The journal of
PROSTHETIC AND IMPLANT DENTISTRY
Official Publication of Indian Prosthodontic Society
Kerala State Branch

ANCHOR TO CONQUER – IMPLANT STABILITY MEASURING DEVICES

*Y. Sangita, **C. Ravi Kumar, ***M. Sujesh, ***D. Chalapathi Rao, ****G. Harilal

*Postgraduate, **Professor and Head of Department, ***Professor, **** Associate Professor, Dept. of Prosthodontics, Mamata Dental College, Khammam, Telengana | Dr. Y. Sangita Email : drsangita58@gmail.com

Abstract:

Dental implants represent one of the most successful treatment modalities in dentistry[1]. Although high survival rates of implant supporting prosthesis have been reported , failure do occur due to bone loss in the range from 5 to 8% for routine procedures and up to 20% in major grafting cases after at least 5 years of function[1,2]. Achieving primary stability is of greatest importance, at the time of implant placement by new bone apposition at the bone–implant interface. A rigid mechanical engagement of implant within the host bone, with limited micromotion at the interface is the most critical factor for successful osseointegration. . Implant stability is estimated at two different stages Primary and Secondary. Primary stability of an implant is the absence of mobility in the bone bed upon insertion of the implant and mostly comes from mechanical interaction with cortical bone. It is also named as -Mechanical Stability which is the result of compressed bone holding the implant tightly in the bone.. Secondary implant stability is developed from regeneration, remodelling of the bone and tissue around the implant after insertion and is affected by primary stability. Implant instability with relative displacements above 50-150µm[3] could result in fibrous encapsulation with resultant failure. It is of utmost importance to be able to assess implant stability at various times and to project a long term prognosis for successful therapy. The review focuses on different methods used for evaluation of implant stability and recent advances.

Introduction

Osseointegration is a direct bone anchorage to an implant body which can provide a foundation to support prosthesis.[4,5] Branemark defined it as "A direct connection between living bone and a load-carrying endosseous implant at the light microscopic level.".A rigid fixation of implant within the host bone, with absence of micromotion at the interface is the most critical factor for successful osseointegration. Implant stability is a requisite characteristic of osseointegration. Without it, long-term success cannot be achieved.

Continuous monitoring of implants in a quantitative and objective manner by setting up experimental methods is important to determine the status of implant stability. The majority of implant losses may be explained as biomechanically induced failures, since low primary implant stability, low bone density, short implants and overload have been identified as risk factors[1]. Hence, achievement and maintenance of implant stability are pre-conditions for a successful clinical outcome with dental implants.

Dental implant stability can be divided into primary and secondary components. Primary stability refers to the initial mechanical bracing of the implant in bone and absence of any micromovement, while secondary stability refers to successful osseointegration of the implant with the surrounding bone.[7]

Achieving Primary stability is of utmost importance, at the time of implant placement.

If an implant is not sufficiently stable at the time of implant placement, micro-motions may occur, normal healing process may then be disrupted and a fibrous tissue capsule may form, resulting in clinical mobility and subsequent implant failure.

Bone quantity and quality, surgical techniques including the skill of the surgeon, implant (geometry,length, diameter,drill size and surface characteristics) are major factors affecting primary stability[8]. Bone quality and quantity modification can be done by augmentation procedures or by use of bone grafts but the quality of bone is one parameter were in the clinician has limited control as compared to other parameters such as implant design and surgical procedure. Using a smaller size drill in diameter than implant produces compressive stress around implant-tissue interface,resulting in compression of the bone in the implant vicinity when implant is surgically driven. Such stresses are beneficial in terms of attaining good primary stability,but if these stresses surpasses optimum levels than it may result in local ischemia of bone and necrosis[8]. Change in implant stability after insertion is due to regeneration and remodelling of bone at implant tissue interface is considered to be secondary stability. Secondary stability is a biological stability. It involves regeneration and remodelling of bone and tissue around the implant over a period of time. It depends upon primary stability, bone formation and remodelling. Complete bone-implant contact rarely occurs and clinically observed osseointegration corresponds to approximately 80% of bone contact. Though, more than 60% of bone-implant contact is considered to be adequate for implant stability. There are various methods which have been suggested in literature to measure implant stability.[7]

Various methods to check implant stability as categorized as follows:-

Invasive or Destructive methods

1. Histologic/Histomorphologic Analysis
2. Tensional test
3. Push out/Pull out test
4. Removal torque analysis

Non Invasive or Non Destructive Methods

- Surgeon's Perception
- Radiographical Analysis / Imaging Techniques
- Cutting Torque Resistance (for primary stability)
- Insertion torque measurement
- Reverse Torque
- Seating Torque Test
- Modal Analysis And Implant test
- Percussion Test
- Pulsed Oscillation Waveform(POW)
- Periotest
- Resonance Frequency Analysis (RFA)
- Electronic Technology
- Magnetic Technology

