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Primary Implant Stability: A Crucial Pillar in Implantology

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Abstract

A good implant integration and long-term favourable clinical outcome are positively correlated with a secure primary (mechanical) stability of the implant. Consequently, in order to guarantee a successful osseointegration, it is crucial to evaluate the initial stability at various time points. This review explores the importance of the primary and secondary implant stability and various tools and instruments to measure the primary implant stability, and also explains about factors affecting the implant primary stability. Dental implant design and its length, diameter, thread depth plays an important role in obtaining the primary implant stability.This review describes different ways to obtain primary stability in compromised bone such aslow density bone and regenerated bone.

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1. INTRODUCTION

The primary stability of the implant is a crucial component of effective osseointegration and a necessary precondition for immediate or early loading.[1] Primary implant stability is influenced by a number of variables, including the shape of the implant and the quantity and quality of bone (primarily the thickness of the cortical bone) and the surgical drilling method employed.[2] To alter and enhance the implant's primary stability, there are additional unique surgical implant preparation site techniques that are tailored to the type of bone.[3]

The absence of implant movement at the bone site after implant insertion is known as primary stability. Bone growth and remodelling at the implant-bone contact are necessary for secondary stability. Secondary stability has a positive connection with primary stability.[4]

During the implant placement process we can measure primary stability, a crucial need for initial loading, using the insertion torque tool (N/cm). This is a common and easy procedure that does not require any extra equipment as it is frequently used. Implant stability can be assessed, before implant rehabilitation and at various stages of the healing process using additional non-invasive techniques.

2. IMPORTANCE OF MEASURING PRIMARY STABILITY

1. Helps in immediate loading
2. Relationship with secondary stability
3. Correlate with bone tissue contact

Helps in immediate loading

There are three types of dental implant placement: immediate, delayed, and late. The duration between a tooth extraction and the implantation of a dental implant is indicated by each type.[5] Dental implants that are placed soon after a tooth is extracted are known as immediate placement implants. When there is enough bone volume at the extraction site and the implant can be stabilized, this treatment is typically carried out. Immediate implants are a dependable treatment option, as evidenced by their well-established and well-documented advantages, which include shorter recovery times, high patient satisfaction, comfort, and survival rates.[6]

Relationship between primary/mechanical stability and secondary/biological stability

It is critical to distinguish between primary stability and secondary stability, which is the outcome of the healing process. The secondary stability of implant-to-bone contact sites is dependent on a biological process known as osseointegration, while the primary stability is determined by suitable surgical anchoring techniques of the implants. Osseointegration, in which naturally occurring osteogenic processes create a new anatomical and physiological bone contact between the implant surfaces and the surrounding, pre-existing, and newly produced bone tissues.[7]

Following that, the level of secondary stability steadily rises over time, accelerating around 2.5 weeks after implantation, reaching a plateau level at roughly 5 or 6 weeks. It takes about 5-8 weeks to move from the first dominating primary stability phase to the final dominating secondary stability phase.[8]

Factors affecting implant primary stability[9]

1. Bone quality
2. Bone quantity
3. Surgical procedures
4. Implant design

Factors affecting implant secondary stability

1. Primary stability
2. Bone remodelling
3. Implant surface characteristics

3. TOOLS AND METHODS TO MEASURE IMPLANT PRIMARY AND SECONDARY STABILITY

Traditional clinical methods

- Percussion
- Two instruments
- Radiograph

Vibration analysis

- Periotest (damping effect)
- Resonance frequency analysis

Torque test

- Insertion torque
- Reverse torque

Resonance frequency analysis (RFA), percussion, radiography,insertion torque,reverse torqueand vibration in the sonic and ultrasonic bands are techniques used to evaluate the stability of the implant. The majority of research opposes the isolated use of a single technique to evaluate the stability of an implant. Da Cunha et al. and Degidi et al. state that the most effective, dependable, indicated, and widely used techniques for evaluating implant stability are RFA and insertion torque.[10,11]

