 doi:10.20944/preprints202007.0457.v1

Title

Reliability and validity of three instruments for measuring Implant Stability Quotient

Authors

Monica Blazquez-Hinarejos[1], Constanza Saka-Herrán[2], Victor Diez-Alonso[3], Jose Lopez-Lopez J[4], Raul Ayuso-Montero[5]*, Eugenio Velasco-Ortega[6]

[1] Faculty of Medicine and Health Sciences (Dentistry), University of Barcelona, Barcelona, Spain. mblazquezhinarejos@gmail.com.

[2] PhD student. Faculty of Medicine and Health Sciences (Dentistry), University of Barcelona, Barcelona, Spain. constanzasakah@gmail.com. ORCID: 0000-0001-7207-6408

[3] Master degree in Oral Rehabilitation. Faculty of Medicine and Health Sciences (Dentistry), University of Barcelona, Barcelona, Spain. victor.diez.a@gmail.com

[4] Department of Odontostomatology, Faculty of Medicine and Health Sciences (Dentistry), Barcelona University Dental Hospital, University of Barcelona // Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, University of Barcelona, Barcelona, Spain. 18575jll@gmail.com. ORCID: 0000-0001-8035-4412

[5] Department of Odontostomatology, Faculty of Medicine and Health Sciences (Dentistry) // Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, University of Barcelona, Barcelona, Spain. raulayuso@ub.edu. ORCID: 0000-0002-8090-0564.

[6] Department of Stomatology, Faculty of Dentistry, University of Seville, Seville, Spain. ORCID: 0000-0002-0228-484X

*Correspondence: raulayuso@ub.edu; Tel.:+34-934-024-270

Abstract

Background: Actually, resonance frequency analysis (RFA) is the most extended method for measuring implant stability. The implant stability quotient (ISQ) is the measure obtained by the different RFA devices, however, inter- and intra- rater reliability and validity of some devices remains unknown.

Methods: Thirty implants were placed in 3 different pig mandibles. ISQ was measured axial and parallel with Osstell® Beacon, Penguin® and MegaISQ® by 2 different operators and one operator performed a test-retest. Intraclass correlation coefficient was calculated to assess the intra- and inter-rater reliability. Pearson correlation coefficient was used to assess the validity.

Results: The higher inter- and intra- rater reliability was obtained by Penguin® when measuring axial. The highest ISQ values were obtained using Penguin® in an axial measurement; the lowest, using the MegaISQ® in an axial measurement. The highest correlation values with the other devices were obtained by MegaISQ® measuring axially.

Conclusion: Penguin® had a good reliability for measuring ISQ both inter- and intra-rater. Osstell® had good validity for measuring ISQ both axial and parallel and MegaISQ® had the best validity for measuring ISQ axial.

Key words: resonance frequency analysis; implant stability quotient; reliability; validity.

 doi:10.20944/preprints202007.0457.v1

Introduction

Implant stability is particularly important in implant therapy and varies during the osseointegration process, reflecting the changes in bone / implant interface [1,2]. Low levels of implant micromotion are necessary to avoid implant failure and successful osseointegration [3-5].

Several methods have been suggested to measure implant stability, such as Periotest, insertion torque value (IST) or implant stability quotient (ISQ) by means of resonance frequency analysis [6]. Low Periotest values and high insertion torque or ISQ values indicate low levels of implant micromotion and successfully integrated implants. However, Periotest is a damping method that requires to strike the implant abutment [7] and ITV only assess conditions at the time of implant installation [6]. Moreover, ITV and ISQ values shows an inverse correlation with implant micromotion, but the relationship between ITV and implant micromotion becomes exponential for higher values [5]. For these reasons ISQ became the most extended method actually.

The ISQ technique registers the response of an electromagnetic or electromechanical excitement of an abutment fixed to the implant called transducer peg, measuring the implant stability [8]. The device returns a quotient value ranged from 0 (maximum vibration) to 100 (minimum vibration) [9].

