OPEN ACCESS
Global Journal of Research in Dental Sciences
ISSN: 2583-2840 (Online)
Volume 05 | Issue 02 | March – April | 2025
Journal homepage: https://gjrpublication.com/gjrds/
Review Article

Implant Stability: Winning Approach to the Success Formula

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DOI: 10.5281/zenodo.15249049 **Submission Date:** 14 March 2025 | **Published Date:** 19 April 2025

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Abstract
The long-term success of dental implants is critically dependent on implant stability, which ensures proper osseointegration and functional loading. This review delves into the multifaceted concept of implant stability, examining its definition, types, influencing factors, and measurement techniques. Additionally, it differentiates between stability and mobility, underscoring the clinical significance of evaluating implant stability. By synthesizing recent scientific findings, this paper aims to provide a comprehensive understanding of implant stability as a cornerstone of dental implant success.

Keywords: *Dental implant, osseointegration, primary stability, secondary stability, resonance frequency analysis.*

Introduction:
Dental implants offer a dependable solution for replacing missing teeth by serving as a secure base for prosthetic restorations. Their long-term success is primarily influenced by implant stability and the process of osseointegration—the direct and functional connection between the implant and the bone surface. [1] Implant stability plays a vital role in achieving successful osseointegration, as it supports both the mechanical anchorage and biological integration of the implant within the bone structure. [2,3]

Osseointegration:
Following implantation, two types of tissue responses can occur. The first involves the development of a fibrous soft tissue capsule surrounding the implant. This response fails to provide adequate biomechanical stability, often resulting in clinical failure of the dental implant. The second response entails direct contact between the bone and the implant surface, with no intervening connective tissue layer—a phenomenon known as osseointegration. [4] Osseointegration is essential for the success of dental implants and is defined as the direct structural and functional connection between living bone and the surface of a load-bearing implant. [1]

The implant–tissue interface is a highly dynamic zone characterized by complex interactions. These interactions encompass not only the properties of the biomaterial and its biocompatibility but also changes in the mechanical environment. Osseointegration begins with a primary mechanical interlock between the implant and the surrounding alveolar bone, followed by biological fixation achieved through ongoing bone deposition and remodeling along the implant surface. This intricate process is influenced by numerous factors that govern both the initial formation and long-term maintenance of bone at the implant interface. [5]

Several key elements affect osseointegration, which can be categorized into distinct groups: factors related to the implant itself, the condition of the host bone bed, mechanical stability, the application of supportive therapies, and the remodeling activity of the periprosthetic bone at the interface. [6]

Implant Stability:
Implant stability plays a pivotal role in the success of dental implants, as it indicates how securely the implant is anchored within the bone both at the time of placement and following osseointegration. This stability develops in two distinct phases: primary and secondary. Primary stability results from the immediate mechanical engagement between the

implant and the surrounding bone upon insertion, whereas secondary stability arises over time through biological processes such as bone formation and remodeling around the implant. [7,8,9,10] While primary stability is crucial for initiating osseointegration, secondary stability is key to maintaining the implant's long-term success. [2]

Primary stability sets the foundation for predictable secondary stability, which typically begins to improve around four weeks after implant placement. [11] This period, however, is also when implant stability tends to be at its lowest. Through the process of osseointegration, the initial mechanical stability is gradually enhanced or replaced by biological stability, with the overall implant stability ultimately being the combined result of both. Primary stability is essential for achieving successful osseointegration. [12] Research has shown that high primary stability minimizes the risk of micromovements and unfavorable tissue responses, such as the formation of fibrous tissue at the bone–implant interface during the healing and loading phases. [13]

Factors Affecting Implant Stability:

Implant stability is affected by various factors, including the quality and volume of the bone, the design and geometry of the implant—such as thread configuration and surface properties—and the surgical technique employed. [14,15] Among these, bone density is especially critical for attaining primary stability, as denser bone offers stronger mechanical support for implant anchorage. [3]

According to *Atsumi et al. (2007)*, several factors affect primary implant stability, including the quantity and quality of the bone, the surgical technique—particularly the surgeon's expertise—and the implant's characteristics such as geometry, length, diameter, and surface properties. Secondary stability, on the other hand, is influenced by the initial primary stability, the processes of bone modeling and remodeling, and the condition of the implant surface. [13]

The design, length, and diameter of an implant are key determinants of both primary and secondary stability. Implants with greater length and diameter typically offer enhanced primary stability, while specific design features can positively impact the biological integration during the healing phase. [7,16,17,18]

