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"Factors Influencing the Primary Success of Implant Stability in Dental Practice" - A Review of Literature

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Abstract
The use of dental implants has become widespread and a predictable treatment modality for the restoration of missing teeth. Success of implant dentistry depends on stability of the implant, whether biological or mechanical. Stability are often classified into two types: Primary and secondary stability. Many factors influence primary and secondary stability of the implants which include implant design, implant surface topography, bone quality and patient related factors. Hence it's essential to understand the multitude of things that persuade the implant stability and to research the results of implant therapy. Measurement of implant stability could also be a valuable tool for creating decisions concerning treatment protocol and it also improves dentist patient communication.
KEYWORDS*: Primary implant stability, Secondary implant stability, Bone density, Implant design, Insertion torque, Resonance frequency analysis*

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I. Introduction

Implant stability is significant for osseointegration without it, long-term success cannot be achieved. Continuous monitoring during a quantitative and objective manner is significant to figure out the status of implant stability. Stability of any implant is often classified into two types as follows: primary stability that's measured immediately after implant placement, secondary stability which is measured after the healing of bone around the implant. Primary stability could also be a natural phenomenon that happens because of interlocking of bone to implant immediately after implant placement, whereas secondary stability occurs through a cascade of events, like bone deposition and remodeling at the bone implant interface. Various methods are developed to assess implant stability like Histological Analysis, Radiographs, Percussion test, Reverse torque test, Cutting Torque Resistance Analysis, Periotest, and Resonance Frequency Analysis (RFA) () device. Primary stability comes with old bone. Secondary stability comes with new bone

II. Biological Stability

The gradual shift from primary to biological stability is poised at around three weeks , this is often seen by littlest amount stable time point where viscoelastic , stress relaxation of the bone, in conjunction with remodelling results in the loss of primary stability. While secondary stability is that the progressive increase in stability associated with biologic events at the bone to implant interface like new bone formation and remodelling, it's absent at the time of implant placement and increases with time.

III. Bone Quality And Quantity

Bone density could also be a serious determinant of implant stability measurement. Immediate correlation exists between bone density and implant stability values. Implant stability is higher within the denser bone of mandible than in maxilla. Poor bone quality and quantity are the maximum risk factors for implant failure. RFA could also be a useful clinical method to predict bone implant contact% values and RFA is used to seem at implant stability which further predicts the degree of osseointegration. Higher stability was recorded in type 2 than in type 4 bone by Kashi et al. In 2015. Implants with a progressive thread design placed at 11° angulation had higher primary stability than other implant angulations. Placement of tapered implant design using tapered drills resulted in higher primary implant stability than control implants that were placed using subtle taper and straight drills suggesting the impact of drilling protocols on primary stability in several bone densities. There was a statistically significant increase in implant stability and bone density values during the 6th month observation period suggesting a correlation between bone density estimated by cone beam computed tomography and stability of dental implants estimated by resonance frequency device osstell ISQ.

Methods to Guage Implant Stability

Stability are often evaluated by Histological analysis, Radiographic analysis, Percussion test, Periotest, RFA, Insertion torque, Cutting torque resistance, Reverse torque test, Ultrasonic wave propagation, Finite element analysis

Radiographic analysis

It was one of the first methods applied to guage the condition of implants when they had been placed. Radiographic evaluation could also be a non invasive method which can be performed at any stage of healing process. Bitewing radiographs were used to measure crestal bone level, defined as distance from the absolute crest of the bone to the position of bone on the implant surface, because it has been suggested as an indicator of implant success. However other studies recommended that the resolution of bitewing radiographs cannot be used because the sole tool to guage either primary or secondary stability. Moreover crestal bone changes are often only reliably measured if there is no distortion within the radiographic pictures.

Push out/ Pull out test

In a typical pushout or pull out test, a cylinder type implant is placed transcortically or intramedullarly in bone and then removed by applying a force parallel to the interface. The utmost load capability is defined because of the force displacement. However the pushout and pull out tests are only applicable for cylinder type implants, whereas most of clinically available fixtures are of threaded design

Percussion test

The percussion test may involve the tapping of a mirror handle against the implant carrier and is supposed to elicit a ringing sound or crystal sound from the implant as a symbol of fantastic stability or osseointegration. Dull sound means weak or failing osseointegration. However, this method could even be subjective according to the examiner and will give inaccurate measurements for implants thanks to the high rigidity of implants and thus the shortage of periodontal ligaments that results in displaying digitally and audibly as Periotest values (PTVs) on a scale of –8 (low mobility) to 50 (high mobility).

