Implants at the Same Level of Periimplant Circular Vertical Defects

Vertical Defect (mm)	ISQ Values			MM Values		
	One Stage	Two Stage	*P*	One Stage	Two Stage	*P*
0	72.7 ± 2.2	73.5 ± 1.9	0.309	−2.4 ± 1.5	−3.7 ± 0.9	0.01*
1	70 ± 0.3	71.7 ± 1.3	0.001*	−1.4 ± 0.7	−2.7 ± 1	0.001*
2	69.9 ± 0.2	70 ± 0.3	0.111	−1 ± 0.7	−1.9 ± 0.9	0.009*
3	67.5 ± 2	68.7 ± 1.3	0.105	−0.8 ± 0.6	−1.4 ± 1	0.014*
4	65 ± 3.6	66.6 ± 1.9	0.431	−0.8 ± 0.3	−0.9 ± 0.3	0.04*
5	63 ± 3.6	64.4 ± 0.8	0.491	−0.5 ± 0.8	−1.2 ± 0.1	0.001*

For the same amount of vertical defect, ISQ values for 2-stage implants were higher than those for 1-stage implants. The mean ISQ values of 1-stage and 2-stage implants decreased from 72.7 ± 2.2 and 73.5 ± 1.9 (baseline) to 63 ± 3.6 and 64.4 ± 0.8, respectively, when 5-mm circular vertical bone was performed. MM values of 2-stage implants were lower than those of 1-stage implants for the same amount of defect. The mean MM values of 1-stage and 2-stage implants increased from −2.4 ± 1.5 and −3.7 ± 0.9 (baseline) to −0.5 ± 0.8 and −1.2 ± 0.1, respectively, when 5-mm circular bone was removed.
*Statistically significant.

As the data were not normally distributed, Mann-Whitney *U* test was used to explore the differences in periimplant defects, and ISQ and MM values between 1-stage and 2-stage dental implants. Spearman test was performed to evaluate the correlations between ISQ and MM values. A value of $P < 0.05$ was considered statistically significant.

RESULTS

The mean ISQ and MM values obtained for 1-stage and 2-stage implants with regard to bone defect, including the significance levels, were shown in Table 1. Table 2 demonstrates *P* values of 1-stage and 2-stage implants measured among vertical defects.

When the statistical data of 1-stage and 2-stage dental implant systems were evaluated for the same amount of defect, there was a statistically significant increase for the mean ISQ values obtained only at 1-mm defect for 2-stage compared to 1-stage implants ($P < 0.05$). However, a trend of increase for ISQ values was also noted for other increments at 2-stage implants compared to 1-stage implants. When MM values were concerned, a statistically significant decrease was observed at all defects for 2-stage implants compared to 1-stage ones ($P < 0.05$) (Table 1). When periimplant defects were compared in 1-mm increments (Table 2), a significant decrease in ISQ values was noted for both 1-stage and 2-stage implants. However, MM values demonstrated only significant differences at 2-stage implants at the increment range of 0 to 1, 1 to 2, and 4 to 5 mm ($P < 0.05$).

When 1-stage and 2-stage implants were pooled together, irrespective of dental implant system, there was a significant correlation between the ISQ and MM values ($r = 521$; $P = 0.01$).

