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Original Research

Evaluation of Variation in Implant Stability Quotient at Different Time Intervals after Immediate Loading in the Posterior Mandible using Penguin Resonance Frequency Analysis System

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Abstract

Purpose: The aim of this *in vivo* study is to compare the variation in implant stability quotient (ISQ) values of implants using resonance frequency analysis (RFA) to access the immediately loaded (within 24 h) implants at different time intervals using Penguin RFA system. **Materials and Methods:** Ten Nobel Replace Tapered RP implants were placed in posterior mandible region of patients. Patients were included in the study after fulfilling the inclusion criteria. Prior to enrolling in the study, thorough information about the procedure was provided to the patients, and written consent was obtained for the same. Immediate loading was done within 24 h using tooth-colored self-cure acrylic resin. Penguin RFA System was used to measure the ISQ of dental implants. The ISQ values were recorded immediately after implant placement, after 4 weeks, after 8 weeks, and after 12 weeks. **Results:** The mean ISQ values of the immediately loaded implants at the time of placement were 82.60, after 4 weeks were 80.60, after 8 weeks were 83.70, and after 12 weeks were 87.10. There was a statistically significant difference between the ISQ values at the time of placement of implants and after 12 weeks. **Conclusion:** This study concluded that immediate loading in posterior mandible single tooth region is a safe and predictable option.

Keywords: Immediate loading, implant stability quotient, Penguin resonance frequency analysis system, resonance frequency analysis

Submitted: 10-Dec-2020; **Accepted:** 16-Jan-2021; **Published:** 22-Mar-2021

Introduction

For replacement of missing teeth, various treatment options (fixed and removable prosthesis) have been developed over time. Due to comfort, esthetics, and ease in maintenance, dental implants are preferred and considered as the best treatment option to replace missing tooth or dentition. Initially, two-stage surgical protocol was followed, in which implants were loaded after 3–6 months after placement. However, nowadays, even one-stage surgical protocol is gaining popularity, in which implants are immediately loaded. Reliable supportive guidelines are required to decide about the loading time and thus determine the prognosis of implants.[1]

According to Ostman *et al*.[2] and Kanth *et al*.,[3] implant stability is a measure of the clinical immobility of an implant, which is an indirect indication or a requisite characteristic of osseointegration. The ability to measure osseointegration is an important diagnostic as well as clinical tool to determine the life and success of dental implant. Increased implant stability may indicate good osseointegration, and decreased implant stability values may indicate a lack of osseointegration and may also tell about situations, in which it is best to unload.

Historically, the gold standard method used to determine the status of implant stability was microscopic and histological analysis. However, due to the invasiveness of this method and related ethical issues, various other methods have been proposed such as the surgeon's perception of implant stability, radiographic assessment, the percussion test, periotest, cutting torque resistance measurement,

Access this article online

Quick Response Code:

Website: www.ijds.in

DOI: 10.4103/IJDS.IJDS_212_20

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How to cite this article: Kaur A, Kuckreja H, Kaura S, Oberoi N, Kaur J, Arora J. Evaluation of variation in implant stability quotient at different time intervals after immediate loading in the posterior mandible using penguin resonance frequency analysis system. Indian J Dent Sci 2021;13:87-92.

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application of reverse torque, implatest, and resonance frequency analysis (RFA) method.[4]

Out of all these, RFA method is considered best because it is a noninvasive, reliable, easily predictable, and the objective method of quantifying implant stability. RFA has been used to determine the effects of loading or to assess changes in stability over time.[5]

Therefore, the aim of this *in vivo* study is to compare the variation in implant stability quotient (ISQ) values of implants using RFA to access the immediately loaded (within 24 h) implants at different time intervals using Penguin RFA system.

Materials and Methods

The present study was conducted in the Department of Prosthodontics and Crown and Bridge, Baba Jaswant Singh Dental College, Hospital and Research Institute, Ludhiana, after approval from the ethical committee of the college. In this study, a total of ten implants were placed in partially edentulous patients who had missing teeth in posterior mandible region and wanted implants**.** Patients were included in the study after fulfilling the inclusion criteria of having healthy, sufficient, and stable soft-tissue architecture; age more than 18 years old; D2 and D3 types of bone; edentulous site free from infection; and patient's understanding and willingness to follow the scope of the study (including procedures, follow-up evaluations, and any potential risks involved). The exclusion criteria included irradiation in the head and/or neck region, immunosuppressed or immunocompromised conditions, infected alveolar sockets, uncontrolled diabetes, pregnant or nursing women, patients with psychiatric problems and/or unrealistic expectations, poor oral hygiene, and untreatable periodontitis. Prior to enrolling in the study, thorough information about the procedure was provided to the patients, and written consent was obtained for the same. The presurgical evaluation of the concerned region consisted of clinical and radiographic examination including making of diagnostic casts for the analysis of edentulous area. Nobel Replace Trichannel implants of diameter 4.3 mm and length varying from 10 mm to 16 mm were placed in all the patients using one-stage surgical protocol after the administration of local anesthetic agent (lignocaine hydrochloride with adrenaline, 1:200,000).