Peak Insertion Torque (Peak IT)

The Insertion Torque used during placement of implants was measured through a surgical handpiece it is often use to predict implant survival and to estimate healing time. However, this method is nonsubjective, noninvasive, and extensively utilized in clinical practice during implant placement to assess primary stability. Peak IT gives us a static measurement, which is taken at one occasion, while force that's required for each and every thread of the implant to travel through the bone will not be at an equivalent torque. Thus, it allows only one measurement at implant insertion and will not be used for evaluating secondary stability. Insertion Torque only assesses condition at the time of implant placement.

Cutting Torque Resistance Analysis (CRA)

This method was originally developed in 1994 by Johansson and Strid and later improved in vitro and in vivo models. This method works on the principle that the energy required in isolating a unit volume of bone during implant surgery is measured. This energy has been shown to be significantly correlated with bone density, which has been suggested as a factor that significantly influences implant stability. The benefits of this method are detecting bone density and quality during surgery. The main limitation of CRA is that it doesn't give any information on bone quality until the osteotomy site is prepared.

Reverse Torque Test (RTT)

It was proposed in 1984 by Roberts et al, measures the critical torque threshold when bone implant contact is broken. This indirectly provides information on the degree of bone implant contact during a given implant.

Histological Analysis

It quantitatively assesses the bone contact and bone area within threads. This system generally requires a light-weight microscope with microvid computers. Ultra structural studies are mostly performed on the decalcified specimens sectioned for transmission microscopy. But thanks to invasive nature of this system its use has only limited to non clinical and experiments studies.

Ultrasonic Wave Propagation

An alternative method to assess implant stability is quantitative ultrasound as suggested by De Almeida et al. They used implant as a wave guide and showed a huge correlation between the experimental 1MHz ultrasonic responses of an aluminum threaded piece and thus the screwing depth in an aluminum block. They concluded that ultrasonic waves are sensitive to bone implant interface properties.

Periotest

Periotest was originally a musical instrument designed to perform quantitative measurements of the damping characteristics of the periodontal ligament surrounding a tooth, thereby establishing a worth for its mobility. The outcome of Periotest measurements is influenced by the space from the striking point to the primary bone contact, it's evident that placement of the implant within the vertical dimension, abutment height, the extent of marginal bone loss, and therefore the striking position on the abutment/implant are critical factors for accuracy and/or reproducibility. Single readings of Periotest determinations are of limited clinical value and haven't been demonstrated to reflect on the character of the bone/implant interface. By performing repeated measurements of an equivalent implant over time, implant stability could also be confirmed.

Resonance Frequency Analysis (RFA)

RFA measures the stableness by application of a bending load, which mimics the clinical load and direction and provides information about the stiffness of the implant-bone junction. It evaluates the micromobility or displacement of the implant in bone under a lateral load, applying microscopic lateral forces to the implant with a vibrating transducer. The first commercial version of the RFA technique stated by Osstellt, Goteborg, V Stergtland and Bohusl, Sweden. The results are given as implant stability quotients (ISQs), which are affected by three main factors: 1)The stiffness of the implant fixture2) The interface with surrounding tissue 3) The design of the transducer and thus the entire effective implant length above bone level. The stiffer the interface between the bone and implant, the upper the frequency and better the frequency, higher is that the ISQ level. The ISQ unit is predicated on the underlying RF and ranges from 1 (lowest stability) to 100 (highest stability). Literature states that an implant can tolerate a degree of micromotion, thought to be 100-150, and this is often what ISQ measures. The RFA values are still not definitive as no actual threshold value has been established to differentiate a stable, integrated implant from a failing/failed implant however, it's been suggested that an ISQ value above 57 at 1 year after loading represents a successful implant outcome while a worth below 50 indicates a risk of implant failure. There is a scarcity of correlation between IT and thus the ISQ as measured by RFA in an implant that's driven in at 30 ncm and has the same ISQ, because the one that required 100 ncm of torque. Although extensively utilized in clinical research together parameter to observe implant stability. It's to be realized that RFA is affected by factors like bone tissue characteristics and implant sink depth, diameter, and surface characteristics. Research indicates that implants yielding high ISQ values during follow-up appear to require care of stability. Low or decreasing ISQ values could even be indicative of developing instability. However, no established normative range of ISQ values is out there thus far. The destructive methodologies, like removal torque assessment and pullout and pushout techniques are generally used only in preclinical applications. While these methods could even be useful as research techniques, they're of limited value in clinical use thanks to ethical concerns related to the invasive nature of such methodology.