The industry has provided some devices for measuring ISQ, and some authors have provided data regarding the reliability of some instruments such as Osstell® and Penguin® [10-13]. However, some of these authors have reported differences between devices and, to the best of our knowledge, inter- and intra- rater reliability and validity of some devices remains unknown.

The main objective of this study was to determine and compare the inter- and intra-reliability of Osstell® Beacon, Penguin® and MegaISQ®. This study also aimed to explore the validity between these devices for ISQ measurement.

Material and methods

In this in vitro study, 30 BioHorizons® Internal implants (BioHorizons, Birmingham, USA) were inserted in fresh pig mandibles (Figure 1). The manufacturer drilling protocol was performed to locate 10 implants (4.6 diameter, 12mm height) in 10 different positions of 3 different mandibles (Figure 1). Considering an alpha error of 0.05 and a beta error of 0.2, in a two-sided test, a minimum of 20 samples were necessary on each group to identify a statistically significant difference greater than or equal than to 2 units. Based on a recent study [14], standard deviation was assumed to be 5 and the correlation coefficient measurements was 0.9.

Figure 1. Implant locations in a representative mandible.

ISQ was measured with three different devices. The first device was Osstell® Beacon (W&H, Göteborg, Sweden). The transducer peg for Osstell (smartpeg) was inserted on each implant according to the manufacturer instructions and two measures were recorded axially and parallel (lingual).

The second device was Penguin® (Integration Diagnostics Sweden AB, Göteborg, Sweden). The transducer peg for Penguin (multipeg) was inserted on each implant according to the manufacturer instructions and two measures were obtained in the same conditions.

The third device was MegaISQ® (Megagen Implant CO, Daegu, Korea). The transducer peg for MegaISQ® (smartpeg) was inserted on each implant according to the manufacturer instructions and two measures were recorded both axially and parallel (lingual).

All procedures were repeated by 2 different operators (MB and RA), in order to assess the inter-rater reliability, and one of this two operators (RA) repeated the procedures 5 minutes later in order to perform a test-retest check for measuring the intra-rater reliability in the same conditions. While it was not possible to blind the device used, the order in which implants were measured and which device was used were randomized. The measures were coded by these two operators in order to blind the statistical analysis.

Statistical analysis

Shapiro-Wilks and Levene tests were respectively used for assessing criteria of normality and homogeneity of variances. Test–retest was used to calculate the intraclass correlation coefficient (ICC) using a mixed model with a random effect for the individual for assessing the intra- and inter-rater reliability. ICC values were classified as poor-moderate-good according to Koo et al. criteria. [15]. Absolute ISQ values obtained using each method were reported as mean (95%CI). The validity between the devices was assessed by means of Pearson correlation coefficient. To establish the level of agreement and the correlation between the different devices a mean value from the two operators was calculated. All analyses were performed using the IBM Statistics for Windows v24.0 software package (IBM Corp., New York, USA) ($P < 0.05$).

Results

The higher inter- and intra- rater reliability was obtained by Penguin® when measuring axial. The lowest inter- rater reliability was obtained by MegaISQ® measuring parallel, Osstell® Beacon measuring parallel, and MegaISQ® measuring axial. The lowest intra-rater reliability was obtained by Osstell® Beacon (Table 1).

Table 1. Reliability (ICC; 95% CI) of the three devices used to measure ISQ.

RELIABILITY		ICC Classification		
INTER-RATER			INTRA-RATER	
METHOD	ICC (95% CI)		ICC (95% CI)	
OSSTELL® axial	0,37 (0,40 to 0,64)	poor	0,65 (0,38 to 0,81)	moderate
OSSTELL® parallel	0,20 (-0,17 to 0,52)	poor	0,47 (0,13 to 0,71)	poor
PENGUIN® axial	0,86 (0,72 to 0,93)	good	0,85 (0,70 to 0,92)	good
PENGUIN® parallel	0,57 (0,26 to 0,77)	moderate	0,78 (0,56 to 0,89)	good
MEGAISQ® axial	0,26 (-0,11 to 0,57)	poor	0,60 (0,26 to 0,79)	moderate
MEGAISQ® parallel	-0,01 (-0,38 to 0,36)	poor	0,57 (0,27 to 0,77)	moderate
ICC- 2-way random, absolute agreement for single measurement				

The highest ISQ values were obtained using Penguin® in an axial measurement; the lowest, using the MegaISQ® in an axial measurement (Table 2).

