Primary stability of dental implant: a review

Alhassan Mohammed Ajeebi¹,²*, Shahad Ahmed Alquraishi³

ABSTRACT

Dental implant is considered to be one of the most successful methods for teeth replacement and needs stability for achieving a successful implant such as the primary stability that comes after implant placement and considered as a gold standard for a successful implant. The present review aimed to outline the essential factors impacting the primary stability of dental implants and to show the impact of varied surface treatments on titanium dental implants. The implant stability was measured according to the periotest values and implant stability quotient of Osstell’s resonance frequency analysis. The primary stabilization of implants is negatively affected by the presence of guided bone regeneration. The geometrical factors of implants, such as shape, length, and diameter, may impact the primary implant stability. Furthermore, increasing the length and diameter of the implant had significantly increased the primary stability. Therefore, in the cases of low bone quality, it is advisable to avoid using narrow platform implants, and it is preferred to do different guided bone regeneration techniques according to pre-surgical evaluation as well as to the surgical situation that played a crucial role in the stability of the primary implant, for example, osteotome technique, piezoelectric surgery, low-level laser therapy, and flapless procedure. Osteoporosis, diabetes mellitus, and smoking are considered as questionable aspects of dental implant placement.

Keywords: Dental implant, primary stability, resonance frequency analysis (RFA).

Introduction

Treatment with dental implants is considered as a routine procedure for replacing the non-restorable or missing teeth and restoring the function and esthetics desires [1]. The implant stability could enhance dental implants’ osseointegration [2], and it could be classified into two definite types. The first type is the stability that obtained a biomechanical property after implant installation to the bone. It results in the absence of implant mobility and affected by various agents such as the quality and quantity of the bone, implant dimensions, features of the design, surgical technique [3], and insertion torque. The second type is the stability that is a biologic action of the bone in the form of regeneration and remodeling around the implant. It is affected by the duration of the wound healing and surface of the implant [4]. The primary stability is a phenomenon that occurred through the overlapping of bone to implant instantly after implant placement [5].

Evaluation of Implant Stability

Several methods were developed for pre-operative bone density analysis to assess implant stability. These approaches are radiographic assessment and the resistance at drilling during preparing the implant site [6]. A cone-beam computerized tomography has been used as a reliable method for analyzing the bone quality and quantity for implant planning. Moreover, it has a higher degree of predictability [7]. On the other hand, different procedures have also been established to assess the post-operative implant stability, such as radiographic, percussion, periotest (Siemens AG, Bensheim, Germany), and measurement of insertion and cutting torque [6]. Radiographic examination of the implant reflects any crestal bone changes around the implant. The percussion test is the easiest and simplest method to evaluate implant stability. Using metal instruments for percussion
generates either sharp ringing indicating stable implant or dull unclear sound indicating the loss of stability [8]. The periotest comes up with a metallic rod that could be generated electromagnetically and stimulates signals that could change into periotest values (PTVs), which ranged from almost (−8) to (+50), and the stability of implant increased by decreasing the value of PTV [9]. PTV could be measured through a perpendicular position of the instrument tip toward the implant transfer axis, by the calculation of three measurements/implant [10]. Besides, resonance frequency analysis (RFA) of the Ostell is an accurate, easy, and non-invasiveness technique, so it was used for assessing the primary stability [11]. Furthermore, the resonance frequency was used to measure the implant–bone interface through a reaction, in which oscillations were extended to the implant, and the implant stability quotient (ISQ) was used to express the results [10]. By using a torque application device OsseoCare, the implant was seated in its position through an initial torque (in Ncm) [12]. This procedure is non-subjective and was used for assessing the primary stability in most of the clinical practices [13]. Therefore, an advanced version of devices would apply, such as Penguin, which appeared as a rod-like structure that makes the device usage simpler but without any significant difference in the obtained ISQ values using the Ostell’s device.

Effect of Volume and Bone Density on the Primary Stability

Bone density was used for the prediction of dental implants’ outcome, in addition to its role in the stability of the primary implants [12]. An implant stability was impacted by the quantity and quality of the bone, maturity, and mineral density [14]. Hence, the mandible was found to have higher survival rates for dental implants than the maxilla due to the differentiation in the quality of the bone [15]. The bone was divided into four categories according to the trabecular bone and cortical characteristics: D1—the cortical bone is dense, D2—the cortical and coarse trabecular bone are porous, D3—the cortical are thin and porous, and the trabecular bone is fine, and D4—the trabecular bone is fine [16]. It was found that the ISQ values in D1 type are significantly more than those in bone D3 [17].