DISCUSSION

In the past, clinicians used 2-stage screw-type implants with submerged or nonsubmerged approaches.[25,26] However, to date, with the development of 1-stage and 2-stage dental implants, they have options to select specific dental implants according to the stage of the surgical treatment. The long-term success of dental implants depends mainly on the primary stability, which is largely associated with surgical techniques used, bone quality and quantity, and implant design. Minimizing implant micromovement, especially during early healing periods, is a key to achieve implant osseointegration. Although many *in vivo* studies compared the success of implants placed by submerged and nonsubmerged procedures,[31–33] to the best of our knowledge, no information was available in the literature in terms of the primary stability comparison between 1-stage and 2-stage dental implants. In the current study, the latest version wireless RF analyzer (Osstell ISQ, Osstell AB) and newer wireless MM device (Periotest M, Medizintechnik Gulden e.K) were used to evaluate primary stability/mobility of 1-stage and 2-stage dental implants. The wireless type RF device has a transducer (magnetic probe) and metallic rod with a magnet on top (smart peg, Osstell Smart Peg; Osstell AB), which is screwed onto an implant. This device, differently from the RF device with cable (Osstell cable, Osstell AB), may allow the operator to measure implant stability without being influenced by probe orientation from parallel to perpendicular to the long axis of the cortical bone models or to the smart peg. Valderrama et al[13] presented that changes in implant stability measured with the newer magnetic wireless RF analyzer (Osstell Mentor, Osstell AB) correlated moderate with those found with the previous electronic cable RF analyzer. An *in vitro* study[15] also reported that newer wireless electromagnetic RF analyzer

Table 2. Comparison of ISQ and MM Values of Implants With Consecutive Defect Formation

	ISQ Values (*P*)		MM Values (*P*)	
	One Stage	Two Stage	One Stage	Two Stage
0–1 mm	0.001*	0.004*	0.59	0.004*
1–2 mm	0.04*	0.002*	0.41	0.017*
2–3 mm	0.001*	0.001*	0.96	0.149
3–4 mm	0.037*	0.001*	0.29	0.08
4–5 mm	0.04*	0.001*	0.08	0.016*

When ISQ values were concerned, statistical significances were noted for each 1-mm increments at 1-stage and 2-stage implants, which may mean that circumferential vertical defects around implants may cause the loss of stability. However, MM device may not determine the mobility of implants sensitively when periimplant defects were created.
*Statistically significant.

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

(Osstell Mentor) was a suitable, sensitive, and reliable device to measure implant stability, where it could detect circular, vertical periimplant defects simulated in acrylic mandibular models. In a human cadaver study, Tözüm et al[18] compared the primary stability of implants inserted into extraction sockets by using RF with cable, RF wireless, and new wireless MM (Periotest M; Medizintechnik Gulden e.K) devices. They concluded that RF with cable and RF wireless seem to be suitable in the assessment of primary implant stability and in the determination of circular defects around implants ranging between 0 to 5 mm in all increments.[18] The previous MM device with cable (Periotest; Medizintechnik Gulden e.K), which was invented for natural tooth, has been used for few years to quantify the mobility of natural tooth and also the stability of implants. Due to its disadvantages, such as low sensitivity in combination with low resolution, observer dependence, and less prognostic value to detect loss of implant stability, this method was criticized by some researchers, and a newer wireless MM device has then been developed, which measures both the dampening characteristics of the periodontium of the natural tooth and the determination of the stability of the implant.[6,7,34]

Zix et al[35] compared the previous RF analyzer with cable with the previous mobility measurement device with cable in clinics, and they found a moderate to good correlation between both devices. Significant correlation between the previous RF analyzer with cable and the MM device with cable was also reported in the study by Seong et al,[36] where the primary stability of screw-shaped implants placed into edentulous maxillae and mandibles of fresh human cadavers were evaluated. The results of the present study are in agreement with those previous studies, where new wireless RF analyzer and wireless MM device, both noninvasive wireless diagnostic devices, demonstrated significant high correlation with each other in assessing implant stability of different implant types for all tested bone defects.

Many studies dealt with the correlation between periimplant bone defects and ISQ values with different types of implants.[15,21,24,37,38] Lachmann et al[29] compared the performance of damping capacity assessment to RF analysis in the assessment of periimplant bone loss in an *in vitro* study. They concluded that MM device with wire and RF device with wire were both suitable to detect a decrease in implant stability, as indicated by periimplant bone loss. Sennerby et al[24] evaluated bone tissue and associated implant stability changes that occurred during induction and resolution of periimplantitis using RF analysis, radiography, and histology. They placed 24 implants in the mandibles of 4 dogs and induced periimplantitis for 3 months, in which the authors found a linear relationship between marginal bone level and ISQ values.[24] Ohta et al[37] aimed to evaluate the association between ISQ values and various factors, such as magnetic probe orientation, implant diameter, insertion torque, and periimplant bone defects, where they presented statistically significant correlation between the ISQ values and periimplant vertical defects ranging from 0 to 3 mm. Merheb et al[38] investigated the influence of bony defects on implant stability by wireless RF device and MM device with wire and concluded that both devices were sensitive only for marginal bone loss compared to periapical and lateral bone loss. In agreement with those previous studies, regardless of implant type, significantly lower ISQ values were obtained as the amount of the defects increased. However, for both implant systems, only a few significances were noted in MM values.

