Review Article

A review on primary stability of implants

R. Sasikala[1], Ashish R. Jain[2]*, Ajay Ranganathan[3], V. Rakshagan[4]

ABSTRACT

The dental implant therapy has a phenomenal rise in today's dentistry. The researchers are in a constant effort toward improvement, excellence, and simplification of implant therapy. For a successful implant placement, implant stability is important. Implant instability could result in fibrous encapsulation leading to implant failure. Measuring implant stability helps to make decisions about the loading of implants. Primary stability depends on the quality and quantity of the bone, implant type, and placement technique. Secondary stability is attributed to bone formation and remodeling at the implant interface and around the bone. Primary stability is the initial engagement between the bone and the implant. If the primary stability is good, the implant can be done immediately.

KEY WORDS: Bone, Implant, Osseointegration, Primary stability

INTRODUCTION

Osseointegration is a prerequisite for successful implant treatment. The term was defined by Branemark (1985) as "a direct structural and functional connection between ordered, living bone, and the surface of a load-carrying implant." Primary implant stability is known to be an essential criterion for the achievement of such osseointegration. Dental implant stability is a measure of the quality of anchorage of an implant in the alveolar bone and is considered to be an important parameter in dental implant therapy. Implant stability occurs at two different stages: Primary and secondary.[1] Implant stability can affect the process of osseointegration, the pattern of implant loading, and, finally, the success of an implant.[2] Primary stability of an implant is due to the mechanical engagement with cortical bone which prevents the formation of a connective tissue layer between implant and bone and ensures bone healing. Therefore, the primary stability of an implant is a prerequisite to undisturbed peri-implant bone healing. Secondary stability provides biological stability through bone regeneration and remodeling.

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Secondary stability seen after the healing period is primary stability with a further gain instability due to bone formation around theimplant.[3]

OSSEOINTEGRATION

For successful implant, osseointegration is essential, and for successful osseointegration primary implant stability is essential. Implant stability refers to a lack of clinical mobility. Implant instability might lead to fibrous encapsulation having resulting failure.[2,4] Osseointegration of dental implants may be affected by numerous factors. In 1981, Albrektsson *et al*.[1] demonstrated the six major parameters of osseointegration which are the implant material, the implant surface, the implant design, the condition of the bone at the host bed, the surgical technique, and the loading conditions.

1. Implant-related factors: The biocompatibility of the material, the topography, composition, and coating of the surface, the shape and design of the implant and the length and diameter of the fixture
2. Host bed factors: The bone volume, density, and vascularity
3. Surgical factors: Achieving primary stability, mechanical trauma, and thermal trauma or infection
4. Biomechanical factors: Loading conditions and patient-related factors: Systemic disease, systemic medication, radiotherapy, and parafunctional habits.

[1]Department of Prosthodontics, Vinayaka Missions Sankarachariyar Dental College and Hospitals, Salem, Tamil Nadu, India, [2]Reasearch Scholar, Department of Prosthodontics, Saveetha Dental College and Hospitals, Saveetha University, Chennai, Tamil Nadu, India, [3]Department of Prosthodontics, Vivekanandha Dental College for Women, Namakkal, Tamil Nadu, India, [4]Department of Prosthodontics, Saveetha Dental College and Hospitals, Saveetha University, Chennai, Tamil Nadu, India

***Corresponding author:** Dr. Ashish R. Jain, Research Scholar, Department of Prosthodontics, Saveetha Dental College and Hospitals, Saveetha University, Poonamallee High Road, Chennai – 600 127, Tamil Nadu, India. Phone: +91-09884233423. E-mail: dr.ashishjain_r@yahoo.com

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Primary Stability

Primary stability is defined as the absence of mobility in the bone bed following the implant placement.[5] During the early stages of healing, mechanical stability decreases and biological stability increases. In an osseointegrated implant, the stability depends on the biological component.[6]

Primary stability is the mechanical anchorage of an implant within the fresh bone socket. Primarily, this contact between the bone and the implant two materials has only mechanical connection characteristics and not biological. Due to surgical trauma to the bone due to the surgery, about 1 mm periphery around the body of the implant is devitalized, resorbed, and remodeled.[7-9] This leads to loosening of the bone-to-implant contact which decreases the mechanical contact between the implant and the bone thereby decreasing the implant's primary mechanical stability and prevents the connective tissue layer between the bone and the implant and promotes bone healing. As bone formation occurs around the body of the implant due to osseointegration, the contact between bone and implant increases thereby increasing the secondary stability, leading to an osseointegrated implant.

