RESONANCE FREQUENCY ANALYSIS OF DENTAL IMPLANT STABILITY DURING OSSEOINTEGRATION PERIOD

[1]Dr Shivani Dadwal Salaria, [2]Dr Anoop Bhushan, [3]Dr Shweta Bali, [4]Dr Priyanka Aggarwal, [5]Dr Promod Kumar Rathore

[1,2,3,4,5] From Department of Periodontics, Santosh Dental College & Hospital, Santosh Deemed to be University, Ghaziabad, Delhi NCR

INTRODUCTION

Teeth are meant to be in a dynamic occlusal equilibrium and loss of even a single tooth causes disharmony. The effects of tooth loss may range from malocclusion, hyper-eruption, speech- defects, periodontal problems, drifting of adjacent teeth to even TMJ problems. These difficulties have adverse consequences. Hence replacement of a single missing tooth is equally important as replacement of a group of teeth.

A dental implant is an artificial tooth root, when placed in the jaw, holds the crown or bridgework. Dental Implants are a more conservative treatment choice as they do not relying on the neighbouring teeth for support.

OSSEOINTEGRATION:

In 600 A.D. in the Mayan population, pieces of shell were implanted into the extraction sockets of mandibular teeth. (Ring 1985).[1] Branemark et al. in 1969 utilized a titanium implant chamber to study the microscopic circulation in a rabbit for bone marrow healing. At the end of the experiment it became impossible to remove titanium chambers from the bone and they realised that the chambers had integrated with the bone. The discovery was termed as Osseointegration and was defined as "the direct, structural, and functional contact between live bone and the surface of a functionally loaded implant". It was later emphasised that establishment and maintenance of Osseointegration depends on the capacity of the tissues for healing, repair, and remodelling.[2] It wasn't until 1980s that the concept of bone-anchored titanium implants in the oral cavity were introduced to the dental fraternity.[1] Schröeder et al. (1981) defined the bone-implant union as a "functional anchylosis". The initial formulations have been accepted and Osseointegration is considered as a histological terminology denoting direct bone apposition on the implant surface without any soft tissue interposition. Though clinical assessment is based on mechanical criteria rather than histological. This mechanical criteria could be divided into Primary Stability and Secondary Stability.[2]

SINGLE TOOTH IMPLANT:

In 1986, Jemt introduced the use of dental implants for single tooth replacement cases.[3] For a single-tooth implant restorations, a systemic review reports a success rate of 95.1%. A single osseointegrated implant (SOI) allows greater preservation of adjacent tooth and at the same time presents a challenge because the restoration doesn't rely on the adjacent

dentition for support. An SOI is subjected to greater masticatory force without stabilizing support from tooth or tissue, which increases the risk of failure.[4].

Primary stability is a prerequisite to achieve osseointegration and suggested by a few authors is a good predictor for osseointegration. A clinically applicable, non-invasive technique that gives a linear definition of implant stability level would help clinicians to measure Primary Stability and then Secondary stability before loading them. These measurements help in predicting the long term biologic and mechanical integrity of the SOI.

IMPLANT STABILITY:

Implants capacity to withstand load in axial, lateral and rotational direction is known as stability.[5] It can also been considered as absence of clinical mobility, which is suggested definition of Osseointegration.[6]

Primary Stability depends on the quality and quantity of bone, surgical technique and implant design. Secondary stability depends on the bone formation and bony remodelling at the implant-bone interface. It is influenced by the surface of the implant and the wound healing time. During clinical function, load applied is in axial, lateral and rotational direction. The axial loads can be intrusive and extrusive. The lateral load can occur from any 360° direction. Rotational can be clockwise and anti-clockwise. Thus the outcome of analysis of implant stability is highly dependent on the type of test used and direction of the applied force.[6]

MEASUREMENT OF IMPLANT STABILTY

Pre-requisite for successful integration of bone to the implant surface is achievement of Primary Stability. It is essential to have a quantitative baseline measurement for osseointegration which can be followed up at repeated intervals in time. The traditional clinical methods of assessing the implant bone relationship are Radiographic Evaluation, Percussion Test and Reverse Torque Application. A Radiograph is a 2D image of a 3D structure, giving false sense of security in cases of buccal dehiscence which is not visible on a radiograph. While tomograms offer better diagnostic performance, in many cases they may not be cost effective.[7] The Percussion Test results are not quantifiable and more of subjective assessment. Reverse Torque Application may disturb the implant bone osseointegrating surface.[6] These methods have obvious limitations in clinical settings and also necessitate for a method that is more quantifiable and repeatable.