IV. Implant Design

Implant design modifications over the implants also influenced implant stability values. Cylindrical wide body and parallel design implants were replaced by tapered implants to strengthen esthetics, assist implant placement between adjacent teeth and to provide a degree of compression of cortical bone in an implant site with inadequate bone. Retention grooves at the neck design or microthreads assist in distributing stress, reducing the extent of bone loss and thereby preserving the crestal bone through time of the function. Thread design decreases compression of crestal bone and preserves it. Implant stability was influenced by implant design and bone level. Reasons for top primary stability could be attributed to implant features like those implants with a body that features a conical shape because it matches the drill thereby ensuring primary fixing rather cylindrical shape. Symmetrical, spiral shaped thread design, and microrings at the cervical a neighborhood of implant are preferred because it enhances contact with surrounding cortical plate. Threads at various levels of height on implant surface that allows greater secondary implant stabilities even in soft bone by preventing further bone resorption. During a study conducted by Markovi et al., self tapping implants did achieve significantly higher primary stability compared to non-self tapping implants. this could be explained by the intimate bone to implant contact resulting from the compressive threads and thus the minute lateral displacement exerted on bone tissue during implant insertion, whereby loose bone trabeculae are pushed closer together. Thus, local bone contained within the pitch regions (between two adjacent implant threads) becomes denser. By improving the characteristics of the local bone in these regions (the bone responsible for primary stability) the implant receives firmer support consequently resulting in increased primary stability. Regarding primary implant stability measurements, data retrieved from the available literature indicates a far better RFA exhibition in conical implants compared to the cylindrical ones. Contradictory results to the results of those studies, however, have also been reported. During a study conducted by Brouwers et al. (2009) cylindrical implants exhibited a better RFA compared to tapered implants. Similarly, Bilhan et al. (2010) observed superiority of cylindrical implants. Consistent with the authors, this superiority was associated with the various mechanical engagement achieved by these two different implant macro designs. Tapered implants don't use the apical half drilled bone for stability just like the cylindrical implants and therefore the stability obtained from tapered implants is all at the cervical part which will create a risk for loosening within the apical part (Bilhan et al., 2010). Despite the controversy over the effectiveness of various implant designs in implant stability, the prevalence of tapered implants in specific clinical applications has been well emphasized by Markovic et al. Another clinical advantage of this implant is that it are often placed altogether regions where the location of a daily diameter implant is planned and with none risks of damaging the roots of neighboring teeth. With the utilization of this implant, there's also an opportunity of decreasing the horizontal defect dimension between the implant and bone, although complete elimination of the vertical/horizontal alveolus defect buccolingually appears impossible for all sort of implants test.