Primary implant stability is influenced by the shape and design of the implant, the quality and quantity of the bone, the surgical technique and skills of the surgeon, presence of parafunctional habits interfere, and the healing capacity of the implant site.

How Implant Stability is Measured

Implant stability can be measured with the bone-to-implant contact percentage or by recording the reverse torque value during implant removal.[10,11] Clinically, the implant stability can be measured by recording the insertion torque value or by the use of the resonance frequency analysis. Insertion torque measurement determines primary stability during implant placement.[12,13]

Implant insertion torque determines its primary micro movement and, therefore, its primary stability.[12] Furthermore, it has been reported that insertion torque is directly related to the initial bone-to-implant contact percentage at the time of implant placement.[14] It is also reported that insertion torque value is related to the removal torque value of an implant after 2 or 4 weeks of osseointegration period.[15,16] Implant primary stability is positively related to the insertion torque exercised.[17]

Atsumi *et al*.[1] proposed the following factors that affect primary stability:

1. Bone quantity and quality
2. Surgical technique, including the skill of the surgeon
3. Implant (e.g., geometry, length, diameter, and surface characteristics).

The factors affecting primary implant stability can be divided into:

1. Patient-related (i.e., bone volume and quality)
2. Procedure-dependent parameters
   i. Type of implant (drill-size implant size, pretapped or self-tapped implant)
   ii. Type of surgical procedure.[18]

Insufficient primary stability causes poor healing related to the early loss of the implant.[1]

The main two factors affecting implant stability are the location and the stiffness of the implant in the surrounding tissue. The stiffness can be considered in three ways:

1. The stiffness of the implant components themselves associated with the geometry and material composition
2. The stiffness of the implant-bone interface; and
3. The stiffness of the bone itself associated with the trabecular/cortical bone ratio and bone density.

Increasing the Primary Stability of an Implant

A key factor for the implant primary stability is the bone-to-implant contact. Factors such as implant shape, length, and diameter that cause an increase in the contact area between the implant and bone may increase the implant primary stability. The quality of the bone bed plays an important role in shaping the BIC area.

Dental implants inserted at the posterior region of the maxilla exhibit the lowest success rates[19,20] mainly due to the thin cortical plate and the low-density trabecular bone by which this region is characterized.[21] Bicortical anchorage or bicortical fixation also shows a significant increase in primary implant stability.

Under preparation of the implant bed using as the last drill, one or more sizes smaller than the implant diameter also helps in increasing the primary stability of implants. Stepped osteotomy is also a method of under preparation of the implant bed which provides greater implant stability in terms of insertion torque than the conventional osteotomy technique in soft bone.

TECHNIQUES OF DETERMINING IMPLANT STABILITY

The techniques of determining implant stability clinically are Periotest, resonance frequency analysis, clinical perception, cutting torque resistance analysis, percussion test, and reverse torque test.[22]

Resonance Frequency Analysis

Resonance frequency analysis is a diagnostic method that measures bone density and implant stability by

application of a bending load and provides information about the stiffness of the implant-bone junction. It evaluates the micro mobility or displacement of the implant in the bone under a lateral load, applying microscopic lateral forces to the implant with a vibrating transducer.[22] Resonance frequency analysis is only records the rigidness of the matrix to which the instrument's probe is connected.

Clinical Perception

The clinical view of the primary implant stability is based on the mobility tested with blunt-ended instruments. This can also be checked by observing implant's cutting resistance while inserting it. If the implant stability is good, it can be identified by sensing an abrupt stop at the implant's seating. Tapered implants' root forms offer a firm stop and probably a false sensitivity of high stability.[23]

Periotest

Periotest is an electronic instrument which performs quantitative measurements of the damping characteristics of the periodontal ligament surrounding a tooth, thereby establishing a value for its mobility.[24] This instrument has a tapping rod impacting the abutment or implant assembly which is drawn by a propulsion coil toward it. The coil moves at a velocity from the moment leaving the handpiece at a distance of 4 mm approximately. The end of the rod inside the handpiece is connected to an accelerometer, which produces an output proportional to its acceleration.