Periotest has a handpiece that has an electronically controlled translational hammer bearing an 8-gram rod with a sensor at its tip. On activation, the rod taps the implant abutment up to 16 times in four seconds like a retractable ball point pen. These millisecond measurements are converted into Periotest Values, showing measurement from -8 PTV (low mobility) to 50 PTV (high mobility). Slight changes in the recording position and angulation of the instrument can significantly alter the PTV readings. Also placement of abutment or crown on implant changes the dynamics and significantly alters the PTV value. Hence there is lack of consistency with the instrument Periotest.

RESONANCE FREQUENCY ANALYSIS

Resonance Frequency Analysis (RFA) has been established as a non-invasive quantitative measurement of implant bone integration. RFA has been documented to establish whether an implant is sufficiently

stable to receive prosthesis and also to identify "at risk" implants.[8] Meredith and colleagues developed this hand held frequency response analyser and a transducer. The transducer is screwed on to the implant that shakes the implant at a constant input and amplitude. The pitch is increased till implant resonates. The units of measurement initially were in Kilohertz ranging from 3500 to 8500 hertz. Implant Stability Quotient (ISQ) was later developed with a scale of 1 to 100, with higher value indicating high stability. It was suggested that this reading may be performed for baseline reading for future comparison.[9]It is useful to know the stability of implant just after placement since it would help to know the best time for loading.[10]

MATERIAL AND METHOD:

The study was carried out on 54 selected patients in need of single tooth replacement in the Department of Periodontics and Oral Implantology, Santosh Dental College and Hospital, Pratap Vihar, Ghaziabad with the aim to evaluate the stability of dental implants during osseointegration period using Resonance Frequency Analysis at $0,4^{th},8^{th},12^{th}$ and 14^{th} week.

The inclusion criteria for collection of data was age 18 and above; one bounded edentulous space in the mandible; i.e. a single missing tooth with intact proximal teeth with sufficient bone quality and quantity to allow for implant placement; irrespective of sex, should have good systemic health with no systemic disease; motivated and hygiene conscious patient and ability to provide informed consent. The exclusion criteria was systemic diseases or medication possibly affecting the healing process, .e.g. Diabetes (regardless of control); metabolic bone disease, including post-menopausal women not on hormone replacement therapy; treatment with therapeutic radiation to head within past 12 months; pregnancy; severe bruxism or clenching habit; active infection or severe inflammation in the areas intended for implant placement; absence of keratinized tissue at implant site; need for simultaneous hard or soft tissue grafting; unable or unwilling to comply with study procedures and visits and smokers.

Armamentarium and aids included the Diagnostic Instruments, Surgical armamentarium, Implant Placement Surgical kit – Alpha Bio Surgical Instrument system, Dental Implants, Physiodispensor with 20:1 reduction handpiece and Resonance Frequency Analyser- The Osstell ISQ

Following the inclusion and exclusion criteria, the selected patients were explained about the nature and surgical procedure in detail, purpose of the study and were made to sign an informed consent as a part of protocol requirements.

Each Patient underwent a full diagnostic work up which included a detailed case history record; intra Oral Periapical radiograph of the site and orthopantogram; study cast and digital clinical photographs and routine Blood Investigation- for complete hemogram and Random Blood Sugar. Implant length and diameter was selected for each patient based on intra oral examination, radiographic evaluation (IOPA X-ray and OPG) and diagnostic casts.

After insertion of the implant in the osteotomy site, the Smart peg was screwed over the implant and stability quotient was recorded using Resonance Frequency Analyser- Osstell- ISQ. The Smart peg was retightened and the readings were

recorded again. The Smart peg was unscrewed. The cover screw was secured onto the implant. Sutures were placed after implant placement in stage. Suture removal was done after 10 days post surgery.