Insertion Torque

Johansson and Strid developed the concept of insertion torque, which Frieberg refined in the 1990s. A torque wrench is used to apply the insertion torque, according toBaldi et al.and it represents the amount of frictional resistance the implant experiences when rotating on its axis to advance apically. As a result, this approach provides data regarding implant primary stability and bone quality at the implant placement site.[12]

RFA

Meredith established the RFA in the latter part of the 1990s. Implant micro-deflection quantitative measurement forms the foundation of the RFA technique. According to Herrero-Climent et al., the RFA is a non-invasive diagnostic method that makes use of a piezoelectric transducer to cause implant vibration by emitting a sinusoidal signal at a particular frequency.The instrument measures the implants resistance to vibration, converting it into an implant stability quotient (ISQ) on a scale from 0 to 100, where 100 represents the maximum implant stability. RFA has been utilized in clinical settings to evaluate the initial stability and long-term stability of implants.As a result, the RFA makes it possible to assess and determine an implants failure risk before it happens.[13]

There are multiple techniques for evaluating the primary stability of an implant. There are two types of methods that they fall into: invasive and non-invasive. It is a reliable indicator of the primary stability of the implant since it provides an estimate of the rotational friction of the device. The resonance frequency of the implant-bone complex at the time of implant placement is the main focus of RFA. This approach might be expensive and skill-dependent.[14,15]

A transducer is positioned in the buccolingual direction of the implant to monitor the device's frequency response. With a maximum amplitude of 1 V, the resonant sign is calibrated at frequencies between 5 and 15 kHz, and the initial flexural resonant frequency is noted.[16]

4. INFLUENCE OF IMPLANT DESIGN ON PRIMARY STABILITY

Implant body

An important area of implantology is the impact of the implant body form on primary stability.[17]Cylindrical implants provide static friction to the base of the implantalong the implant axis, tapered implants are largely anchored by the lateral and the vertical bone compression.[18] One possible explanation for the greater primary stability of tapered implants may be related to the lateral compressive pressures that they apply to the cortical bone.[19] Selecting conical implant systems with low thread helix angleanddouble threads is recommended because immediate implant placement necessitates good primary stability.[20]

Implant length, diameter and depth

Numerous in vivo parameters, including bone structure, instrument location, implant surface changes, implant diameter, and implant length, have been shown to affect implant stability in various investigations.[21] Research has demonstrated a relationship between implant longevity and length over various periods. This could, therefore, suggest that when longer lengths are utilized, invasive bone augmentation operations are required.[22]

Milan Stoilov et al. research investigated how primary stability in various bone qualities was impacted by the form, length, and diameter of implants. The results showed that, in actual practice, the drilling protocol needs to be modified according to various bone characteristics. The effect of these modified methods on implant outcomes has to be further studied.[23]

Ali Tareef Noaman et al. assessed the relationship between implant dimensions and implant stability characteristics, namely the resonance frequency analysis and the insertion torque (IT) value, in connection to the bone density value in the Hounsfield unit obtained from cone beam computed tomography (CBCT).There was no significant link found between the IT (Insertion Torque) and the Implant dimensions. One dependable technique for determining implant stability and bone density is cone beam computed tomography. While implant length had no effect on implant stability, implant diameter had a positive impact.[24]

Juan Manuel et al. showed that when it comes to length, 10mm implants have higher ISQ values than 11.5mm implants over time and larger stability values at three months after implant insertion, according to resonance-frequency research carried out at various intervals.[25]

Thread depth

In the beginning, threaded implants were created to provide more cortical bone compression at locations with low bone quality.[26] The ratio of the implant's exterior shape to its main body determines the thread depth. It shows the separation between the coils and the implant's main body. The surface and the load distribution increase with increasing distance.[27] Due to the larger functional surface and enhanced primary stability in conditions with softer bone and high occlusal stresses, greater thread depths may be beneficial. However, deeper threads may also make insertion accuracy less accurate.[28]

An implant's functional surface increases with the number of threads and depth of threads.[29] Research has indicated that implants including a progressive thread exhibit superior primary stability and a greater bone-implant contact area both histomorphologically and radiologically when compared to cylindrical ones.[30]

Implant roughness

Better implant surface qualities promote more rapid and stronger bone growth, which may provide more stability as the wound heals. In this regard, surface roughness and bone-to-implant correlation are positively correlated.[31] Creating a more osteophytic surface that draws bone-forming cells is undoubtedly the ultimate aim of implant surface modification.[32] According to Sennerby and Meredith Et al.[33] surface structure and implant design may affect the stability of the implant during its early healing phase.