When the ISQ values of 1-stage (nonsubmerged) and 2-stage (submerged) implant types were evaluated, a trend of higher ISQ values were demonstrated using 2-stage dental implants compared to 1-stage implants for all bone defects; however, only 1-mm bone defect reached to statistical significance. The MM values obtained for 2-stage dental implants were all significantly lower than those obtained for 1-stage dental implants, which means less mobility. Because both types of implants had the same surface characteristics and were placed into acrylic models, the reason for the differences between primary implant stabilities of 2 dental implant types may be attributed to different geometrical designs of dental implants. The 2-stage dental implant used in this study was a self-tapping implant with straight body shape, whereas the 1-stage dental implant was a self-tapping implant with its conical enlargement in the crestal area and the tapered apical end. A comparison of different implant types was examined in the study of O'Sullivan et al,[39] where the primary stability characteristics of 5 different implant designs, specifically the standard polished implant, Mark II self-tapping implant, Mark IV self-tapping implant, Osseotite implant, and Tioblast implant were compared. The study demonstrated higher ISQ and insertion torque values for tapered implants than for nontapered implants, indicating better stability in tapered implants, especially in low-density bone[39]; however, they expressed that no statistically significance was noted in type 2 bone between all different geometrical implant designs used. Furthermore, in a clinical study conducted by RF analyzer, Friberg et al[40] found that conical rough surface implants had significantly higher primary stability in type 4 bone (low-density bone) than standard polished surface implants that served as controls. Based on the results of the present study and above-mentioned studies, due to its tapered design, one could expect higher primary stability values for 1-stage dental implants than 2-stage dental implants with straight body shape. However, similar ISQ values were noted for 1-stage implants compared to 2-stage ones. This could be explained by the height of the implant above the level of marginal bone. Meredith[6] demonstrated the relationship between exposed implant height and RF *in vitro*. According to this relationship, RF values decrease as the exposed implant height increases, where a trend of decrease was noted in 1-stage implants compared to 2-stage ones, which may be related to height of the platform. With respect to the study by O'Sullivan et al[39] on low-density bone about stability, one may speculate that because the acrylic resin models were used in the present study, which act like dense bone when set, the

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

lateral compression effect of the 1-stage implants could have minor effect on force distribution into the surrounding bone. This might have masked the impact of achieving higher ISQ values due to the use of hard acrylic resin model like type 1 bone (high-density bone).

CONCLUSIONS

Within the limits of this study, the following conclusions were drawn:

1. The ISQ values significantly decreased at 1-stage (nonsubmerged) and 2-stage (submerged) implants when periimplant bone defects increased.
2. Similar ISQ values were found in 1-stage and 2-stage implants; however, significantly lower MM values were noted for 2-stage system compared to 1-stage.
3. When pooled 1-stage and 2-stage implants together, the results indicated a significant association between wireless RF analyzer and wireless MM device.
4. Implant stability of the both types of implants (1-stage and 2-stage) used in this study can be evaluated *in vivo* to confirm the clinical effectiveness of the findings of the present study.

DISCLOSURE

All authors have no conflict of interest.

ACKNOWLEDGMENT

This study was supported by Hacettepe University, Scientific Research and Development Office Fund (grant number 09A201003) Ankara, Turkey.

REFERENCES

1. Attard NJ, Zarb GA. Long-term treatment outcomes in edentulous patients with implant overdentures: the Toronto study. *Int J Prosthodont*. 2004;17:425–433.

