Resonance Frequency Analysis as a Prognostic Determinant for Implant Outcomes

Phuong Thao T. Nguyen, DDS*, Panos Dragonas, DDS, MS*, Pooja Maney, BDS, MPH, PhD*, Thomas E. Lallier, PhD†

* Department of Periodontology, Center of Excellence in Oral and Craniofacial Biology, School of Dentistry, Louisiana State University Health Science Center, New Orleans, LA.

† Department of Cell Biology and Anatomy, Center of Excellence in Oral and Craniofacial Biology, School of Dentistry, Louisiana State University Health Science Center, New Orleans, LA.

Phuong Thao Nguyen, 1100 Florida Avenue, New Orleans Louisiana 70119

Phone: (504) 941-8390

Fax: (504) 941-8391

Word Count: 1876 Figures: 1 Tables: 4 References: 19

Short Title: Resonance Frequency Analysis and Implant Outcomes

Summary: Resonance Frequency Analysis is not associated with implant outcomes, but length of less than 10mm is associated with higher rate of peri-implantitis

Abstract

Background: As dental implant therapy becomes a more common treatment modality to replace single or multiple missing teeth, there is an increased interest in methods to predict implant survival and failures. Using the Resonance Frequency Analysis (RFA) device Osstell ISQ is one method to measure implant stability at any stage after implant placement.

Methods: This retrospective study aims to study the correlation of ISQ values, peri-implantitis and implant failures for implants placed at Louisiana State University Post-Graduate Periodontics clinic (LSU-PGPE).

Results: A chart review was performed for patients who had received an implant placement at LSU-PGPE from between January 1st, 2015 and December 31st, 2019 with ISQ values recorded at time of placement, uncovery or treatment of peri-implantitis. A total of 903 implants on 454 patients were analyzed. Six implants (0.66%) in six patients (2 male and 4 female) were treated for peri-implantitis.. The ISQ at time of placement fell in the range of 55 to 82. Statistical analysis was performed between implant outcomes with seven parameters (gender, age, length, diameter, ISQ values, brand, and anatomic site).

Conclusion: Based on Fisher's exact test, only length of implants had a significant association with implant outcomes, whereas ISQ values did not show any significant association with implant complications.

Keywords: resonance frequency analysis, ISQ, implant failure, peri-implantitis

Introduction

Dental implant therapy has become a predictable and successful treatment option for partially and completely edentulous implant patients. Recent studies estimate 10-year implant survival rate of 96.4%[1]. One of the most important criteria for a successful osseointegration is achieving primary and secondary implant stability [2]. Primary stability is defined as the

biomechanical stability upon implant insertion, whereas Secondary stability is defined as stability from new bone formed around implant after osseointegration [3]. Many factors influence primary and secondary stability including bone quantity and quality, geometric design of the implant, surgical technique, and insertion torque [4]. Implant stability status helps guide decisions on loading protocol on patients individually. Various methods have been used for measuring implant stability including reverse torque test, the percussion test, histologic or histomorphometric analysis, insertion torque and resonance frequency analysis (RFA) [5].

Ostell§ is a device that use resonance frequency analysis (RFA) to measure the lateral stability of implants and indirectly measure the degree of osseointegration [6]. The measurement is performed during implant surgery for primary stability and at time of uncovery for secondary stability. This objective, repeatable, and non-invasive measurement is done by placing the SmartPeg, which contains a magnet, on top of the implant. The magnet is excited with magnetic pulses from the Ostell probe and will vibrate accordingly to the stiffness in the interface between the implant surface and the bone. The unit of measurement is implant stability quotient (ISQ), which ranges from 1 to 100. It has been established that an ISQ value of ≥70 means high stability, 60-69 means medium stability, and <60 means low stability, according to the manufacturer. A recent ex vivo study by Yao et al. has shown that ISQ values can be used to detect narrow intrabony marginal bone defects, and therefore can lead to early diagnosis of conditions affecting the marginal bone, such as peri-implantitis [7]. Another retrospective study by Chen et al. showed that a low initial ISQ value of 52 or less might indicate higher failure risk for implants [8].