For immediate loading, a closed tray abutment level impression was made. Tooth-colored self-cure polymethyl methacrylate was used for fabrication of temporary screw-retained prosthesis [Figure 1].



Figure 1: Immediate loading done using temporary screw-retained prosthesis

RFA system was used to measure the ISQ of dental implants. This method records ISQ value which is a function of bone-implant stiffness using Penguin RFA system that uses RFA that measures the frequency with which a device vibrates. The ISQ value is presented as a value from 1 (lowest stability) to 100 (highest stability).

The ISQ was recorded by Penguin RFA system with a commercially available transducer (multipeg) adapted to the implants. The transducers were fixed using the supplied hand screwdriver [Figure 2]. The measuring device was then held perpendicular to the multipeg and in close proximity to its uppermost portion [Figure 3]. For each implant, two measurements were taken – one from buccal direction and one from proximal direction.

The ISQ values were recorded immediately after implant placement, after 4 weeks, after 8 weeks, and after 12 weeks. Each visit involved questioning the patient with regard to pain level, removal of temporary screw-retained prosthesis, and placement of multipeg on the implant and hand tightening it. The ISQ readings were taken two times to ensure repeatability of the instrument. The temporary prostheses were then replaced.

Results

The mean ISQ values of the immediately loaded implants at the time of placement were 82.60, after 4 weeks were 80.60, after 8 weeks were 83.70, and after 12 weeks were 87.10 [Figure 4]. The ISQ value was found to be highest after 12 weeks of placement and lowest after 4 weeks. There was a statistically significant difference between the ISQ values at the time of placement of implants and after 12 weeks [Table 1]. Therefore, the study results support immediate loading in the posterior single tooth region of mandible as safe and predictable option as long as the initial stability is high.



Figure 2: Transducer in patient's mouth

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Table 1: Mean implant stability quotient values at different time intervals after immediate loading. Inference – Table 1 shows the progression of mean implant stability quotient values from the time of placement of implant, after 4 weeks, after 8 weeks, and after 12 weeks. It is evident from the table that the mean implant stability quotient values are statistically significant at the end of 12 weeks ($P = 2.960$)

	Mean ISQ Values			
	Time interval			
	Placement	4 weeks	8 weeks	12 weeks
Mean	82.60	80.60	83.70	87.10
S.D.	1.897	4.648	3.889	3.247
Number	10	10	10	10
Maximum	85	89	88	92
Minimum	80	75	77	81
Range	5	14	11	11
F Test		14.510		
Table Value at 0.05		2.960		
P		0.000		
Result		Significant		
Tukey's method for Pairwise comparison		Placement		
Result with mean difference of Pair>	4 weeks	2NSIG	4 weeks	
	8 weeks	1.11NSIG	3.11NSIG	8 weeks
	12 weeks	4.5SIG	6.5SIG	3.4SIG



Figure 3: Penguin resonance frequency analysis system used for making implant stability quotient measurement

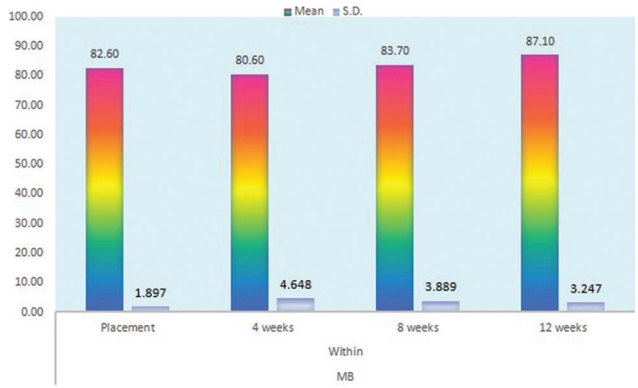


Figure 4: Comparison of implant stability quotient at different time intervals after immediate loading