Percussion Test

The percussion test is done using the handle of a mouth mirror. The handle is used to tap against the implant carrier. If a ringing sound is elicited from the implant, it indicates good stability or osseointegration of the implant.[6] However, this method is not accurate for implants due to rigidity and the lack of periodontal ligament.

Biological Stability

Around 3 weeks of implant placement, there will be a gradual shift from primary stability to biological stability where viscoelastic stress relaxation of the bone, along with remodeling, and results in the loss of primary stability. While secondary stability is the progressive increase in stability related to biologic events at the bone-to-implant interface such as osteogenesis and remodeling, biological stability is absent at the time of implant placement and increases as progress.[25]

Reverse Torque Test

When a reverse or unscrewing torque is applied, the implant should not rotate. Implants that rotate under the applied torque are considered failures and are then removed. This method is used to assess implant stability at the time of abutment connection. Insertion torque measurement is used for the assessment of only primary stability during implant placement.[26]

Some studies have also preferred insertion torque as a determinant of implant stability, and torque values of 32, 35, or 40 Ncm and higher have been chosen as thresholds for immediate loading.[27,28] This threshold seems to be important due to the selection of implant-abutment connections, which have the need of this torque to engage the abutment to the implant body through the fixation screw based on the manufacturer guidelines. Furthermore, implants placed in a weak bone (poor bone quality) may be loaded immediately and demonstrate high survival rates when the final torque in the implant-abutment connection is lower, i.e., nearly 15–20 Ncm.[29]

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.[9-11] The energy correlates to bone density, which is one of the factors determining implant stability. However, the lower limit value has not been established, which can denote the potential failure of the implant. Moreover, it can only be used during the surgery and not as a diagnostic aid, and it cannot assess the secondary stability by new bone formation and remodeling around the implant.[30]

Reading Interpretation

- −8 to 0 – Osseointegration is good; loading of the implant can be done.
- +1 to 9 – Examination is required, loading is not possible in many cases.
- +10 to +50 – Osseointegration is not completed, the implant cannot be loaded.

Implant micromotion is the only direct method to assess implant stability. However, no instrument has been developed to measure implant micromotion intraorally.

CONCLUSION

Primary stability is proved to be essential criteria for osseointegration. Factors such as surgical technique, quality of the bone, and implant geometry; bone density and surface roughness have a huge impact on primary stability. Hence, primary stability is considered as the "password of implant integration account."

REFERENCES

1. Albrektsson T, Brånemark PI, Hansson HA, Lindström J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. Acta Orthop Scand 1981;52:155-70.
2. Meredith N. Assessment of implant stability as a prognostic determinant. Int J Prosthodont 1998;11:491-501.