Implant Dimensions and Design

Dental implant length is approximately ranged from 6 to 20 mm, and the length of the natural root is ranged from 8 to 15 mm, which considers the natural length of the implant [18]. In the case of Type IV bone that has poor quality, it is very important to increase the length of the implant to increase the stability of the implant [19]. Bataineh et al. [20] found that the value of ISQ increased to 73.47 if the length of the implant increased to 15 mm. O’Sullivan et al. conducted a study to analyze how to taper implant influenced on titanium implants’ primary stability. It was found that a good primary stability was resulted due to taper implant. Besides, the tissues of the bone did not influence by the tapered design [21].

Another study was conducted by Garcia-Vives et al. [22]. They investigated the relationship between implants’ primary stability and different length of the implant (7, 8.5, 10, 11.5, 13, 15, and 18 mm). They demonstrated that increasing the length of the implant from 8.5 to 10 mm increased the primary stability. Moreover, at the length of the implant ranged from 10 to 13 mm, the primary stability was not changed, whereas at the length of 15 and 18 mm, the primary stability decreased in comparison with a length of 13 mm of the implant. This might be attributed that they generated more heat while drilling due to their longer length. Regarding the implant diameter and how it is correlated with primary stability was shown that the analysis of the experimental data of narrow platform implants resulted in significantly lower ISQs compared to wide implants. Therefore, at low bone quality, it is advisable to avoid using narrow platform implants, and it is preferred to do different guided bone regeneration techniques according to pre-surgical evaluation as well as to surgical situation. Basically, using the narrow platform implants must be restricted to the frontal of the mandible, where implants are imposed on mild occlusal force [23]. Regarding dental implant shape, the overall meta-analysis did not find significant differences in the values of ISQ between parallel-walled dental implants and tapered during placement of the implant. Some reviews revealed that peaked dental implants possess a greater insertion torque during placement. However, the difference was not statistically significant [24]. Staedt et al. [25] concluded that the greatest primary stability was found in conical double-peaked implants in comparison with other designs according to the measurement by an Ostell® device. This was achieved by conical implants inserted at 40 Ncm and cylindrical implants inserted at 30 Ncm. Still, this is considered limited evidence for supporting the effectiveness of tapered dental implants to obtain a greater stability of the implant over parallel-walled dental implants [26]. In general, an optimum increase of implants’ length and diameter should be seriously considered to accomplish greater primary stability of implants fixed in low bone quality [23].

Surgical Technique

It was used to enhance the primary stability of the implant, for example, the undersized surgical preparation, osteotome technique, piezoelectric surgery, low-level laser therapy, and flapless procedure. Bone with low density used the undersized drilling technique as a conventional surgical preparation, which used a small drill diameter that will reach an osteocompression between the bone bed and the surface of the implant [27]. Lahens et al. [28] assessed the impact of osseodensification method on the primary stability, and they recorded that higher primary implant stability values for osseodensification were shown with the regular drilling technique of
implant geometry. Marković et al. [29] also stated that the techniques of the bone significantly increased the primary stability of the implant in the bone of poor density. Besides, piezoelectric bone surgery was applied by utilizing an ultrasonic surgical system [30]. It was believed that the piezoelectric surgery is superior to the conventional technique through decreasing the damaging of blood vessels and nerves and also improving the precision that led to enhancing the visibility with the lack of overheating [31]. It was found that there is no significant difference in primary stability between using a conventional twist drill or piezoelectric technique [32]. Irradiation of laser light was found to possess a biostimulatory impact on the synthesis of collagen, proliferation of fibroblast, and healing of the wound. Besides, the irradiated bone with infrared wavelengths revealed increment of proliferation, the formation of the bone, and deposition of collagen in comparison with non-irradiated bone. On the contrary, irradiated bone osteotomies with infrared wavelengths did not have any effect on the stability of the primary implant [33]. Delgado-Ruiz et al. [10] found a more contact to the implant for osseodensification; this confirmed the result of Slete et al. [34].