5. TECHNIQUES TO IMPROVE PRIMARY STABILITY

One of the simplest and most effective approaches to improve primary stability seems to be under-preparing the implant site.[34] There have also been other approaches to increase implant stability, such as changing the implant's shape from conical to tapered demonstrated to be effective for boosting implant stability.[35]

Osseodensification

Osseodensification is a biomechanical technique for osteotomy preparation that is intended to replace the traditional bone subtractive drilling and improve the implant site's overall quality. It aims to cause a compressive movement at the site where an osseous drill and a specially designed bur called a Densah bur come into contact, causing controlled osseous deformation.

This procedure can increase the implant's primary and secondary stability as well as the percentage of bone-implant contact (BIC) by up to three times when compared to the traditional subtractive drilling technique. The preservation of bone volume, quicker healing since the bone matrix is protected, and regular replacement of the autogenous bone graft matrix along the implant surface are the primary advantages of this technique.

Mechanism of action

The bur presses anticlockwise rotation held autogenous bone fragments both laterally and apically. In the osteotomy, this autogenous compacted graft provides extra mechanical main stability against the implant, and can further serve as a nucleating agent to promote the formation of new bone around the implant. This enhances the overall stability of the implant during the initial healing phase.[36]

A creative method was used in a new osseodensification strategy developed by Rodda et al. that made use of Densah burs, which have several grooves and a diameter that increases counterclockwise. This design was purposefully created to maximize implant site preparation while also increasing implant stability after insertion. The unique aspect of this technique is the burs' counterclockwise rotation, which shows the compaction of autogenous bone at the apical extremity. This fascinating theory opens the door to a gradual raising of the sinus membrane, making this method very useful for sinus lifts. Surprisingly, the use of osseodensification in this situation eliminates the need for graft materials after sinus augmentation, making it a minimally invasive technique with potentially beneficial clinical outcomes.[37]

Implant insertion in the maxillary and mandibular bone

It was suggested that in low-density bones, the osseodensification process increased IT from 25 Ncm for implants placed by the conventional drilling approach to 49 Ncm. If the osseodensified osteotomy site stays unfilled, its diameter will be reduced by 91%. Mostly, this was attributed to the viscoelasticity, or the bone's ability to bounce back, which is thought to be responsible for the compressive load that the implant is subjected to.[38]

When placing implants in the maxillary arches, osseodensification may be particularly beneficial due to the abundance of cancellous bone in these areas. Given the lack of information about the mandibular area, it ought to be used to take caution in areas of bone that are mostly cortical or denser, like the anteriormandible. Additionally, it has been noted that osseodensification drills can increase warmth and, if not used in conjunction with frequent watering, could damage surrounding bone tissue.[39]

6. IMPLANTS PLACED IN NATIVE AND REGENERATED BONE

Implants inserted into native bone demonstrated greater primary and secondary implant stability compared to those placed in regenerated bone. Greater ISQ values were obtained by D1–D2 bone, indicating that primary implant stability is influenced by the quality of the bone at the implant site.

Additionally, Deli et al. 2014 found that implants inserted into regenerated bone had higher ISQ values than implants inserted in non-regenerated bone, but only after the regenerated bone had healed for a minimum of 12 months. They compared implants placed in native bone and regenerated bone, allowing for a 6-month healing period. The results showed that the ISQ values of the regenerated bone implants were lower than those of the native bone implants, but they were still high enough to initiate prosthetic loading.[40]

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