3. 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.
4. Brunski JB. Biomechanical factors affecting the bone-dental implant interface. Clin Mater 1992;10:153-201.
5. Javed F, Romanos GE. The role of primary stability for successful immediate loading of dental implants. A literature review. J Dent 2010;38:612-20.
6. Simunek A, Kopecka D, Brazda T, Strnad I, Capek L, Slezak R, *et al.* Development of implant stability during early healing of immediately loaded implants. Int J Oral Maxillofac Implants 2012;27:619-27.
7. Marković A, Calasan D, Colic S, Stojcev-Stajcic L, Janjic B, Misic T. Implant stability in posterior maxilla: Bone-condensing versus bone-drilling: A clinical study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:557-63.
8. Buchter A, Kleinheinz J, Weismann HP, Kersken J, Nienkemper M, Weyhrother HV, *et al.* Biological and biomechanical evaluation of bone remodeling and implant stability after using an osteotome technique. Clin Oral Implants Res 2005;16:1-8.
9. Nkenke E, Lehner B, Fenner M, Roman FS, Thams U, Neukam FW, *et al.* Immediate versus delayed loading of dental implants in the maxillae of minipigs: Follow-up of implant stability and implant failures. Int J Oral Maxillofac Implants 2005;20:39-47.
10. Strietzel FP, Nowak M, Kuchler I, Friedmann A. Periimplant alveolar bone loss with respect to bone quality after use of the osteotome technique. Clin Oral Implants Res 2002;13:508-13.
11. Nevins M, Nevins ML, Schupbach P, Fiorellini J, Lin Z, Kim DM, *et al.* The impact of bone compression on bone-to-implant contact of an osseointegrated implant: A canine study. Int J Periodontics Restorative Dent 2012;32:637-45.
12. Mombelli A, Cionca N. Systemic diseases affecting osseointegration therapy. Clin Oral Implants Res 2006;17 Suppl 2:97-103.
13. Manzano-Moreno FJ, Herrera-Briones FJ, Linares-Recatala M, Ocaña-Peinado FM, Reyes-Botella C, Vallecillo-Capilla MF, *et al.* Bacterial contamination levels of autogenous bone particles collected by 3 different techniques for harvesting intraoral bone grafts. J Oral Maxillofac Surg 2015;73:424-9.
14. Huwais S, Meyer EG. A novel osseous densification approach in implant osteotomy preparation to increase biomechanical primary stability, bone mineral density, and bone-to-implant contact. Int J Oral Maxillofac Implants 2017;32:27-36.
15. Green JR, Nemzek JA, Arnoczky SP, Johnson LL, Balas MS. The effect of bone compaction on early fixation of porous-coated implants. J Arthroplasty 1999;14:91-7.
16. Kold S, Bechtold JE, Ding M, Chareancholvanich K, Rahbek O, Søballe K, *et al.* Compacted cancellous bone has a spring-back effect. Acta Orthop Scand 2003;74:591-5.
17. Lioubavina-Hack N, Lang NP, Karring T. Significance of primary stability for osseointegration of dental implants. Clin Oral Implants Res 2006;17:244-50.
18. Turkyilmaz I, Aksoy U, McGlumphy EA. Two alternative surgical techniques for enhancing primary implant stability in the posterior maxilla: A clinical study including bone density, insertion torque, and resonance frequency analysis data. Clin Implant Dent Relat Res 2008;10:231-7.
19. Molly L. Bone density and primary stability in implant therapy. Clin Oral Implants Res 2006;17 Suppl 2:124-35.
20. Geckili O, Bilhan H, Geckili E, Cilingir A, Mumcu E, Bural C, *et al.* Evaluation of possible prognostic factors for the success, survival, and failure of dental implants. Implant Dent 2014;23:44-50.
21. Trisi P, Berardini M, Falco A, Vulpiani MP. New osseo densification implant site preparation method to increase bone density in low-density bone: *In vivo* evaluation in sheep. Implant Dent 2016;25:24-31.
22. The Implant Stability Quotient Whitebook: The Relationship between Reliable Diagnostics and Safe, Successful Dental Implant Procedures. 1st ed. Available from: http://www.citagenix.com/pdf/Osstell_ISQ_Whitebook_1.pdf. [Last assessed 2014 Jul 27].
23. Elias CN, Rocha FA, Nascimento AL, Coelho PG. Influence of implant shape, surface morphology, surgical technique and bone quality on the primary stability of dental implants. J Mech Behav Biomed Mater 2012;16:169-80.
24. Norton M. Primary stability versus viable constraint-a need to redefine. Int J Oral Maxillofac Implants 2013;28:19-21.
25. Aparicio C, Lang NP, Rangert B. Validity and clinical significance of biomechanical testing of implant/bone interface. Clin Oral Implants Res 2006;17 Suppl 2:2-7.
26. Steeves M, Stone C, Mogaard J, Byrne S. How pilot-hole size affects bone-screw pullout strength in human cadaveric cancellous bone. Can J Surg 2005;48:207-12.
27. Hui E, Chow J, Li D, Liu J, Wat P, Law H, *et al.* Immediate provisional for single-tooth implant replacement with brånemark system: Preliminary report. Clin Implant Dent Relat Res 2001;3:79-86.
28. Lorenzoni M, Pertl C, Zhang K, Wimmer G, Wegscheider WA. Immediate loading of single-tooth implants in the anterior maxilla. Preliminary results after one year. Clin Oral Implants Res 2003;14:180-7.
29. Romanos GE. Bone quality and the immediate loading of implants-critical aspects based on literature, research, and clinical experience. Implant Dent 2009;18:203-9.
30. Nedir R, Bischof M, Szmukler-Moncler S, Bernard JP, Samson J. Predicting osseointegration by means of implant primary stability. Clin Oral Implants Res 2004;15:520-8.

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