---

§ Integration Diagnostics, Savedalen, Sweden

Peri-implantitis is a plaque associated pathologic condition occurring in the tissue around dental implants, characterized by inflammation and subsequent loss of supporting bone. Peri-implantitis is the most frequent implant related complication. In a systematic reviewed by Lee et al in 2017, the prevalence of implant-base and subject-based peri-implantitis was 9.6% and 18.8%, respectively [9]. In another systematic review, Muñoz et al. concluded that the prevalence of peri-implantitis is 10% [10]. According to a consensus report of the 2017 World Workshop, peri-implantitis is defined as a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone [11]. The criteria for peri-implantitis diagnosis includes: red, swollen soft tissue, bleeding on probing, probing depth of ≥6mm, progressive bone loss beyond initial remodeling, or ≥3mm bone loss surrounding implants if baseline radiographs unavailable, and with or without suppuration. Implant survival rates achieved in dental school may also differ from the survival rates achieved in an experienced clinician's practice.

There is currently no clinical study that has looked at the association of ISQ values with the rate of peri-implantitis, implant failure and progressive bone loss. Only one animal study by Monje et al found a strong negative correlation between ISQ and marginal bone loss (MBL), as well as a decrease in one ISQ unit is related to 1mm of MBL [12].

This retrospective study aims to study the correlation of ISQ values, peri-implantitis and implant failures.

Materials and Methods:

This study was a retrospective chart review. The study protocol was approved by the Louisiana State University Health Sciences Center – New Orleans Institutional Review Board (IRB# 19-1249-LSUHSC-DNT). Patients included in the study were treated in the Department of Periodontics Postgraduate Clinic at LSUHSC School of Dentistry (SOD) from January 1st 2015 to December 31st 2019. Charts of patients were reviewed to identify individuals that

conformed to the following inclusion criteria: ISQ values were measured at time of placement, and patients whose implants were placed and removed at a later point of time due to failure were also included.

Data Collection

On charts that met the inclusion criteria, the following information was collected for each patient: A. demographic data (gender and age) and B. Implant-related parameters: brands, length, width, anatomic location

In this study, implant failure was defined as an endosseous implant that was placed within the aforementioned time frame and subsequently removed due to loss of osseointegration or terminal bone loss. Peri-implantitis was defined as progressive bone loss beyond normal bone remodeling, presence of suppuration, inflammation, infection, or pain. These cases were identified by periapical radiographs at follow up appointments (for bone loss), electronic records that mentioned peri-implantitis, or report of i-brush usage to decontaminate implants. A combination of search strategies was utilized. Initially, a report was generated for all implant placement codes and implant removal codes in the electronic health records at LSU-PGPE to identify the total numbers of implant placement and removal. Each chart was reviewed in entirety for data collection. The charts with incomplete records or those removed on the same day of placement due to lack of primary stability were excluded from this study.

Upon completion, data collected was entered into a master Microsoft Excel spreadsheet and statistical analysis is conducted to determine the relationship between ISQ values and implant failure as well as peri-implantitis. Table 2 provides the description and the test results for the association between length and implant outcome.

Statistical analysis

A Fisher' exact test was used to check know the association between each variable versus the implant outcome (peri-implantitis, failure, and normal (total-peri-failure). The primary parameter was ISQ values, and the other six parameters (gender, age, length, diameter, ISQ values, brand, and anatomic site) were secondary. All parameters were statistically analyzed for their association to implant outcome.

Results:

The initial search yielded 1319 implant placed in the Department of Periodontics by residents between January 1st, 2015 and December 31st, 2019. After elimination of charts that did not meet the inclusion criteria, a total of 903 implants on 454 patients were analyzed. The demographics make up consisted of 188 male and 266 female with age range from 25 to 91.