Discussion

The stability of an implant is determined by a firm contact between bone and implant and is considered as a crucial factor for the maintenance of osseointegration. Successful osseointegration is a prerequisite for functional dental implants and is dependent on the primary stability of implant in the bone. Primary implant stability at the time of placement is a mechanical phenomenon and is dependent on the local bone quality and quantity, the type of implant, and the type of placement technique used. Secondary implant stability is the rise in stability due to bone formation and remodeling at the implant/tissue interface and in the surrounding bone.[6] The success of a dental implant is dependent on multiple systematic and local factors. Initially, it was suggested to keep the implant submerged in the bone until the osseointegration has taken place. However, literature has shown enough evidence over time that implants that are loaded immediately can function as well as the delayed loaded implants. Initially, implants were loaded after the healing period of 3–6 months which could be unacceptable to many patients. In the present study, immediate loading within 24 h has shown significantly better stability after 12 weeks as compared to the stability at the time of insertion of implant. The recommendation for the restoration of implants is observational in nature, and clinicians have questioned their validity from time to time. Particular attention has been paid to the timing of restoration with no occlusal contact and/or loading with occlusal contact in centric occlusion or maximum intercuspation. Subsequently, the clinician needs reliable and supportive objective guidelines to determine on an individual basis the prognosis of a given implant, if immediately loaded, early loaded within 6–8 weeks, or left classically to heal for a 3–6-month period. The gold standard method to evaluate

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the degree of osseointegration was microscopic or histologic analysis. However, this is an invasive method; therefore, certain ethical issues may be involved. Various other methods of analysis have been proposed such as clinically checking for mobility with the help of blunt-ended instruments, radiographs, cutting torque resistance, reverse torque, and RFA.[6-8]

Measuring implant stability supports making good decisions about when to load, allows advantageous protocol choice on a patient-to-patient basis, indicates situations in which it is best to unload, and supports good communication and increased trust.[9]

The clinical perception of the primary stability of implant is frequently based on the mobility which is detected by blunt-ended instruments. It is a very unreliable and nonobjective method. The percussion test may involve the tapping of a mirror handle against the implant carrier and is designed to elicit a ringing sound from the implant as an indication of good stability or osseointegration.[10]

Application of a reverse or unscrewing torque has also been proposed for the assessment of implant stability at the time of abutment connection. Implants that rotate under the applied torque are considered failures and are then removed.[8]

However, the implant surface in the process of osseointegrating, albeit slowly, may fracture under the applied torque stress. In cutting torque resistance analysis, the energy required for a current-fed electric motor in cutting off a unit volume of bone during implant surgery is measured. The energy correlates to bone density, which is one of the factors determining implant stability. Periotest is a device which is an electrically driven and electronically monitored tapping head that percusses the implant a total of 16 times.

Resonance frequency analyzer is a noninvasive diagnostic method that measures implant stability and bone density at various time points using vibration and structural principle analysis. Two commercially devices have been developed to assess implant stability. The original (electrical) method uses a direct connection (wire) between the transducer and the resonance frequency analyzer. The second method uses magnetic frequencies between transducer and resonance frequency analyzer. In the electronic device, the transducer is L-shaped cantilever beam which connects to the implant through a screw attachment. A piezoelectrical crystal on the vertical portion of the L beam is used to stimulate the implant/transducer complex; second piezoelectric crystal on the opposite side of the beam is used as a receiving element to detect the response of the beam.

Friberg *et al*., 1999,[11] conducted a study to obtain the values of RFA and cutting torque and to evaluate if any correlation exists between the two at the time of insertion of implants in the edentulous maxilla and concluded that varying bone densities can be evaluated with the help of cutting torque and resonance frequency measurements. Valderrama *et al*., 2007,[12] conducted a prospective clinical trial to determine the ability of magnetic RFA device to detect the changes in stability that occurs during early healing of dental implants and to evaluate the correlation in the values obtained by an electronic device. It was concluded that the electronic resonance frequency analyzer and the magnetic resonance frequency analyzer both are capable of measuring similar changes in the implant stability over time. Ramakrishna and Nayar[13] conducted an *in vivo* study to evaluate the effects of immediate loading on the primary stability of implants by measuring the stability over a period of time, using RFA. Implant stability values were measured at baseline (day 1), 15th day, 30th day, 60th day, and 90th day for each of the eight implants using Osstell™ resonance frequency analyzer (Integration Diagnostics, Sweden). The results showed adequate initial stability at baseline with an ISQ >50 for all the implants. Implant numbers 1, 3, 4, 7, and 8 showed a high initial stability at baseline (ISQ >65), following which a decrease in the stability was recorded during the 15th day, 30th day, and 60th day. By the 90th day, the stability values were nearly equivalent to those obtained at baseline. The highest mean stability value was recorded on the day of implant placement. The lowest mean stability recording was obtained on the 30th day after implant osteotomy. By the 90th day, the mean stability value was nearly equivalent to that obtained at baseline. Within the limitations of this study, it can be concluded that immediate loading of implants placed in the maxillary and mandibular incisor region does not seem to have an adverse effect on the osseointegration of implants, which achieved a high primary stability. The use of the resonance frequency analyzer as a tool to monitor the variation in the stability of the implants over a period of time has been validated.