Table 2. Mean values (95% CI) of ISQ according to the device and the orientation record.

DEVICE	TECHNIQUE	ISQ	Difference with mean ISQ values 62.1 (59.2 to 65)
OSSTELL®	axial	62.2 (59.5 to 64.9)	0.1 (-0.1 to 0.1)
	parallel	60.6 (58.0 to 63.3)	-1.5 (-1.7 to -1.15)
PENGUIN®	axial	66.3 (62.4 to 70.1)	4.2 (3.25 to 5.1)
	parallel	63.1 (60.0 to 66.3)	1 (0.85 to 1.3)
MEGAISQ®	axial	60.1 (57.5 to 62.6)	-2 (-2.4 to -1.65)
	parallel	60.2 (57.5 to 62.8)	-1.9 (-2.2 to -1.65)
ISQ- Implant Stability Quotient. 95% CI- 95% Confidence Interval			

A matrix with the Pearson correlation coefficients is shown in Table 3. The highest correlation values with the other devices were obtained by MegaISQ® measuring axially; however, this device obtained the lowest correlation values when measuring parallel. Osstell® obtained high correlation values with the other devices measuring either axially or parallel. Penguin® obtained correlation values lower than Osstell®, both measuring axial and parallel, but higher than MegaISQ® when measuring parallel.

Table 3. Matrix of Pearson correlation coefficients for the different devices used to measure ISQ.

	OSSTELL® axial	OSSTELL® parallel	PENGUIN® axial	PENGUIN® parallel	MEGAISQ® axial	MEGAISQ® parallel	TOTAL
OSSTELL® axial	1	0,723**	0,667**	0,555**	0,766**	0,405**	4,12
OSSTELL ® parallel	0.723**	1	0,575**	0,652**	0,653**	0,525**	4,13
PENGUIN® axial	0.667**	0.575**	1	0,760**	0,691**	0,298*	3,99
PENGUIN® parallel	0.555**	0.652**	0.760**	1	0,675**	0,404**	4,05
MEGAISQ® axial	0.766**	0.653**	0.691**	0.675**	1	0,449**	4,23
MEGAISQ® parallel	0.405**	0.525**	0.298*	0.404 **	0.449 **	1	3,08
*p<0.01;**p<0.001							

Discussion

The present results suggest that Penguin® exhibits good reliability when measuring axially, and moderate to good reliability when measuring parallel. Osstell® Beacon presented a poor to moderate reliability when measuring axially and poor when measuring parallel, and MegaISQ® obtained poor to moderate reliability when measuring both axially and parallel. Our ICC scores were lower than a recent study [13]; however, in this study the mean of the lateral and axial ISQ values was considered the final ISQ of each implant, then the differences of each device measuring axial or parallel could be not detected. Other study with high ICC scores for Osstell®, reported a good reliability for both Penguin® and Osstell® but only when the implant surrounding material was stiff [10]. The differences in bone density between studies could explain the different results obtained.

The inter-rater ICC values were mostly lower than the intra-rater ICC values for the majority of devices and techniques. This observation suggest that the values obtained from these devices can be operator dependent.

All three devices presented higher ICC values when measuring axially than parallel. One study reported increased variability and reduced reliability when measuring buccolingual [11]. These results suggest that the clinical evaluation of implant stability by means of ISQ could be recommended axially.