Invasive or destructive methods

1. Histologic or histomorphologic analysis

This method quantitatively assess the bone contact and bone area from a dyed specimen of the implant and peri-implant bone. Due to invasive and destructive nature of the technique it is limited to non-clinical and experimental studies.[8,10]

2. Tensional test

The strength of the implant was earlier measured by detaching the implant plate from the supporting bone. It was later on modified by applying lateral load to cylindrical implant fixture. However there were difficulties in translating the test results to any area independent mechanical properties.[11]

3. Push out / pull out test

This test evaluates the healing capabilities at the bone implant surface. In this test, a cylinder type implant is placed transcortically or intramedullary in bone and then removed by applying a force parallel to the interface. The maximum load capability is defined as the maximum force displacement. However the push out pull out tests are only applicable for non-threaded cylinder type implants, whereas most of clinically available fixtures are of threaded design and then interfacial failures are solely dependent on shear stress without any consideration for either tensile or compressive stresses.[11,12]

4. Removal torque analysis

In this test an implant is considered stable if the reverse or unscrewing torque is > 20Ncm. Osseointegrated implants resist this torque while failed implant unscrew. However, the drawback is that at the time of abutment connection the implant surface in the process of osseointegration may fracture under the applied torque stress. This test doesn't give a clear clarity of degree of bone healing or bone formation around implant but provides result only about osseointegrated or failed implant bone interface.[8,11,13]

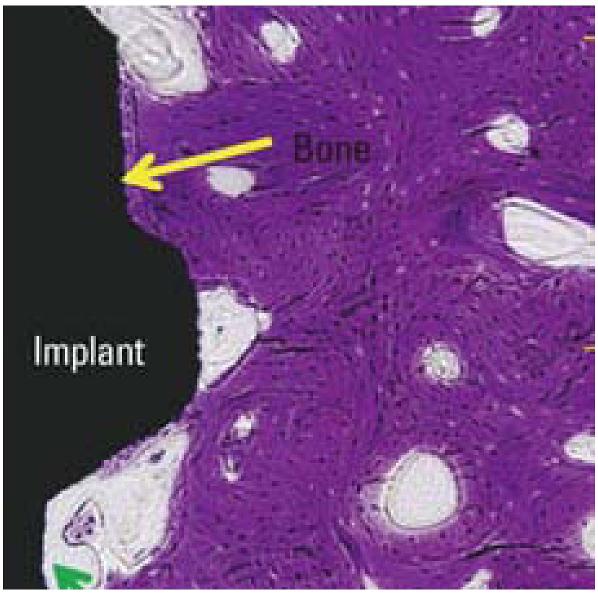
Non – invasive or non destructive methods

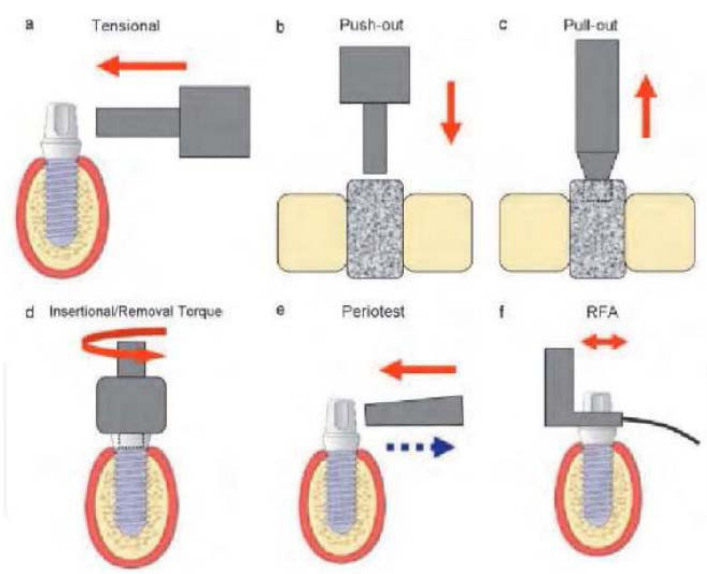
1. The surgeon's perception

One method of trying to evaluate primary stability is quite simply the perception of the surgeon. It is based on the cutting resistance and seating torque of the implant during insertion. A perception of "good" stability may be heightened by the sensation of an abrupt stop when the implant is seated. However, this type of measurement can only be made when the implant is inserted, it cannot be used later, for example, before loading the implant.