2. Turkyilmaz I. Clinical and radiological results of patients treated with two loading protocols for mandibular overdentures on Brånemark implants. *J Clin Periodontol*. 2006;33:233–238.

3. Sennerby L, Meredith N. Implant stability measurements using resonance frequency analysis: biological and biomechanical aspects and clinical implications. *Periodontol 2000*. 2008;47:51–66.

4. Beer A, Gahleitner A, Holm A, et al. Correlation of insertion torques with bone mineral density from dental quantitative CT in the mandible. *Clin Oral Implants Res*. 2003;14:616–620.

5. Ekfeldt A, Christiansson U, Eriksson T, et al. A retrospective analysis of factors associated with multiple implant failures in maxillae. *Clin Oral Implants Res*. 2001;12: 462–467.

6. Meredith N. Assessment of implant stability as a prognostic determinant. *Int J Prosthodont*. 1998;11:491–501.

7. Rabel A, Kohler SG, Schmidt-Westhausen AM. Clinical study on the primary stability of two dental implant systems with resonance frequency analysis. *Clin Oral Investig*. 2007;11:257–265.

8. Al Nawas B, Wagner W, Grotz KA. Insertion torque and resonance frequency analysis of dental implant systems in an animal model with loaded implants. *Int J Oral Maxillofac Implants*. 2006;21: 726–732.

9. Oh JS, Kim SG, Lim SC, et al. A comparative study of two noninvasive techniques to evaluate implant stability: Periotest and Ostell Mentor. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009; 107:513–518.

10. Turkyilmaz I, Tümer C, Özbek EN, et al. Relations between the bone density values from computerized tomography, and implant stability parameters: a clinical study of 230 regular platform implants. *J Clin Periodontol*. 2007;34:716–722.

11. Sennerby L, Meredith N. Resonance frequency analysis: measuring implant stability and osseointegration. *Compend Contin Educ Dent*. 1998;19: 493–498, 500, 502.

12. Tözüm TF, Turkyilmaz I, Yamalik N, et al. Analysis of the possibility of the relationship between various implant-related measures: an 18-month follow-up study. *J Oral Rehabil*. 2008;35:95–104.

13. Valderrama P, Oates TW, Jones AA, et al. Evaluation of two different resonance frequency devices to detect implant stability: a clinical trial. *J Periodontol*. 2007; 78:262–272.

14. Turkyilmaz I, Sennerby L, Tümer C, et al. Stability and marginal bone level measurements of unsplinted implants used for mandibular overdentures: a 1-year randomized prospective clinical study comparing early and conventional loading protocols. *Clin Oral Implants Res*. 2006; 17:501–505.

15. Tözüm TF, Turkyilmaz I, McGlumphy EA. Relationship between dental implant stability determined by resonance frequency analysis measurements and peri-implant vertical defects: an in-vitro study. *J Oral Rehabil*. 2008;35:739–744.

16. Degidi M, Piatelli A, Gehrke P, et al. Clinical outcome of 802 immediately loaded 2-stage submerged implants with a new grit-blasted and acid-etched surface: 12-month follow-up. *Int J Oral Maxillofac Implants*. 2006;21:763–768.

17. Teerlinck J, Quirynen M, Darius P, et al. Periotest: an objective clinical diagnosis of bone apposition toward implants. *Int J Oral Maxillofac Implants*. 1991;6:55–61

18. Tözüm TF, Bal BT, Turkyilmaz I, et al. Which device is more accurate to determine the stability/mobility of dental implants. *J Oral Rehabil*. 2010;37: 217–224.

19. Lang NP, Wilson TG, Corbet EF. Biological complications with dental implants: their prevention, diagnosis and treatment. *Clin Oral Implants Res*. 2000; 11(suppl 1):146–155.

20. 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;7:261–267.

21. Turkyilmaz I, Sennerby L, Yilmaz B, et al. Influence of defect depth on resonance frequency analysis and insertion torque values for implants placed in fresh extraction sockets: a human cadaver study. *Clin Implant Dent Relat Res*. 2009; 11:52–58.