There were 7 different brands implants utilized (519 Zimmer™, 196 Nobel™, 93 Straumann™, 60 Zimmer-Biomet™ 3i, 30 Astra™, 4 Biohorizons™, and 1 other). In terms of diameter, there were 396 implants of with less than 4mm, 451 of width 4.4-9mm, and 56 of ≥5mm. Length wise, there were 107 implants of <10mm, and 796 of >10mm. Lower molars were the most common sites (214), followed by upper premolars (195), upper molars (164), lower anterior (131), upper anterior (101), and lower premolars (99). ISQ ranged from 38 to 90.

6 implants (0.66%) in 6 patients (2 male and 4 female) were treated for peri-implantitis. The ISQ at time of placement ranged from 70 to 82 and all of them were delayed placement. Three were Zimmer™, two were Nobel™ and one was Straumann™. Time of peri-implantitis treatment ranged from 4.5 to 10 months. The common protocol commonly included debridement with titanium brush (iBrush – NeoBiotech), chlorhexidine rinse, and local application of doxycycline or tetracycline, bone grafting with xenograft, allograft, and autogenous graft, and collagen membrane. 2 out of 6 were treated with PRF, and peri-implantitis was rendered between 4.5 to 10 months post placement.

15 implants (1.66%) in13 patients failed and had to be removed at different points of time, ranging from 1 to 23 months after placement. 14 out of 15 were early failures (before definitive prostheses) and were removed before final crown/prosthesis. The ISQ at time of placement fell in the range of 55 to 82. Eight were Nobel™, 5 were Zimmer™, 1 was Zimmer-Biomet 3i™ and 1 was Astra™. The most commonly failed anatomic sites were upper and lower premolars (4 each), followed by lower molars and upper anterior (3 each), and lower anterior (1).

There was no statistically significant correlation found between ISQ values and implant outcomes (P-value 0.2996)

Length was the only secondary parameter that yielded a statistically significant association with implant complications (P-value 0.0002). Among implants less than 10mm in length, the rate of peri-implantitis and failure were 4.58%, which was statistically significant (P-value 0.0001), and 2.93%, respectively. On the other hands, implants of 10mm or more have a peri-implantitis rate of 0.13% and a higher rate of failure at 1.76% .

Discussion

RFA has become one of the most frequently used techniques to assess implant stability and osseointegration due to its nature of being simple, non-invasive and easily utilized in clinical settings. A systematic review in 2011 pointed out that the available literature, which consisted mostly of retrospective studies, supported RFA technique as a diagnostic tool for detecting implant stability during healing and follow up stages [13-15] .

According to Huang et al, there are 13 factors that could potentially influence the ISQ values measured at time of placement and time of uncovery after osseointegration: spatial (anatomical) direction of measurements, gender, implant location, immediate/delayed implantation, diameter, length, insertion torque, macro-design and micro-design, bone quality, time in between measurements, one or two stage approach, implant number, and surgical

design [16]. Among these factors, bone quality emerges as the major parameter for ISQ measurement while implant length and diameter appear to have no clear influence. According to Andersson et al, ISQ value below 70 at placement or below 75 at 3-4 months post placement showed a significantly higher risk for implant failure [17]. Additionally, Atieh showed that implant stability measurements using RFA at 8 weeks post-op showed a better accuracy in predicting implants that were at risk of failure than those taken at the time of implant placement [18]. However, Kim et al showed that Baseline ISQ measurements were not able to predict early failure of immediately loaded implants. the current study did not yield any statistically significant correlation between ISQ values and implant failure [19].

14 out of 15 implants failed and were removed before definitive crown seating, which categorized these as early failures. The rate peri-implantitis at 0.16% reported in this study is significantly lower than the 10% prevalence reported by Munoz et al.

This difference is likely due to lack of a standardization for consistent record keeping regarding peri-implantitis. There are several limitations of the study. As a residency program, various codes for peri-implantitis treatment such as D6081, D6101, 6102, 6103, or D6199 have not been utilized. There is also a lack of accurate diagnostic coding for peri-implant conditions. In addition to that, extraction of relevant information from treatment notes was time consuming and laborious due to the retrospective nature, multiple clinicians, incomplete records, and lack of follow ups on peri-implantitis rate. The PGPE protocol is to dismiss patients who have been periodontally stable for at least a year and refer them to private practice, as the department does not have the capacity to maintain every patient long term. All the aforementioned factors hindered the quality of data collection.