The density and quality of bone at the implant site are crucial for securing both primary and secondary stability. Higher bone density generally enhances primary stability, while the bone's biological response plays a significant role in the development of secondary stability. [7,18,19]

Surgical techniques, such as undersized drilling and the use of osteotomes, can improve primary stability by optimizing the implant's mechanical engagement with the bone. However, their influence on secondary stability remains less well understood and warrants further research. [20] Patient-related factors—including age, gender, and general health—also contribute to implant stability. These variables can affect the bone's capacity to heal and the biological mechanisms involved in establishing secondary stability. [17,18]

Measuring Implant Stability:

Traditionally, microscopic and histological analyses were considered the gold standard for evaluating implant stability. However, due to their invasive nature and associated ethical concerns, alternative, less invasive methods have been introduced. These include clinical assessment by the surgeon, radiographic evaluation, cutting torque resistance (for assessing primary stability), reverse torque testing, modal analysis, and the use of systems like Implatest®. [12] According to *Kittur et al. (2021)*, several techniques are commonly employed to assess implant stability, such as insertion torque, resonance frequency analysis (RFA), and Periotest. [21]

Insertion torque is a method used to evaluate primary stability by measuring the amount of force required to place the implant into the bone. [22]

Periotest® is designed to identify the damping capacity and the stiffness of the natural tooth or implant by measuring the contact time of an electronically driven and electronically monitored rod after percussing the test surface. While this method provides useful insights, it has notable limitations. It tends to be relatively insensitive to subtle changes in implant stability and is influenced by user technique. A major drawback is that the percussive force applied during testing may compromise the stability of implants with poor initial fixation. (23,24) Periotest values (PTVs) range from -8, indicating low mobility and high stability, to +50, indicating high mobility. A PTV between -8 and -6 is generally considered to reflect good implant stability. [23]

Resonance frequency analysis (RFA) is a non-invasive technique that measures the frequency at which an implant vibrates, providing an indication of its stability. [21]

Resonance frequency analysis (RFA) analysis: Osstell®: Introduced by *Meredith*, the RFA measures the stiffness of the bone/ implant interface is calculated from a resonance frequency as a reaction to oscillations exerted onto the implant/ bone system. The method analyzes the first resonance frequency of a small transducer attached to an implant fixture or abutment. The unit of measurement in this approach is the implant stability quotient (ISQ); and a high ISQ value indicates greater stability whereas a low value implies instability. The scale ranges from 1 to 100 and the acceptable stability range lies between 55-85 ISQ. [25]

Implant Mobility:

Implant mobility is a sign that a connective tissue capsule has formed around the implant. Clinical studies on osseointegration have shown that when mobility is present, the implant becomes sensitive to percussion or pressure. Over time, this mobility tends to increase, often necessitating the removal of the implant. [26] Implant mobility refers to the movement of the implant within the bone and is typically viewed as an indicator of implant failure or insufficient osseointegration. [1]

Measuring Implant Mobility:

The measurement of implant mobility is a specific clinical indicator, but it lacks sensitivity in detecting early loss of osseointegration. This parameter is more likely to identify the final stages of osseointegration failure, making it a sign of late-stage implant loss. [27] There is a strong demand for a simple, predictable, and non-invasive test to quantify implant stability and assess osseointegration. [28] Mobility can be evaluated using tools like Periotest and RFA, which provide objective measurements [29], radiographic analysis, which can detect pathological changes [30], and manual testing, where force is applied to the implant to assess movement. [24]

Difference Between Implant Mobility and Implant Stability:

Stability indicates the absence of movement, signaling successful osseointegration, while mobility points to implant failure caused by insufficient bone support or failed osseointegration. [31] Stability reflects the strong fixation of the implant within the bone, whereas mobility signifies a lack of this fixation. Stability is a positive sign of implant success, while mobility suggests possible complications with osseointegration. [1,3]

Conclusion:

Dental implant stability is a multifaceted concept crucial for the success of osseointegration. It involves both mechanical and biological factors, with primary stability being essential for initial implant success and secondary stability ensuring long-term integration. Understanding the factors affecting stability and employing accurate measurement techniques are vital for predicting implant success and addressing potential issues early.

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CITATION

Wael M. Zakaria. (2025). Implant Stability: Winning Approach to the Success Formula. In Global Journal of Research in Dental Sciences (Vol. 5, Number 2, pp. 34–37).
https://doi.org/10.5281/zenodo.15249049