22. Gomez-Roman G, Lukas D. Influence of the implant abutment on the Periotest value: an in vivo study. *Quintessence Int*. 2001;32:797–799.

23. Hollender L, Rockler B. Radiographic evaluation of osseointegrated implants in jaws. *Dentomaxillofac Radiol*. 1980;9:91–95.

24. Sennerby L, Persson LG, Berglundh T, et al. Implant stability during initiation and resolution of experimental periimplantitis: an experimental study in the dog. *Clin Implant Dent Relat Res*. 2005;7:136–140.

25. Esposito M, Grusovin MG, Chew YS, et al. Intervention for replacing missing teeth: 1-versus 2-stage implant placement. *Cochrane Database Syst Rev*. 2009;3:1–24.

26. Buser D, Mericske-Stern R, Dula K, et al. Clinical experience with one-stage, non-submerged dental implants. *Adv Dent Res*. 1999;13:153–161.

27. Koczorowski R, Surdacka A. Evaluation of bone loss at single-stage and two-stage implant abutments of fixed partial dentures. *Adv Med Sci*. 2006;51(suppl 1):43–45.

28. Tözüm TF, Turkyilmaz I, Bal BT. Initial stability of two dental implant systems: Influence of buccolingual width and probe

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

orientation on resonance frequency measurements. *Clin Implant Dent Relat Res*. 2010;12:194–201.

29. Lachmann S, Laval JY, Jager B, et al. Resonance frequency analysis and damping capacity assessment Part 2: periimplant bone loss follow-up. An in vitro study with the Periotest and Ostell instruments. *Clin Oral Implants Res*. 2006;17:80–84.

30. Kahraman S, Bal BT, Asar NV, et al. Clinical study on the insertion torque and wireless resonance frequency analysis in the assessment of torque capacity and stability of self-tapping dental implants. *J Oral Rehabil*. 2009;36:755–761.

31. Barber HD, Seckinger RJ, Silverstein K, et al. Comparison of soft tissue healing and osseointegration of IMZ implants placed in one-stage and two-stage techniques: a pilot study. *Implant Dent*. 1996;5:11–14.

32. Becktor JP, Isaksson S, Billstrom C. A prospective multicenter study using two different surgical approaches in the mandible with turned Brånemark implants: conventional loading using fixed prostheses. *Clin Implant Dent Relat Res*. 2007;9:179–185.

33. Cecchinato D, Olsson C, Lindhe J. Submerged or non-submerged healing of endosseous implants to be used in the rehabilitation of partially dentate patients. *J Clin Periodontol*. 2004;31: 299–308.

34. Aparicio C, Lang NP, Rangert B. Validity and clinical significance of biomechanical testing of implant/bone interface. *Clin Oral Implants Res*. 2006;17 (suppl 2):2–7.

35. Zix J, Kessler-Liechti G, Mericske-Stern R. Stability measurements of 1-stage implants in the maxilla by means of resonance frequency analysis: a pilot study. *Int J Oral Maxillofac Implants*. 2005;20:747–752.

36. Seong WJ, Holte JE, Holtan JR, et al. Initial stability measurement of dental implants placed in different anatomical regions of fresh human cadaver jawbone. *J Prosthet Dent*. 2008;99:425–434.

37. Ohta K, Takechi M, Minami M, et al. Influence of factors related to implant stability detected by wireless resonance frequency analysis device. *J Oral Rehabil*. 2010;37:131–137.

38. Merheb J, Coucke W, Jacobs R, et al. Influence of bony defects on implant stability. *Clin Oral Implants Res*. 2010;21: 919–923.

39. O'Sullivan D, Sennerby L, Meredith N. Measurements comparing the initial stability of five designs of implants. A human cadaver study. *Clin Implant Dent Relat Res*. 2004;6:24–32.

40. Friberg B, Jisander S, Widmark G, et al. One-year prospective three-center study comparing the outcome of a 'soft bone implant' (prototype MK IV) and the standard Brånemark implant. *Clin Implant Dent Relat Res*. 2003;5:71–77.

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.