Based on the findings of this retrospective study, it was concluded that RFA ISQ values did not help predict outcomes of implants. Implants shorter than 10mm appeared to have a higher rate of peri-implantitis, and implants of 10mm or more had higher rate of implant failure.

Footnotes

* Department of Periodontology, Center of Excellence in Oral and Craniofacial Biology, School of Dentistry, Louisiana State University Health Science Center, New Orleans, LA.

† Department of Cell Biology and Anatomy, Center of Excellence in Oral and Craniofacial Biology, School of Dentistry, Louisiana State University Health Science Center, New Orleans, LA.

§ Integration Diagnostics, Savedalen, Sweden

References

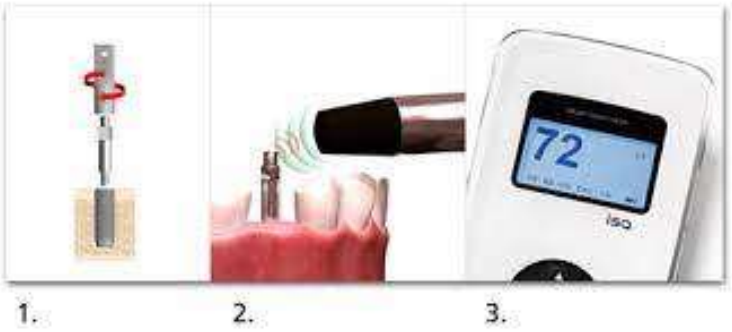
1. Howe, M. S., Keys, W., & Richards, D. (2019). Long-term (10-year) dental implant survival: A systematic review and sensitivity meta-analysis. *Journal of dentistry*, *84*, 9–21.
2. Albrektsson, T., Zarb, G., Worthington, P., & Eriksson, A. R. (1986). The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *The International journal of oral & maxillofacial implants*, *1*(1), 11–25.
3. Sennerby, L., & Meredith, N. (2008). Implant stability measurements using resonance frequency analysis: biological and biomechanical aspects and clinical implications. *Periodontology 2000*, *47*, 51–66.
4. Gómez-Polo, M., Ortega, R., Gómez-Polo, C., Martín, C., Celemín, A., & Del Río, J. (2016). Does Length, Diameter, or Bone Quality Affect Primary and Secondary Stability in Self-Tapping Dental Implants?. *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons*, *74*(7), 1344–1353.
5. Atsumi M, Park SH, Wang HL: Methods used to assess implant stability: Current status. Int J Oral Maxillofac Implants 22:743, 2007
6. Yao, C.J., Ma, L., Mattheos, N. (2017) Can resonance frequency analysis detect narrow marginal bone defects around dental implants? An ex vivo animal pilot study. *Australian Dental Journal*, 62: 433–439.
7. Chen, M. H., Lyons, K., Tawse-Smith, A., & Ma, S. (2019). Resonance Frequency Analysis in Assessing Implant Stability: A Retrospective Analysis. *The International journal of prosthodontics*, *32*(4), 317–326
8. Lee, C. T., Huang, Y. W., Zhu, L., & Weltman, R. (2017). Prevalence of peri-implantitis and peri-implant mucositis: systematic review and meta-analysis. *Journal of dentistry*, *62*, 1–12.
9. Munoz, V., Duque, A., Giraldo, A., Manrique R. (2018). Prevalence of Peri-implant Disease According to Periodontal Probing Depth and Bleeding on Probing: A Systematic Review and Meta-Analysis. *International Journal of Oral Maxillofacial Implants.* 2018 Jul/Aug;33(4)