Implant Surface Characteristics

Various surface modifications are attempted for enhancing osseointegration of dental implants like chemical treatments and deposition of phosphate coatings with fluoride and zinc ions. Characteristics of titanium implant surfaces are modified by additive methods like titanium plasma spraying to vary macro-topography and subtractive methods like blasting and acid etching to vary the micro-topography. Four categories of bioactive agents could also be applied to coat the titanium implant surface, namely, (1) biocompatible ceramics, (2) bioactive proteins and growth factors like Bone morphogenic proteins, transforming growth factor , fibroblast protein (FGF) 2, platelet derived protein , insulin like protein , arginylglycylaspartic acid peptides, (3) ions, and (4) polymers. A bioactive surface forms a favorable substrate for the osseous deposition to occur and actively participates within the osseointegration process thanks to the reaction between the chemically modified surface coating and surrounding bone. The feel of an implant surface, surface roughness and surface energy can influence bone to implant interface and mechanical stability. The altering surface topography of an implant enhances implant stability. Surface modified, oxidized, sandblasted implants showed greater stability than machined implants. Rough implant surfaces present a bigger area thereby allowing firmer mechanical link to surrounding tissues. Acid etched and sandblasted implant surface promotes long lasting osseointegration, optimizes tissue response and stimulates early bone deposition. Studies have demonstrated that sandblasted implant surfaces promote peri-implant osteogenesis by enhancing growth and metabolic activity of osteoblasts. Surface topography and roughness like sandblasting and acid etching positively influence the healing process by promoting cellular response and cell surface interactions. Implant surface coatings also influence primary stability just like the oxide layer of thickness and anodized surface are active throughout the implant enhances active bone growth that quickly promotes mechanical (primary) stability. This multilayer surface allows bony tissue to grow deeper and in between micropores. Microporous structure grows through the whole thickness of the oxide layer. titanium dioxide film is enriched with calcium hydroxyapatite (HA) that enhances cell viability, cellular, and tissue response that benefits osseointegration. Jung et al. evaluated the secondary stability of micro thickness HA coated, tapered implants without measuring primary stability. Sul et al. conducted an experimental study to research whether oxide properties of titanium implants influenced bone tissue responses after an in vivo implantation time of 6 weeks and to research which oxide properties are involved in such bone tissue responses. Implants that had an oxide thickness of roughly 600, 800, and 1000 nm demonstrated significantly stronger bone responses within the evaluation of removal torque values than did implants that had an oxide thickness of roughly 17 and 200 nm. However, there was no difference between implants with oxide thicknesses of 17 and 200 nm. it had been concluded that oxide properties of titanium implants, which include oxide thickness, micropore configurations and crystal structures greatly influence the bone tissue response within the evaluation of removal torque values. Pimentel Lopes de Oliveira et al. conducted a randomized controlled clinical split mouth trial to match anodized implant surfaces and implant surfaces modified by acid etching regarding primary and secondary stability. ISQ analysis revealed that the acid etched (AC) group showed statistically higher values than the anodized (ANO) group. Nagayasu Tanaka et al. conducted a study was to examine the effect of basic FGF 2 on the osseointegration of dental implants with low primary stability. This study demonstrates that FGF 2 promoted new bone formation round the dental implants and subsequent osseointegration, leading to promotion of the steadiness of implants with low primary stability. Implant length and diameter also influence implant stability. Longer implants showed higher stability than shorter implants. Higher stability with increased implant diameter and reduced stability in smaller size diameter implants are often attributed to the very fact that within the coronal part there's less friction during insertion. The connection between implant diameter and ISQ values has been well emphasized though in previous studies (Zix et al., 2005). Many authors advocate that since wider implants are more appropriately engaged with buccal and lingual cortical plates and offer a bigger surface for osseointegration, they ought to exhibit more primary and secondary stability. The broader implants aren't always, the more stable ones. Although narrow platform (NP) implants demonstrated the smallest amount in terms of implant primary stability