2. Imaging techniques

Various radiographic and imaging techniques are used to clinically evaluate the quality and





quantity of bone before the placement of implant fixture. The most common methods for assessing bone implant integration analysis are periapical radiography,panoramic radiography,computed tomography (CT),Cone beam computed tomography (CBCT) etc.

3. Cutting – torque resistance analysis

It was originally developed by Johansson and Strid and later improved by Friberg et al. The energy required to remove a unit volume of bone is significantly correlated with bone density and quantifies bone hardness during implant osteotomy at the time of implant placement. It provides information in determining an optimal healing period in a given arch location with a certain bone quality. Longitudinal data cannot be collected to evaluate bone quality changes after placement of implants.[14]

Limitations

1. Does not give any information on bone quality until the osteotomy site is prepared.

2. CRA cannot estimate the value at which the implant would be at rise.

4. Insertion torque measurement

Insertion torque values have been used to measure the bone quality in various parts of the jaw during implant placement.[15,16] It is a mechanical parameter generally affected by a surgical procedure, implant design and bone quality at the implant site.[17] A disadvantage of this method is that the insertion torque varies depending on the cutting properties of the implant and the presence of fluid in the preparation. It can only be used during implant placement and not possible at later stages of the treatment.

5. Reverse torque test

It was proposed by Roberts et al[14,19] and developed by Johannson and Alberktsson. It evaluates the secondary stability of the implant. It measures the torque threshold where bone implant contact was destroyed. Measurement of lateral mobility is more useful than measurement of rotational stability as an indicator of successful treatment result. It cannot quantify the degree of osseointegration as threshold limits vary among patients, implant material, bone quality and quantity. The studies showed, the stress of applied torque may in itself be responsible for the failure.[20]

6. Seating torque test

Like insertion torque, the final seating torque gives some information about the primary stability of the implant when the implant reaches its final apico-occlusal position. It is done after implant placement.[16]

7. Percussion test

A simple method used to measure the level of osseointegration. This test is based upon vibrational acoustic science and impact response theory. The clinical judgement of osseointegration is based on the sound heard upon percussion with a metallic instrument. A clearly ringing 'crystal' sound indicates successful osseointegration whereas a 'dull' sound may indicate absence of osseointegration. This method mostly relies on the doctor's experience level and subjective belief. Therefore, it cannot be used experimentally as a standardized testing method.[14,17]

8. Periotest

Quantifies the mobility of an implant by measuring the reaction of the peri-implant tissues to a defined impact load. The periotest was introduced by Dr.Schulte to perform measurements of the damping characteristics of the periodontal ligaments, thus assessing the mobility of natural tooths.[20,21] It uses an electromagnetically driven and electronically controlled tapping metallic rod in a hand piece. Periotest value range from -8 (low mobility) to +50 (high mobility). Response to a striking'' is measured by a small accelerometer incorporated into the head. The reliability of this method is questionable because of poor sensitivity,susceptibility to many variables[22]. The factors that influence the periotest value are the quality of the hard tissue in the region of the implant, so that no specific values can be deemed as appropriate for higher or lower degrees of integration. The measurements are significantly affected by direction and position. It measures implant stability and bone density at the time of implant placement and post surgical placement of the implant

9. Pulsed oscillation wave form

Kaneko[23] described the use of a pulsed oscillation wave form (POWF) to evaluate the properties of mechanical vibrations of the bone-implant interface using forced excitation of a steady state wave. POWF is based on estimation of frequency and amplitude of the vibration of the implant induced by a small pulsed force.

A multi frequency pulsed force of about 1 kHz is applied to an implant by lightly touching it with two fine needles connected with piezoelectric elements (contained in an accous to electric driver AED, and acoustoelectric receiver AER). It is used for in-vitro and experimental studies. The sensitivity of the POWF test depended on load directions and positions

10. Resonance frequency analysis

In 1998, Meredith[25] suggested a non-invasive method of analyzing implant stability and bone density at various time periods using vibration and a principle of structural analysis. This method has L-shaped transducer that is tightened to the implant or abutment by a screw. The transducer provides a high frequency mechanical vibration and record the frequency and amplitude of the signal received.

The transducer comprises of two ceramic elements, one of which is vibrated by a sinusoidal angle (5 – 15 kHz) while the other serves as a receptor. The transducer is screwed directly to the implant body and shakes the implant at a constant input and amplitude starting at a low frequency and increasing in pitch until the implant resonates. High frequency resonance indicates stronger bone-implant interface.

