

Osstell Resonance Frequency Measurement Values as a Prognostic Factor in Implant Dentistry

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Resonance frequency analysis (RFA) using the Osstell device (Osstell AB, Gothenburg, Sweden) has been advocated for quantifying implant stability on a relative scale of implant stability quotients (ISQ). It was the goal of this prospective clinical study to evaluate whether a certain ISQ level, at the time an implant is placed, correlates with successful osseointegration as some have claimed. Four hundred ninety-five implants (Straumann AG, Basel, Switzerland), varying in length and diameter, were placed in a private practice, strictly adhering to the implant manufacturer's surgical protocol. After placement and after healing periods of 42 days in the mandible and 56 days (implant manufacturer's protocol) in the maxilla, implant stability was measured using RFA. After healing, implants were torqued forward at 35 Ncm and allowed to heal further if the patients felt discomfort. Statistical analysis of the data obtained was based on Welch tests and Kolmogorov-Smirnow tests (level of significance $\alpha = 0.05$). Results showed that 432 implants were osseointegrated after the predefined healing periods while 8 implants were lost and, in 55 cases, healing was prolonged. Both at insertion ($P = .025$) and after healing ($P < .001$), successful implants showed significantly different ISQ values as compared to implant failures or implants with prolonged healing. However, overlapping ISQ distributions at implant insertion demonstrated that there was no correlation among the data that could be used to predict successful osseointegration. Within the limits of this study, the prognostic value of ISQ values appears to be ambiguous.

Key Words: resonance frequency analysis, torque testing, osseointegration, implant failure, Osstell, ISQ, implant success

INTRODUCTION

Primary implant stability has been identified as a major prognostic factor for successful osseointegration.¹⁻³ Various clinically applicable techniques have been described for evaluating alveolar bone quality and implant stability. In particular, radiographic examinations including computerized tomography (CT) scans,⁴⁻⁷ tactile sensation of the surgeon during implant site preparation,⁸⁻¹⁰ implant insertion torque measurements (insertion torque value [ITV])^{2,5,11-15} as well as reverse torque testing of healed implants¹⁶ have been advocated. Following implant placement, damping capacity assessments with the Periotest device (Medizintechnik Gulden, Modautal, Germany; Periotest value [PTV])¹⁷ and resonance frequency analysis (RFA) with the Osstell device (Osstell AB; implant stability quotient [ISQ])¹³ can be used for measuring implant stability on relative scales. Later systems have been shown to be of comparable diagnostic value,¹⁸⁻²⁰ although it has also been claimed that PTV and ISQ measurements are not sensitive enough.^{21,22}

While the predictive value of implant stability measurements has repeatedly been questioned,²³⁻²⁵ research has been strongly focused on the Osstell device in recent years as a tool

for measuring implant stability.^{2,26-29} In that context, it has been claimed that RFA measurements could be used for predicting implant success,² for selecting the appropriate loading protocol,^{2,20,30} as well as for monitoring a specific implant during healing and prosthetic reconstruction.^{19,27,30-33} In general, a positive correlation between implant stability and ISQ exists with a value of 65 characterizing a successful implant and a value below 50 indicating an implant at risk.³

It was the goal of this prospective study to evaluate the correlation of RFA measurements with osseointegration of dental implants. A distinctive feature of this investigation was that torque testing³ of the implants after healing was used as a test for successful osseointegration. In particular, the question whether or not a certain ISQ level at implant placement is predictive of an implant that will successfully osseointegrate was to be investigated.