After the non- loaded Osseointegrated period of 4 weeks, stage 2 surgery was performed. At this time another reading of the ISQ was recorded with the help of a Resonance Frequency Analyser - Osstell-ISQ. This uncovering of the implant and placement of the Healing Abutment (gingival former) facilitated the subsequent repeated ISQ readings to be taken at 8^{th}, 12^{th} and 14^{th} week.

RESULT:

The data was recorded and analysed by SPSS (version -16). To observe the difference among the means of paired observations, repeated ANOVA followed by Post Hoc test and Bonferroni correction was done. P value < 0.05 is considered to be statistically significant.

The study was conducted in 54 subjects with mean age 36.35 years ± 7.88 S.D., with minimum age of 26 years and maximum age of 57 years. Among the 54 subjects, 40 (74%) were male and 14 (26%) were female.

Mean Value for ISQ at the time of surgery was 72.90 ± 7.25, at 4 weeks post operative was 64.85±7.33, at 8 weeks post operative was 68.70±5.99, at 12 weeks post operative was 70.90±5.02 and at 14 weeks post operative 71.55±4.21. (Table 1)

Table- 1: Mean and Std. Deviation (SD) of ISQ value at different times.

Time	Mean ISQ	Std. Deviation	95% Confidence Interval	
			Lower Bound	Upper Bound
0 week	72.90	7.25	69.51	76.30
4^{th} week	64.85	7.33	61.42	68.28
8^{th} week	68.70	5.99	65.90	71.50
12^{th} week	70.90	5.02	68.55	73.25
14^{th} week	71.55	4.21	69.58	73.52

Repeated ANOVA was done for comparison of mean ISQ at different times. There was a significant difference among the means of ISQ at different points of time. ($F_{4,76} = 41.64$, P=0.00) (Table 2)

Table – 2: Repeated ANOVA for comparison of mean ISQ in within Subjects at different points of time.

Source	Sum of Squares	df	Mean Square	F	Sig.
ISQ	**791.86**	**4**	**197.97**	**41.64**	**.000**
Error (ISQ)	**361.34**	**76**	**4.75**		

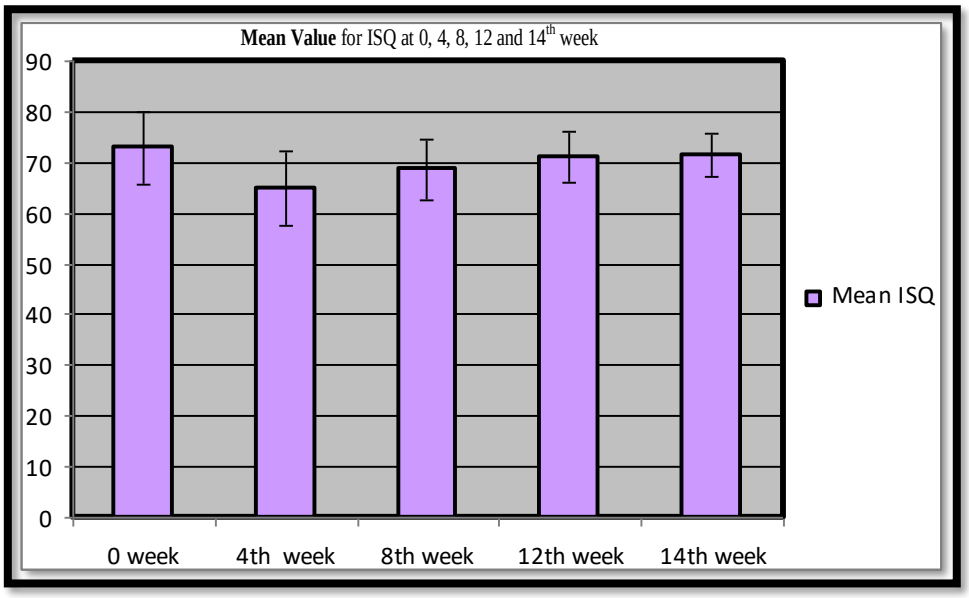
Post hoc Test was done with Bonferoni correction for comparisons of differences of mean ISQ at different time. (Table 3)

Table – 3: Post Hoc Test with Boneferroni correction for pairwise comparisons of Differences of Mean ISQ at different times.