RFA has been widely used for clinically assessing osseointegration, as well as for prognostic evaluation. The most recent version of RFA is a wireless gadget. A metal rod is attached to the implant with a screw connection. The rod has a small magnet attached to its top that is stimulated by magnetic impulses from a handheld electronic device. The rod mounted on the implant has two fundamental resonance frequencies, it vibrates in two directions, perpendicular to each other. One of the vibrations is in the direction where the implant is most stable and the other is in the direction where the implant is least stable.

11. Electronic Technology Resonance Frequency Analysis (Osstell)

It was the first commercially available product for measuring implant stability. The electronic technology combines the transducer, computerized analysis and the excitation source into one machine.

Implant stability quotient (ISQ) is the measurement unit (ISQ of 0 to 100) used. When used at the time of implant placement it provides baseline reading for future comparison and post-surgical placement of the implant.

Vibration tests are based on the assumption that the resonance frequency is directly related to the stiffness of the bone–implant interface, and of the surrounding bone: they act like two springs in series, therefore the softer one plays the greatest influence[26]. As a general rule, high values of resonance frequency are produced by successfully integrated implants, while low values may be signs of ongoing mobilization and/or marginal bone loss. Caution has been expressed by the European Association of Osseointegration (EAO), since it has been realized that Resonance Frequency Analysis (RFA) is affected not only by bone tissue characteristics, but also by the effective implant length, diameter, and surface characteristics. This is the reason why no established normative base on RFA is available yet, and the trend of resonance frequency versus time is thought to be significant, rather than its absolute value, measured at a certain time step.

Implant stability quotient (ISQ) is the measurement unit (ISQ of 0 to 100) used.[27] When used at the time of implant placement it provides baseline reading for future comparison and post-surgical placement of the implant.

12. Magnetic Technology Resonance Frequency Analysis (Osstell Mentor)

The transducer has a magnetic peg on the top and is fixed to implant or abutment. On activation by magnetic resonance frequency probe the pegs activated, which vibrates and induces electric volt sample by magnetic resonance frequency analyzer. Values are expressed as ISQ of 0 – 100.

At the time of implant placement it provides base line reading for future comparison and post-surgical placement of the implant.

However this method is expensive and technique sensitive as it requires respective transducer and magnetic peg. It should maintain a distance of 1 – 3 mm, angle of 900 and should be 3 mm above the soft tissue otherwise the measured value will be affected.[28,29]

13. Modal Analysis

Modal analysis is also known as vibration analysis. It measures the natural frequency or displacement signal of a system in resonance, which is initiated by external steady – state waves or a transient impulse force.

It can be performed in two models Theoretical and experimental.

The theoretical modal analysis includes finite element analysis. It investigates vibrational characteristics of objects. It is done to calculate stress and strain in various anticipated bone levels. It is used in clinical studies and experimental studies.

The experimental modal analysis is a dynamic analysis. It measures natural characteristic frequency, mode and attenuation- via vibration testing. It is used in non-clinical studies in-vitro approach and provides reliable measurements.[30]

Conclusion

The description of various techniques in the above literature states that the advanced and tests and equipments may play a more prominent role in the assessment of implant stability as compared to conventional methods. The ability to monitor life expectancy of an implant and its osseointegration is a valuable diagnostic and a clinical tool. Although RFA has attracted considerable scientific interest in recent years, it can also be used to evaluate the effect of early and delayed loading assess stability over a period of time and early diagnosis of implant failure. However, more research is necessary to invent an accurate instrument which will help gauge the implant stability.

References

1. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributingto failures of osseointegrated oral implants.(I). Success criteria and epidemiology. EurJ Oral Sci. 1998;106:527-51.
2. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated oral implants: A review of the literature. The International Journal of Prosthosontics.1998;11(5):408-20.
3. Szmukler-Moncler, S.; Salama, H.; Reingewirtz, Y.; Dubruille, J.H. Timing of loading and effect of micromotion on bone-dental implant interface: Review of experimental literature. J. Biomed. Mater. Res.., 43, 192–203.
4. 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;1:11-25.