MATERIALS AND METHODS

From May 2011 to April 2012, a total of 495 tissue level dental implants (Straumann AG) with varying lengths of 6–14 mm and diameters ranging from 3.3–4.8 mm were placed in a private practice limited to oral and maxillofacial surgery strictly adhering to the implant manufacturer's surgical protocol. Patients were referred to the practice for implant placement once the implants had been categorized as conforming by the surgeon, while the referring dentists rendered prosthetic treatment. To that end, patients were recalled by the surgeon 42 days after implant placement in the mandible and 56 days

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TABLE 1

Number of implants, mean values and standard deviations of implant stability quotient (ISQ) values at implant insertion and after healing for the different implant categories

	Augmented Implants		Non-augmented Implants		Immediate Implants	
	Mean	SD	Mean	SD	Mean	SD
Maxilla – anterior						
Number of implants		12		22		5
ISQ – insertion	69.04	2.13	70.50	8.28	74.90	3.45
ISQ – healing	71.63	4.60	71.83	6.02	75.20	6.02
Maxilla – posterior						
Number of implants		43		114		1
ISQ – insertion	71.06	1.03	70.58	8.14	77.50	NA
ISQ – healing	75.71	8.73	73.85	5.90	73.00	NA
Mandible – anterior						
Number of implants		4		51		3
ISQ – insertion	67.50	6.87	74.55	4.79	74.17	6.29
ISQ – healing	75.50	5.00	75.88	4.86	72.25	10.96
Mandible – posterior						
Number of implants		23		213		4
ISQ – insertion	74.85	4.94	76.08	5.23	75.38	4.23
ISQ – healing	76.28	6.13	78.04	5.12	76.67	2.08

after implant placement in the maxilla. These healing times reflect recommendations from the implant manufacturer. Both after implant placement and at recall, implant stability was measured by means of RFA (Osstell ISQ, Osstell AB) using the respective SmartPeg abutment (Osstell AB). According to the manufacturer’s recommendations, two ISQ values were obtained for each implant at both times, one from the mesial and one from the buccal aspect. For statistical analysis, the mean values of both measurement scores were calculated, and the implants were divided into four groups according to their location in the anterior or posterior aspects of the upper and lower jaw (anterior: canine to canine; posterior: first premolar to third molar). The implants were further categorized as non-augmented implants, where no adjunctive surgical procedures such as bone augmentation were required; augmented implants, where simultaneous or previous bone augmentation, including sinus floor elevation was done; and immediate implants that were placed immediately following extraction.

As part of the surgeon’s general protocol and in addition to clinical examination and RFA measurements, torque testing of the implants was performed after healing.¹⁶ For that purpose, the hand-tightened healing caps of the transmucosally placed implants were further tightened using the implant manufacturer’s manual ratchet until a torque value of 35Ncm was reached. Whenever the patients felt discomfort as a result, or if the implant rotated, the implant was categorized as nonconforming and was allowed to heal further. Following additional healing, the implants were either classified as conforming following clinical examination or they were removed.

Statistical analysis was based on two sample *t*-tests for samples with unequal variances (Welch tests) as well as on comparisons of empirical distributions (Kolmogorov-Smirnow tests). The statistical computing package R has been used (R Development Core Team [2009] R, Vienna, Austria) with the level of significance set at $\alpha = 0.05$ for all statistical operations.

RESULTS

The distribution of implants in the different regions of the jaws, their further categorization as well as their mean values and standard deviations for RFA measurements at implant placement and after healing are shown in Table 1. ISQ levels at implant insertion ranged from 14–85 (mean: 73.65), while after an average healing time of 57.88 days (range: 28–167 days), ISQ values ranging from 30–87.50 (mean: 76.03) were observed. For a total of 10 implants, no ISQ values could be obtained after healing because those implants were lost or the patient was in severe discomfort. Later implants were allowed to heal further. Out of 495 implants placed, 432 implants were conforming after the predetermined healing period, while 8 implants were lost and, in 55 cases, healing was prolonged due to patient discomfort during torque testing (nonconforming implants).

The ISQ values obtained for implants conforming after healing, lost implants, and nonconforming implants both at insertion and after healing were used as a basis for Welch tests (Table 2A) and Kolmogorov-Smirnoff tests (Table 2B). Both statistical tests indicated that there was a significant difference in mean ISQ and ISQ distribution between conforming implants and nonconforming implants, both when considering ISQ at insertion (Welch: $P = .025$; Kolmogorov-Smirnoff: $P = .041$) and after healing ($P < .001$). Based on the frequency of their occurrence in the different groups of implants, density plots for ISQ values at implant insertion were set up (the Figure). Due to the substantial overlap of these plots, it becomes obvious that the ISQ distributions did not allow for any predictions to be made.