Week			Mean Difference of ISQ	Std. Error	95% Confidence Interval for Difference[a]		Sig.[a]
					Lower Bound	Upper Bound	
0	**vs**	**4**	8.05*	.66	5.96	10.14	0.00
	vs	**8**	4.20*	.50	2.63	5.77	0.00
	vs	**12**	2.00*	.80	-0.52	4.52	0.21
	vs	**14**	1.35*	1.01	-1.85	4.55	1.00
4	**vs**	**8**	-3.85*	.43	-5.22	-2.48	0.00
	vs	**12**	-6.05*	.72	-8.34	-3.77	0.00
	vs	**14**	-6.70*	.98	-9.82	-3.58	0.00
8	**vs**	**12**	-2.20	.42	-3.54	-0.87	0.00
	vs	**14**	-2.85	.67	-4.98	-0.73	0.00
12	**vs**	**14**	-0.65	.36	-1.78	0.48	0.85

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.



DISCUSSION

The implant- tissue interface is considered to be a region of dynamic interaction. There is a change in character of the region from genesis i.e. placement of implant into the bony site, to its maturity.[11]

Woven bone forms rapidly in response to growth and injury. It has a random fibre orientation with low mineral density.

Following surgical placement of endosseous implants, the woven bone provides stabilization during the initial healing, though it lacks physical strength to resist functional loading as compared to compact bone because of this random fibre orientation. Lamellar bone then forms slowly that demonstrates an organized matrix that is highly mineralized. It is the principal load-bearing tissue of the mature bone-implant complex. Composite bone, the last step in bone healing following placement of an endosseous implant, is a combination of lamellar bone deposited on the woven bone matrix.[12]

According to Albrektsson and Pilliar et al., for osseointegration to occur, there should be absence of movement or limited micromovement between an implant and bone. Excessive micromotion causes scaffold disruption which in turn leads to scar-type fibrous healing.[13]

Criteria for Implant success, according to Albrektsson et al. included absence of implant mobility; absence of peri-implant radiolucency; no more than 0.2 mm vertical bone loss annually after the first year of service; absence of persistent and /or irreversible sign and symptoms such as pain, infections, neuropathies, paresthesia, and violation of the mandibular canal.[14]

Reliable clinical indicators of adequacy of the bone-implant complex are necessary in order to have an early intervention to arrest or reverse early deterioration of the bone-implant complex.[15] It has been reported that implants with better initial stability would lead to a higher secondary stability and require reduced healing periods than those fitted with a lower initial stability. The knowledge of primary stability at the time of placement may serve as a guide to making a decision regarding the choice of treatment protocol; immediate-, early or delayed loading. Implants when placed in healed bone of adequate horizontal and vertical dimension have high rates of survival. Implant lengths ≥10 mm and widths ≥4mm remain the standard dimensions for the high rates of implant survival as reported in the literature.[16]

Resonance Frequency Analysis helps to diagnose a failing implant at an early stage as it can be done at any time during the osseointegration period. Very low ISQ values at 2 months indicate a risk of future implant failure. ISQ values of 57-82 at 1 year indicate implant success (Balleri et al 2002). A study by Glauser et al (2004), revealed that the risk of failure increased with decreased ISQ value, as measured after 1 month of loading.

Thus ISQ is a quantitative method of osseointegration assessment that serves as a baseline and can be followed up with time. The measurement of secondary stability may confirm a successful healing and facilitate decision-making with implants that demonstrate low stability.[17]

The Mean Value for ISQ at the time of surgery (0 week) was 72.90 (95% CI 69.51 to 76.3) which was concurrent with a study by Park et al[18] who reported the mean ISQ to be 76.6. According to two different studies conducted by Boronat Lopez et al[10,19], the mean ISQ of all measured implants at the time of surgery was 62.6 and 62.1 respectively.