5. Albrektsson T, Talbrektsson B. Implant fixation by direct bone anchorage.New York: Raven Press Ltd.; 1983. p. 87-97.
6. Mesa F, Muñoz R, Noguerol B, de Dios Luna J, Galindo P, O'Valle F. Multivariatestudy of factors influencing primary dental implant stability. Clin Oral Implants Res.2008;19(2):196-200.
7. Sennerby L, Meredith N. Implant stability measurements using resonancefrequency analysis: Biological and biomechanical aspects and clinical implications. Periodontology 2000. 2008;47:51-66.
8. Meredith N. Assessment of implant stability as a prognostic determinant. International Journal of Prosthodontics. 1998;11: 491-501.
9. Sachdeva et al.; BJMMR, 12(3): 1-10, 2016; Article no.BJMMR.21877.
10. Park JC, Lee JW, Kim SM, Lee JH. Implant stability measuring devices and randomized clinical trial for ISQ value change pattern measured from twodifferentdirections by magnetic RFA. Implant Dentistry – A Rapidly Evolvin PracticePublisher: In Tech; 2011.
11. Chang PC, Lang NP, Giannobile WV. Evaluation of functional dynamics duringosseointegration and regeneration associated with oral implants. Clin Oral Implants Res. 2010;21(1):1-12.
12. Brunski JB, Puleo DA, Nanci A. Biomaterials and biomechanics of oral andmaxillofacial implants: current status and future developments.Int J OralMaxillofacImplants. 2000;15(1):15-46.
13. Johansson CB, Albrektsson T. A removal torque and histomorphometric study of commercially pure niobium and titanium implants in rabbit bone.ClinOral ImplantsRes. 1991;2(1):24-9.
14. Atsumi M, Park SH, Wang HL. Methods used to assess implant stability: Current status. Int J Oral Maxillofac Implants. 2007;22:743-54.
15. Irinakis T, Wiebe C. Initial torque stability of a new bone condensing dental implant. A cohort study of 140 consecutively placed implants. J Oral Implantol2009;35:277-82.
16. O'Sullivan D, Sennerby L, Jagger D, Meredith N. A comparison of two methods of enhancing implant primary stability. Clin Implant Dent Relat Res 2004;6:48-57.
17. Bayarchimeg D, Namgoong H, Kim BK, Kim MD, Kim S, Kim TI, et al. Evaluation of the correlation between insertion torque and primary stabilityof dentalimplants using a block bone test. J Periodontal Implant Sci2013;43:30-6.
18. Roberts WE, Simmons KE, Garetto LP, DeCastro RA. Bone physiology and metabolism in dental implantology: Risk factors for osteoporosis and othermetabolic bone diseases. Implant Dent 1992;1:11-21.
19. Friberg B, Sennerby L, Gröndahl K, Bergström C, Bäck T, Lekholm U. Oncutting torque measurements during implant placement: A 3-year clinical prospective study. Clin Implant Dent Relat Res 1999;1:75-83.
20. Schulte W, Lukas D. Periotest to monitor osseointegration and to check the occlusion in oral implantology. J Oral Implantol 1993;19:23-32.
21. Schulte W, d'Hoedt B, Lukas D, Muhlbradt L, Scholz F, Bretschi J, et al.PeriotestA new measurement process for periodontal function. ZahnarztMitt 1983;73:1229-30, 1233-6, 1239-40.
22. Salvi GE, Lang NP. Diagnostic parameters for monitoring peri-implantconditions. Int J Oral Maxillofac Implants 2004;19 Suppl:116-27.
23. Kaneko T. Pulsed oscillation technique for assessing the mechanical state of the dental implant-bone interface. Biomaterials 1991;12:555-60.
24. Mall N, Dhanasekar B, Aparna IN. Validation of implant stability: A measureof implant permanence. Indian J Dent Res 2011;22:462-7.
25. Aparicio C, Lang NP, Rangert B. Validity and clinical significance of biomechanical testing of implant/bone interface. Clin Oral Implants Res2006;17:2-7.
26. Zanetti, E.M.; Ciaramella, M.; Calì, M.; Pascoletti, G.; Martorelli, M.; Asero, R.; Watts, D.C. Modal analysis for implant stability assessment: Sensitivity of thismethodology for different implant designs. Dent. Mater.2018, 34, 1235–1245.
27. Park JC, Lee JW, Kim SM, Lee JH. Implant Stability – Measuring Devices and Randomized Clinical Trial for ISQ Value Change Pattern Measured from Two Different Directions by Magnetic RFA, Rapidly Evolving Practic2011;5:111-30.
28. Evaluation of two different resonance frequency devices to detect implantstability: A clinical trial. J Periodontol 2007;78:262-72.
29. Dario LJ, Cucchiaro PJ, Deluzio AJ. Electronic monitoring of dental implantosseointegration. J Am Dent Assoc 2002;133:483-90.
30. Cairns NJ, Adam CJ, Pearcy MJ, Smeathers J. Evaluation of modal analysis techniques using physical models to detect osseointegration of implants intransfemoral amputees. ConfProc IEEE Eng Med BiolSoc2011;2011:1600-3