DISCUSSION

With RFA measurements being based on freshly inserted or osseointegrated dental implants, a multitude of factors may have an influence on ISQ values.^{1,3} The data obtained here could

TABLE 2A

Mean values and standard deviations of implant stability quotient (ISQ) values at implant insertion and after healing used as a basis for comparisons between conforming implants, nonconforming implants, and lost implants. Welch two sample tests.

	ISQ at Implant Insertion		
	Nonconforming Implants	Conforming Implants	Lost Implants
Mean ISQ	71.35	73.95	73.38
SD	8.02	7.00	6.81
Nonconforming implants			
70.38		0.025*	0.461
7.42			
Conforming implants			
76.75	<0.001*		0.825
5.44			
Lost implants			
N.A.	N.A.	N.A.	
N.A.			
ISQ after healing			

*Significant.

TABLE 2B

Mean values and standard deviations of implant stability quotient (ISQ) values at implant insertion and after healing used as a basis for comparisons between ISQ distributions for conforming implants, nonconforming implants, and lost implants. Kolmogorov-Smirnoff tests.

	ISQ at Implant Insertion		
	Nonconforming Implants	Conforming Implants	Lost Implants
Mean ISQ	71.35	73.95	73.38
SD	8.02	7.00	6.81
Nonconforming implants			
70.38		0.041*	0.626
7.42			
Conforming implants			
76.75	<0.001*		0.667
5.44			
Lost implants			
NA	NA	NA	
NA			
ISQ after healing			

*Significant.

also be used for evaluating such effects; however, this would interfere with the primary goal of this investigation. Nevertheless, general tendencies already described in the literature and validated by this investigation should briefly be discussed.

Alveolar bone quality^{20,24,34} appears to be one major parameter for RFA measurements, with implants placed in mandibular bone showing higher ISQ values as compared to those placed in the maxilla.³⁵⁻³⁷ On the contrary, implant related factors such as length^{19,25,33,36} and diameter^{19,32,36,38} seem to have only minor effects on ISQ levels. Similarly, bone augmentation performed previously or simultaneously to implant placement as well as immediate implant placement in extraction sites neither had an effect on ISQ at implant insertion nor after healing. In general, greater ISQ values were observed after healing as compared to implant insertion^{25,28,33,39} although the duration of healing itself had no effect on ISQ.³¹

Reverse torque testing has been described as a reliable method for verifying osseointegration.¹⁶ In this study, the implants were torqued forward to avoid any loosening of the cylindrically shaped implants in case they were not fully osseointegrated. The torque applied (35 Ncm) reflects the torque recommended by the implant manufacturer for tightening abutments and thus would have been applied by the restorative dentist as part of the regular protocol. Nevertheless, it may be argued that by doing so, already existing low levels of osseointegration were possibly compromised.

When comparing the ISQ levels of nonconforming or lost implants with those of conforming implants, both after placement and after healing, significant differences could be detected. In order to evaluate the usefulness of ISQ values at implant insertion for predicting future osseointegration, the frequency of occurrence of all ISQ values measured was illustrated in density plots for all three groups (lost implants, conforming implants, nonconforming implants). These density

plots showed substantial overlap of ISQ distribution recorded at implant placement demonstrating no correlation between initial ISQ and final outcome. It should be kept in mind that the numbers of lost implants and nonconforming implants were relatively small compared to the number of successful implants, thus limiting conclusions based upon statistical analysis of those two groups. Though substantially differing