A significant decrease in ISQ readings was seen at 4th week post surgery with mean ISQ at 64.85 (95% CI 61.42 to 68.28) which is in line with Lopez et al.[19] , who demonstrated the lowest mean stability measurement in 4th week for all bone types (60.9). However, for Barewal et al.[20] and Ersanli et al.[21], the third week was the most

critical in terms of significant decrease seen in ISQ readings regardless of the defined bone quality.

During the initial weeks of healing, bone modelling and remodelling takes place around the implant surface. This phase of formation of lamellar bone from woven bone may cause a decrease in primary bone contact.[21]

At 8th week post surgery, the mean ISQ was 68.7. There was a significant increase in ISQ post 4th week. The mean difference of ISQ between 4th week and 8th week was –3.85 (95% CI -5.22 to -2.48).

The mean ISQ at 12th week was 70.9. Between 4th week and 12th week, there was a significant difference in mean ISQ which was -6.05 (95% CI -8.34 to -3.77). Hence after a stability dip at the 4th week (which corresponds with the bone remodelling stage), there is a significant increase in stability quotient.

The mean difference of ISQ at the time of surgery versus 12th and 14th week were not statistically significant, though the ISQ values at the time of surgery were higher than those at 12th and 14th week.

A significant decline in ISQ value was seen from 0 week to 4th week, indicating 4th week to be a critical time during the period of Osseointegration. Thereafter an increase is seen in the ISQ value at 8th week, which stabilizes around 12th to 14th week. (Graph 1)

Ostman et al.[5] in a long-term study established that the differences found between RFA with respect to sex were not clinically relevant as there were no differences in the failure rates between men and women. The interaction effect of gender to bone quality did not have a significant effect on primary stability.

The ISQ of the mandibular and maxillary implants showed no statistical significant difference (Lopez et al[19]), although lower ISQ values were always found in the maxilla. Implant stability was higher in posterior than in anterior regions, inspite of the fact that implant placement generally is regarded as more challenging in posterior regions because of anticipated more frequent presence of soft bone quality.[2]

However, the results of clinical studies should be evaluated with caution since there are several factors influencing the resonance frequency of dental implants including boundary height (actual height of alveolar bone surrounding the implant), width, and density of bone.[22]

CONCLUSION:

Primary implant stability is an essential criterion for obtaining Osseointegration. It occurs at the time of implant placement and is related to the level of primary bone contact. The secondary stability is the result of the formation of secondary bone contact of woven and then lamellar bone.[23] A clinician needs methods, preferably a specific test or tests that prognosticate implant survival at the time of placement (Primary Stability), prior to subsequent prosthodontic management (Secondary Stability), and at different times in future during recall assessments. Resonance Frequency Analysis (RFA) is one of the most dependable methods that is simple, clinically applicable non- invasive test to assess implant stability. Furthermore, it is likely possible that RFA may detect failing implants earlier than the traditional methods.

The use of RFA may provide possibility to individualize implant treatment with regard to healing periods, detecting failing implants, type of prosthetic construction

needed, and when one- or two- staged procedures should be used.

REFERENCES:

1. Hutlin M: Factors affecting the peri-implant tissue reactions: 2001 Deptt of Periodontology, Institute of Odontology, Karolinska Institute, Stockholm, Sweden.
2. Quesada-García M, Prados-Sánchez E: Measurement of dental implant stability by resonance frequency analysis: A review of the literature:Med Oral Patol Oral Cir Bucal. 2009 Oct 1;14 (10):e538-46.
3. Mayer T, Hawley C,. Gunsolley J, and Felman S: The Single- Tooth Implant: A Viable Alternative For Single- Tooth Replacemnt: J Periodontol, July 2002.
4. Kim SK, Heo S J, Koak J Y, Lee J H, Kwon J Y: Development of Predictable Stability Test For Assessment of Optimum Loading Time In Dental Implant: J Koren Acad Prosthodont 2008 Vol 46 No 6.
5. Ostman P, Hellman M, Wedelhag I, Sennerby L: Resonance Frequency Analysis Measurements of Implants at Placement Surgery. Int J Prosthodont 2006; 19:77-83.
6. Sennerby L & Meredith N: Implant stability measurements using resonance frequency analysis: biological and biomechanical aspects and clinical implications: Periodontology 2000, Vol. 47, 2008, 51–66.
7. Dario L, Cucchiaro P, Deluzio A: Electronic monitoring of dental implant osseointegration: J Am Dent Assoc 2002:133:483-490.
8. Valderrama P, Oates T, Jones A, Simpson J, Schoolfield J, Cochran D: Evaluation of Two Different Resonance Frequency Devices To Detect Implant Stability: A ClinicalTrial: J Periodontol Feb 2007, 262- 272.
9. Oh J, Kim S, Lim S, Ong J: Comparative study of two noninvasive techniques to evaluate implant stability: Periotest and Osstell Mentor : Oral Surg Oral Med OralPathol Oral Radiol Endod 2009;107:513-518.
10. López A, Diago M P, Cortissoz O, Martínez I: Resonance frequency analysis after the placement of 133 dental implants: Med Oral Patol Oral Cir Bucal 2006; 11:E272-6.
11. Misch CE. Density of bone: Effect on treatment planning, surgical approach, and healing. In: Misch CE, ed. Contemporary Implant Dentistry. St Louis: Mosby; 1993:469-485.
12. Truhlar R, Morris H, Ochi S: Stability of the Bone-Implant Complex. Results of Longitudinal Testing to 60 Months With the Periotest Device on Endosseous Dental Implants: Ann Periodontol: Vol 5: No. 1: 2000: 42-55
13. Orenstein I, Tarnow D, Morris H, Ochi S: Three-Year Post-Placement Survival of Implants Mobile at Placement: Ann Periodontol: Vol 5: No. 1: Dec 2000: 32-41.
14. Albrektsson T, Zarb G, Worthington P, Eriksson AR: The long-term efficacy of currently used dental implants: A review and proposed criteria of success: Int J Oral Maxillofac Implants 1986; 11-25.
15. Huang H M, Chiu C L, Yeh C Y, Lee S Y: Factors Influencing the Resonance Frequency of Dental Implants: J Oral Maxillofac Surg 61:1184-1188, 2003.
16. Froum S, Casanova L, Byrne S, Cho S: Risk Assessment Before Extraction for Immediate Implant Placement in the Posterior Mandible: A Computerized

Tomographic Scan Study: J Periodontol March 2011: Vol 82: No. 3: 395- 402
17. Vidyasagar L, Salms G, Apse, Teibe U: Dental Implant Stability at Stage I and II Surgery as Measured Using Resonance Frequency Analysis: Stomatologija, BalticDental and Maxillofacial Journal, 2004, Vol. 6, No 3: 67-72.
18. Chan-Jin Park, Yung-Soo Kim, Chang-Whe Kim, Lee-Ra Cho, Yang-Jin Yi: A study on the change of implant stability using resonance frequency analysis: J Korean Acad Prosthodont 2003 ;41 :271-87.
19. López A B, Martínez J , Pelayo J, García C C, Diago M: Resonance frequency analysis of dental implant stability during the healing period: Med Oral Patol Oral Cir Bucal. 2008 Apri1; 13(4):E244-7.
20. Barewal RM, Oates TW, Meredith N, Cochran DL: Resonance Frequency Measurement of Implant Stability in vivo on implants with a sandblasted and acid-etched surface: Int J Oral Maxillofac Implants 2003;18:641-651.
21. Ersanli S, Karabuda C, Beck F, Leblebicioglu B: Resonance Frequency Analysis of One-Stage Dental Implant Stability During the Osseointegration Period: J Periodontol, July 2005: Vol 76, No 7: 1066-1071.
22. Huang HM, Chiu CL, Yeh CY, Lee SY: Factors influencing the resonance frequency of dental implants: J Oral Maxillfac Surg 2003;61:1184-1188.
23. B Friberg, L Sennerby, N Meredith, U Lekholm: A Comparison between cutting torque and resonance frequency measurements of maxillary implants- A 20- month clinical study: Int. J. Oral Maxillofac. Surg. 1999; 28:297-303