The Osstell® Beacon values were the most similar to the mean according to the previous literature [13,16]. In our study, the highest ISQ values were obtained using Penguin® and the lowest values were using MegaISQ®. This observation can lead the clinician to overestimate the implant stability with Penguin®. The MegaISQ® values were the lower, then MegaISQ® tends to underestimate the implant stability. However, the difference with the mean was 2 times lower with MegaISQ® than with Penguin, then the underestimation of MegaISQ® has not the magnitude of Penguin® overestimation.

Comparing the correlation between each instrument, MegaISQ® measuring axial had the higher correlation to the others (considering every instrument and technique). However, the same instrument obtained the lower correlation when measuring parallel. On the other hand, Osstell® Beacon obtained good correlation for measuring both axial and parallel, and Penguin® had similar correlation values with the other methods measuring axial and parallel.

This study has some limitations. The bone density can affect ISQ values [17] and no previous evaluation of the different bone locations where implants were placed was done. However, some aspects that could affect ISQ values, such as implant length and diameter were controlled using the same implant size for all measurements. Other limitation was the manual tightening of the transducers, but this technique was reported to be objective and reliable previously [18]. Finally, it was not possible to blind operators within the instrument used, and further research is needed to clinically assess in vivo the behavior of these devices.

Conclusions

Within the limitations of this study, Penguin® had a good reliability for measuring ISQ both inter- and intra- rater; Osstell® had good validity for measuring ISQ both axial and parallel and MegaISQ® had the best validity for measuring ISQ axial, but not for measuring parallel.

Funding information: This research received funding from Biohorizons-Camlog® Ibérica with the grant number 018582/2019, and from the Faculty of Medicine and Health Sciences, University of Barcelona.

Acknowledgments

The authors gratefully acknowledge Professor Jordi Martinez-Gomis for the statistical analysis support.

Author contributions

Conceptualization, J.L-L., R.A-M. and E.V-O.; Methodology, R.A-M., J.L-L., C.S-H. and E.V-O.; Software, R.A-M and C.S-H.; Validation, M.B-H., C.S-H., V-D-A., J.L-L., R.A-M. and E.V-O; Formal Analysis, R.A-M. and C.S-H.; Investigation, V-D-A., M.B-H., J.L-L. and R.A-M.; Resources, R.A-M. and J-L-L.; Data Curation, V-D-A., M.B-H. and R.A-M.; Writing – Original Draft Preparation, R.A-M. and J.L-L.; Writing – Review & Editing, M.B-H., R.A-M. and E.V-O; Visualization, R.A-M, J-L-L.; Supervision, J.L-L., R.A-M. and E.V-O; Project Administration, M.B-H., R.A-M. and J.L-L.

References

1. Turkyilmaz, I.; Sennerby, L.; Tumer, C.; Yenigul, M.; Avci, M. Stability and marginal bone level measurements ofunsplinted implants used for mandibular

overdentures: a 1-year randomized prospective clinical study comparingearly and conventional loading protocols. *Clin. Oral Implants. Res.* **2006**, 17, 501–505. doi: 10.1111/j.1600-0501.2006.01261.x

2. Huwiler, M.; Pjeturson, B.E.; Bosshardt, D.D.; Salvi, G.E.; Lang, N.P. Resonance Frequency Analysis (RFA) in relation to jaw bone characteristics during early healing. *Clin. Oral. Implants. Res.* **2007**, 18, 275-280. doi: 10.1111/j.1600-0501.2007.01336.x.

3. Trisi, P.; Perfetti, G.; Baldoni, E.; Berardi, D.; Colagiovanni, M.; Scogna, G. Implant micromotion is related to peak insertion torque and bone density. *Clin. Oral Implants. Res*. **2009,** 20, 467–471. doi: 10.1111/j.1600-0501.2008.01679.x

4. Winter, W.; Klein, D.; Karl, M. Micromotion of dental implants: basic mechanical considerations. *J. Med. Eng.* **2013,** 2013, 1. doi: 10.1155/2013/265412.

5. Brizuela-Velasco, A.; Alvarez-Arenal, A.; Gil-Mur, FJ.; et al. Relationship between torque and resonance frequency measurements, performed by resonance frequency analysis, in micromobility of dental implants: an in vitro study. *Implant Dent.* **2015,** 24, 607-611. doi: 10.1097/ID.0000000000000318.