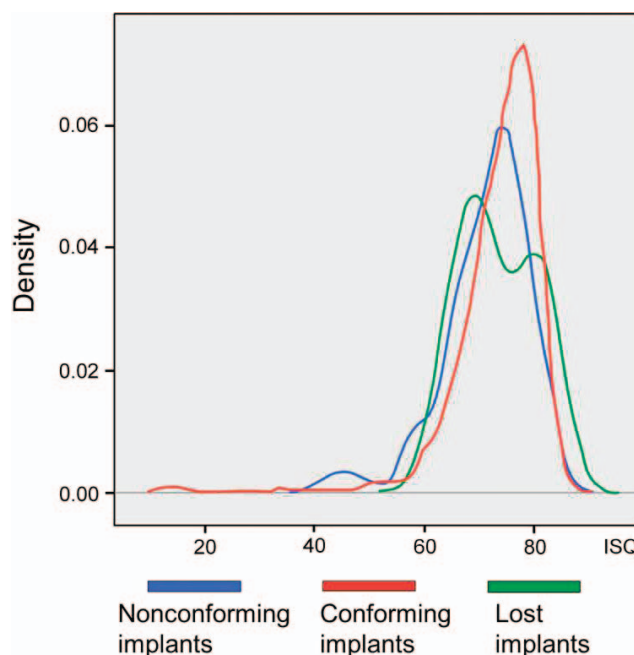


FIGURE. Density plot for ISQ values at implant insertion for conforming implants, nonconforming implants and lost implants. Given the substantial overlap of the distributions, predictions on implant performance based on ISQ measurements at implant insertion appear to be not applicable.

in design, the results presented may be compared to the findings of an animal study conducted by Al-Nawas and coworkers⁴⁰ who found that ISQ values after healing of implants in beagle dogs were not predictive for implant loss in the subsequent loading phase. Additionally, in a clinical study on 4114 Straumann implants, primary implant stability was classified clinically and using RFA measurements. According to the authors, no significant association between primary stability as measured by RFA and implant survival could be established.⁴¹ Similarly, based on a clinical study with repeated RFA measurements, Nedir and coworkers concluded that RFA was not a reliable diagnostic tool for identifying mobile implants.⁴² In the same context, Friberg et al⁸ reported clinical findings showing that cutting torque measurements were also incapable of identifying sites at risk for future implant losses or to determine a lower limit value of cutting torque to achieve successful implant integration.

It may be seen as a potential limitation of this study that only one specific implant system has been used. However, under those conditions, RFA measurements failed to identify implants at risk. Taking into consideration the available variety of implant systems, differing in geometry and surgical protocol, it may be expected that the prognostic value of RFA measurements would even be less than reported here. It therefore appears questionable whether a threshold ISQ value will ever be established that is indicative for a successful implant.³⁷ This is also supported by Balleri and coworkers, who described a broad range of ISQ values from 57–82 for stable, healed implants after one year of loading.⁴³

The factors influencing RFA measurements remain unclear.^{19,31,38} It would be beneficial to have a diagnostic tool which evaluates alveolar bone quality independently from the implant system used.⁴⁴ In the light of the huge number of implant systems available, it appears that such measurement might allow for establishing an objective bone quality scale.⁴⁵ As such, measurement would be done prior to implant placement, both the surgical technique applied⁴⁶ as well as the implant type chosen could be optimized.⁴ In case of insufficient bone quality, the surgeon could for instance opt for undersized drilling of the osteotomy,^{39,47,48} for using osteotomes instead of burrs,^{28,49} and for selecting tapered instead of parallel-shaped implant geometries.^{26,50} By doing so, primary implant stability could be optimized thereby more often allowing for immediate loading protocols.^{39,51} As a matter of fact, such a diagnostic tool could not be used for monitoring specific implants after placement and would have to be supplemented by RFA or PTV measurements.

CONCLUSION

Within the limitations of this study, the results of resonance frequency analysis at implant placement are not predictive of dental implant osseointegration.

ABBREVIATIONS

CT: computerized tomography
ISQ: implant stability quotients

ITV: insertion torque value

RFA: resonance frequency analysis

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