Calandriello and Tomatis, 2009,[14] reported about the clinical and radiological performance of the Brånemark System® TiUnite Wide Platform implants placed at the molar site in mandibular jaw loaded immediately and followed up for 5 years to check their performance. After implant placement, temporary crowns were placed having full centric occlusion contacts, and patients were asked to exercise normal functions of mastication and avoid very hard foods. After 6 months of implant placement, Procera abutments supported screw-retained or cement-retained crowns were given on all implants. Periapical radiographs were taken at surgery and 3, 6, 12, 24, 36, 48, and 60 months, and implant stability was measured using RFA reported as ISQ values (Osstell®, Integration Diagnostics, Göteborg, Sweden) at the time of surgery and at each month, the first half-year. Two implants failed within the course of 5 years concluding the success rate of 95%. It was concluded that immediate loading of implants in the posterior single molar region is safe and predictable as long as the initial stability is high.

González-Jaranay *et al*., 2014,[15] conducted a prospective clinical study to evaluate implant stability by means of a fourth-generation RFA device and to compare the ISQ values between immediate loaded and unloaded implants in the same patient, same area, and same bone type. It was

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concluded that implants with primary stability (ISQ >60) and insertion force ≥30N showed optimal clinical behavior during osseointegration period after immediate loading and that the timing of implant loading in the initial phase did not influence the success rate. The Osstell Mentor was successful to offer an objective method to determine whether implant stability was adequate for immediate loading.

Baltayan *et al*., 2016,[16] conducted a study to investigate the predictive values of RFA to assess implant survival. This study concluded that RFA is a noninvasive method to measure the stability of implants and help guide placement staging and loading protocols and increasing ISQ values correlated with increased sensitivity in detecting implant failure.

Becker *et al*., 2018,[17] conducted a study to compare the ISQ value measured by two different RFA instruments, i.e., Osstell, Osstell USA, Columbia, MD and Penguin, Penguin Integration Diagnostics, Sweden. It was concluded that both the instruments were able to measure the implant stability values without any statistically significant difference. Both instruments were easy to use, rechargeable, and noninvasive, with Penguin device being slightly user friendly because it was lighter, cordless, and readings were easier to evaluate.

Buyukguclu *et al*., 2018,[18] conducted a study to evaluate the repeatability of the new RFA device, Penguin and to compare the ISQ values obtained by Penguin RFA with Osstell RFA. It was concluded that both Osstell ISQ and Penguin RFA are sensitive in detecting the values of density of surrounding materials around implant and produce higher values when implants are placed in stiff materials. Both devices are more reliable in measuring implant stability when implants are placed in stiff materials.

Koyuncuoglu and Demir, 2020,[19] conducted an *in vitro* study to compare and evaluate the ISQ values measured by two different RFA devices, Osstell Mentor and Penguin RFA and concluded that the Penguin RFA system could provide similar ISQ values as Osstell Mentor system.

Conclusion

The results of this study showed immediate loading done at single tooth region in the posterior mandible shows higher values of implant stability after 12 weeks of osseointegration as compared to the implant stability values on the day of placement. This shows that the osseointegration around the implants is not affected by the loading time, if the occlusal forces acting on the impants are within the physiologic limit of the bone. Thus, immediately loaded implants have secondary stability as good as the primary stability. Within the limitations of this study, it was concluded that immediate loading in posterior mandible single tooth region is a safe and predictable option.

Ethical clearance

Certified that the topic of thesis "Comparative Evolution of Variation in the implant stability quotient at different time intervals after immediate and delayed loading" by Dr Akaljot Kaur, M.D.S student of Department of prosthodontics and crown and Bridge has been approved by Baba Jaswant singh dental college, Hospital and research institute ethical committee of the college Ludhiana.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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