6. Aparicio, C.; Lang, N.P.; Rangert, B. Validity and clinical significance of biomechanical testing of implant/bone interface. *Clin. Oral Imp. Res*. **2006,** 17 (Suppl. 2), 2–7. doi: 10.1111/j.1600-0501.2006.01365.x.

7. Lee, D.H.; Shin, Y.H.; Park, J.H.; Shim, J.H.; Shin, S.W.; Lee, J.Y. The reliability of anycheck device related to healing abutment diameter. *J. Adv. Prosthodont.* **2020**,12, 83-88. doi: 10.4047/jap.2020.12.2.83.

8. Brizuela-Velasco, A.; Chávarri-Prado, D. The functional loading of implants increases their stability: A retrospective clinical study. *Clin. Implant. Dent. Relat. Res.* **2019,** 21, 122–129. doi.org/10.1111/cid.12702.

9. Santamaría-Arrieta, G.; Brizuela-Velasco, A.; Fernández-González, F.J.; et al. Biomechanical evaluation of oversized drilling technique on primary implant stability

 doi:10.20944/preprints202007.0457.v1

measured by insertion torque and resonance frequency analysis. *J. Clin. Exp. Dent.* **2016**, 1, 307-311. doi: 10.4317/jced.52873.

10. Buyukguclu, G.; Ozkurt-Kayahan, Z.; Kazazoglu, E. Reliability of the Osstell implant stability quotient and Penguin resonance frequency analysis to evaluate implant stability. *Implant. Dent.* **2018**, 27, 429-433. doi: 10.1097/ID.0000000000000766.

11. Norton, M.R. Resonance Frequency Analysis: Agreement and correlation of implant stability quotients between three commercially available instruments. *In.t J. Oral. Maxillofac. Implants*. **2018**, Oct 3. doi: 10.11607/jomi.6964.

12. Romanos, G.E.; Bastardi, D.J.; Kakar, A.; Moore, R.; Delgado-Ruiz, R.A.; Javed, F. In vitro comparison of resonance frequency analysis devices to evaluate implant stability of narrow diameter implants at varying drilling speeds in dense artificial bone blocks. *Clin. Implant. Dent. Relat. Res.* **2019**, 21, 1023–1027. doi.org/10.1111/cid.12842.

13. Bural, C.; Dayan, C.; Geçkili, O. Initial stability measurements of implants using a new magnetic resonance frequency analyzer with titanium transducers: an ex vivo study. *J. Oral. Implantol*. **2020,** 46, 35-40. doi: 10.1563/aaid-joi-D-19-00126.

14. Lee, J.; Pyo, S.W.; Cho, H.J.; et al. Comparison of implant stability measurements between a resonance frequency analysis device and a modified damping capacity analysis device: an in vitro study. *J. Periodontal. Implant. Sci.* **2020**, 50, 56-66. doi.org/10.5051/jpis.2020.50.1.56

15. Koo, T.K.; Li, M. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J. Chiropr. Med*. **2016,** 15, 155-163. doi:10.1016/j.jcm.2016.02.012.

16. Becker, W.; Hujoel, P.; Becker, B.E. Resonance frequency analysis: Comparing two clinical instruments. *Clin. Implant. Dent. Relat. Res*. **2018,** 20, 308–312. doi.org/10.1111/cid.12598.

17. Sim, C.P.; Lang, N.P. Factors influencing resonance frequency analysis assessed by Osstell mentor during implant tissue integration: I. Instrument positioning, bone structure, implant length. *Clin. Oral. Implants. Res.* **2010,** 21, 598–604. doi:10.1111/j.1600-0501.2009.01878.x.

18. Kästel, I.; de Quincey, G.; Neugebauer, J.; Sader, R.; Gehrke, P. 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, 42. doi: 10.1186/s40729-019-0195-1.