10. Berglundh, T., Armitage, G., et al. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *Journal of Periodontology*. 2018;89(Suppl 1)
11. Monje, A., Insua, A., Monje, F., Muñoz, F., Salvi, G. E., Buser, D., & Chappuis, V. (2018). Diagnostic accuracy of the implant stability quotient in monitoring progressive peri-implant bone loss: An experimental study in dogs. *Clinical oral implants research*, *29*(10), 1016–1024.
12. Sennerby, L., Persson, L. G., Berglundh, T., Wennerberg, A. and Lindhe, J. (2005), Implant Stability during Initiation and Resolution of Experimental Periimplantitis: An Experimental Study in the Dog. *Clinical Implant Dentistry and Related Research*, 7: 136-140.
13. Gupta, R. K., & Padmanabhan, T. V. (2011). Resonance frequency analysis. *Indian journal of dental research : official publication of Indian Society for Dental Research*, *22*(4), 567–573
14. Huang H., Wu G., Hunziker E. (2020). The clinical significance of implant stability quotient (ISQ) measurements: A literature review. *Journal of oral biology and craniofacial research*, *10*(4), 629–638.
15. Andersson, P., Pagliani, L., Verrocchi, D., Volpe, S., Sahlin, H., & Sennerby, L. (2019). Factors Influencing Resonance Frequency Analysis (RFA) Measurements and 5-Year Survival of Neoss Dental Implants. *International journal of dentistry*, *2019*, 3209872.
16. Atieh, M. A., Alsabeeha, N. H., Payne, A. G., de Silva, R. K., Schwass, D. S., & Duncan, W. J. (2014). The prognostic accuracy of resonance frequency analysis in predicting failure risk of immediately restored implants. *Clinical oral implants research*, *25*(1), 29–35
17. Kim, S. J., Ribeiro, A. L., Atlas, A. M., Saleh, N., Royal, J., Radvar, M., & Korostoff, J. (2015). Resonance frequency analysis as a predictor of early implant failure in the partially edentulous posterior maxilla following immediate nonfunctional loading or delayed loading with single unit restorations. *Clinical oral implants research*, *26*(2), 183–190

Figure Legends

Figure 1: Schematic presentation of Osstell device

Figure 1



Tables

Table 1: P-values of Fisher's exact test between seven parameters and implant complications

Table 2: Association between length and implant outcomes

Table 3: Raw data of Gender and Age

Table 4: Raw data of Width, Length, ISQ values

Table 1

	Gender	**Age**	**Length**	**Width**	**ISQ**	**Brand**	**Location**
P-value	0.3083	0.8147	0.0002	0.4908	0.2996	0.2999	0.071

Table 2

Table of Exposure by Response. P value = 0.0002				
Exposure	***Response(implant outcome)***			
Frequency ***Percent*** ***Row Pct*** ***Col Pct***	***Peri-implantitis***	***Failure***	***Normal***	***Total***
<10mm	5 0.55 4.67 83.33	1 0.11 0.93 6.67	101 11.18 94.39 11.45	107 11.85

>=10mm	1 0.11 0.13 16.67	14 1.55 1.76 93.33	781 86.49 98.12 88.55	796 88.15
Total	6 0.66	15 1.66	882 97.67	903 100.00

Table 3

	Patients	**Implants**	**Gender**		**Age**	
			Male	**Female**	**<60**	**≥60**
Total	454	903	188 (41.4)%	266 (58.6%)	177 (38.99)	277 (61.01%)
Peri-implantitis	6 (1.32)%	6 (0.66%)	2	4	2	4
Failure	15 (3.30%)	15 (1.66%)	9	6	7	8

Table 4

	Width			**Length**		**ISQ**				
	<4mm	**4-4.9mm**	**≥5mm**	**<10mm**	**≥10mm**	**<60**	**60-65**	**65.5-70**	**70.5-75**	**>75**
Total	396	451	56	107	796	54	63	160	278	348
Peri-implantitis	3	2	1	5	1	0	0	1	2	3
Failure	8	6	1	1	14	4	0	2	4	5