Medical Conditions

It is very important before the treatment to assess the medical history of patients who might have previous diseases. Osteoporosis, diabetes mellitus, and smoking are considered as questionable aspects of dental implant placement. Osteoporosis was the most common disease known with low bone mass and increasing bone fragility and increases the risk of fracture [35]. The recent studies found that there are no contraindications for using dental implants with osteoporosis cases [36]. The primary stability of the implants has a crucial role in implant integration [37]. Implant primary stability was greatly affected by the density of the bone, whereas the length and diameter of the implant did not have any effect on the stability of the implant, according to RFA [38]. On the other hand, the width and spacing of threads had a significant impact on implant stability. Merheb et al. [39] carried out a study among osteoporotic and osteopenia patients for assessing the effect of bone density and the skeleton on the stability of an implant using RFA. It was reported that the mean of ISQ in the osteoporotic group is low (63.3 ± 10.3) in comparison with the osteopenia group (65.3 ± 7.5), whereas the control group had the highest mean ISQ (66.7 ± 8.7) without any significant difference among all groups. Although bisphosphonate drug has been used for treating osteoporosis [40], it had a harmful effect on wound healing by decreasing the expression of collagen. Besides, it leads to bisphosphonate-related osteonecrosis of the jaw (BRONJ) [41] that changed to Medication-Related Osteonecrosis of the Jaw (MRONJ) to be suitable with the high number of osteonecrosis cases in the maxilla and mandible, which are linked to other treatments such as antiangiogenic or antiresorptive [42]. A systematic review summarized 12 studies, and it was reported that dental implants could be osseointegrated in patients treated with oral bisphosphonates [43].

Diabetes mellitus is considered as one of the chronic diseases that resulted in hyperglycemia and multiple complications. Most of the diabetic patients are suffering from the loss of the tooth and periodontitis [44]. A study was carried out among 32 patients with 42 implants. The patients with type II diabetes were classified by the level of HbA1c. At the time of increasing implant placement, the stability of an implant was achieved [45]. Smoking cigarettes is a critical factor that had a harmful effect on wound healing and decreased bone density after oral surgery. A study was carried out among 164 patients from 27–71-year-old, 67 patients smoked up to 10 cigarettes/day and 97 never smoke. The ISQ values of smokers (60.04 ± 0.4) were lower than ISQ value of non-smokers (62.9 ± 0.6), whereas there are no significant differences in implant stability [46].

Titanium Dental Implant and Surface Treatments

Several treatments, either chemical or mechanical, were suggested through manufacturers for improving osseointegration [47]. Titanium implant surfaces could be acquired through different methods such as acid etching, titanium plasma spray, and grit blasting [47]. The grit-blasting method was used for surface treatments that characterized by the dropping of particles such as titanium (TiO₂) in a definite size from 25 to 75 µm. There are two varied types of titanium forming dental implants: Grade 4 and Grade 5 TiO₂ alloy; both are mechanically different, so when apply Grade 4 TiO₂ to increase the roughness of the surface, dental implants that were obtained should be chemically etched. On the other hand, the dental implant that was obtained from Grade 5 TiO₂ should be sandblasted [45]. Furthermore, different procedures have been used to produce the micro rough titanium surfaces, for instance, acid-etching and sandblasting, or in most of the cases, a combination between two procedures was occurred [48]. Acid etching was the common chemical method for treating the surface; this might be attributed that it could achieve an ideal superficial microtopography, and it could also prove the increment in bone–implant contact [45]. It was shown that titanium wear was increased by the insertion of a rough fixture during the screwing process of the implant placement [48]. Besides, it was confirmed that the release of titanium in a peri-implant bone could be facilitated through torque concentration above a smaller contacted area that resulted in increased localized stress [48].

Conclusion

The present review emphasized the primary stability for achieving perfect implant integration, being influenced by several factors, such as quality and quantity of the bone, dimensions, and design of the implant, and surgical
technique. Furthermore, this review showed the impact of varied surface treatments on titanium dental implants.

**Author details**

Alhassan Mohammed Ajeebi1,2, Shahad Ahmed Alquraishi3
1. Periodontist Consultant, Chairman of Periodontics Department, Dental Hospital, King Saud Medical City, Riyadh, Saudi Arabia
2. Board member of Saudi Society of Periodontology, Riyadh, Saudi Arabia
3. Periodontics Service Resident, Dental Hospital, King Saud Medical City, Riyadh, Saudi Arabia

**References**

Primary stability of dental implant