V. Surgical Technique

Some surgical techniques for implant site preparation are advocated that influences implant primary and secondary stability values. The variability of techniques for implant placement are: (1) undersized drilling technique, (2) Osteotomy technique, (3) Piezoelectric bone surgery, (4) flapless implant placement, and (5) Osseo densification using Densah burs. The undersized drilling surgical technique increases lateral compression during insertion resulting in higher stability. Modification of conventional techniques just like the utilization of small final drill diameter and bone condensing techniques increased the implant stability. Despite the increasing research in recent years, so far there has been little investigation into the influence of implant bed preparation techniques on RFA values. Quesada Garc et al. (2012) compared ISQ for implants placed in beds prepared according to the bone condensing or the bone drilling technique, with or without irrigation. The more commonly used technique for implant placement is that the traditional bone drilling one. However, some authors have suggested superior outcomes following a bone condensation technique where the bony walls of the implantation site are progressively condensed to catch au courant a lower bone quality when needed (Markovi et al., 2013). Data reported by Markovi et al. (2013), indicate that compared to bone drilling technique, bone condensing technique significantly increased primary implant stability in rarity bone regardless of the macro design of the implant used. This increased stability could be thanks to changes within the micro morphology of peri-implant trabecular bone caused by apicolateral condensation. Stacchi conducted a study to longitudinally monitor changes in implant stability using different site preparation techniques: twist drills versus piezosurgery during the first 90 days of healing. Ultrasonic implant site preparation resulted during a limited decrease of ISQ values and in an early shifting from a decreasing to increasing implant stability, as compared to the traditional drilling technique. Krafft T et al (2013) evaluated the efficacies in using osteotomes for implant bed preparation, their effect on material properties of bone and first implant stability as compared to plain implant bed preparation using burs. Use of osteotomes led to higher implant stability values for all the parameters studied except in trabecular bone. Dos Santos et al. (2009) conducted an investigation to assess the influence of design and surface morphology on the first stability of implants. The insertion torque and RFA were used to measure the primary stability as an indicator of osseointegration in an immediate/early loading protocol. Ostman et al. conducted a study to guage primary stability by RFA and correlate its measurements with surgical technique, implant design and patient and conducted a study to match the stableness of dental implants inserted during a 1 stage protocol with or without platelet rich fibrin (PRF). Therapeutic applications of PRF led to faster titanium implant osseointegration, which improves implant stability. Al Juboori conducted a study to match the results of the flapless (FL) and full thickness flap techniques on implant stability. Therefore, the study proves that periosteum preservation during the FL procedure will speed up bone remodeling and end in early secondary implant stability also as early loading. Osseo densification introduced by Salah Huwais 2013, a totally unique surgical technique that creates an autograft layer of condensed bone at the periphery of the implant bed by the assistance of specially designed burs rotating during a clockwise and anticlockwise direction. Osseo densification burs are designed to work during a non subtractive manner, add a non cutting mode because of negative rake angle then expand the osteotomy and smoothly compacting bone within the periphery. Podaropoulos osseodensification could also be a replacement promising procedure for enhancing bone density around dental implants and increase primary stability since the achievement of primary stability is of utmost importance for osseointegration. Trisi et al. evaluated the efficacy of osseodensification technique and stated that this procedure enhances bone density, ridge width, and implant secondary stability. Lahens et al. assessed the effect of osseodensification method on initial stability and early osseointegration of endosteal implants with conical or parallel wall design. He stated that higher primary implant stability values for osseodensification were observed relative to regular drilling technique regardless of implant geometry. Bone to implant contact ratio was also higher when osseodensification technique was used than regular drilling techniques. This could be attributed to densification of autologous bone debris at the bone walls.

VI. TIME

A robust correlation exists between implant stability and time as a function of an increased stiffness resulting from new bone formation and remodeling. The increase or decrease in implant stability is often extrapolated to the changes occurring at the bone implant interface during the primary healing phase. Within the initial bone remodeling phase, bone, and necrotic material are resorbed by osteoclastic activity, which is reflected by a reduction in ISQ value. After this, phase new bone apposition is initiated by osteoblastic cells.

One stage and immediately loaded implants have demonstrated an initial decrease of implant stability which reverses after three months because of healing and remodeling process of bone healing.

VII. Conclusion

This literature review highlights the importance of the numerous factors influencing both primary and secondary stability. Successful implant integration is vital for achieving triumphant primary stability. Bone quality and quantity, implant geometry, and surgical technique adopted may significantly influence implant initial stability and overall success rate of dental implants. The extent of implant stability also can depend on things of the encircling tissues. Impaired primary implant stability has been shown to jeopardize the osseointegration process. Although there are many techniques to measure implant stability that are extensively utilized in clinical research for the past many years . Nonetheless, from available literature, there's still a scarcity of precise information on the correlation between implant stability values and thus the short and future implant outcomes. Different authors have attempted to work out thresholds for primary and secondary stability and highlighted the factors influencing to predict higher risks for implant failure. Only repeated measurements over an extended period would have clinical significance and prognostic value.

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