



REVIEW ARTICLE



Relationship and changes of primary and secondary stability in dental implants: A review

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Abstract

Background: The most important criteria for a successful implant are obtaining and securing the stability of the implant. Various implant systems reach different levels of stability depending on their designs and their arrangement in the bone. Clinical findings suggest that stability of the implant is largely responsible for the success of the implant treatment. Implant stability is categorized into two phases: Initial stability (which is a mechanical phenomenon) and secondary stability (which is a biological phenomenon created by osteointegration). **Aim:** This paper scrutinizes and critically compares the results of different studies on the changes in stability and the correlation between initial and secondary stability. While most studies suggest a correlation between bone density and implant stability, some researches suggest the opposite. These discrepancies in results are most likely because of the differences in the methods used in these studies. For instance, the method of assessing bone quality is different across these studies. The term "bone quality" is not usually well-explained in papers. Moreover, the aforementioned studies have adopted different methods for measuring initial stability. In addition, the inconsistent results of these studies could be the result of using different tools. It was conventionally believed that the stability of the implant increases during the healing process. **Conclusion:** Recent studies suggest that implant stability during the healing process only increases for implants with low initial stabilities. **Clinical Significance:** Loss of stability during the healing can be observed in implants with high initial stabilities.

Keywords: Implant, primary, secondary, stability**Introduction**

What is interesting about implant treatments, nowadays, is that despite some difficulties such as atrophy, diseases and other injuries of the oral system, such treatments are usually successful, and functionality, beauty and appropriate contour for healing can be achieved. Thus, the demand for implant treatments is on the rise.^[1] Decades of experience shows high success rates of implant treatments for toothless or partial toothless patients, given that the specific conditions of using the implants are respected.^[2] The success rate depends on different factors such as the surgery technique, the quality and quantity of the bone, the type of implant, and the condition of the patient. The density of the bone at the site of surgery is a crucial factor in determining the treatment plan, implant design and the best loading time.^[3] However, the density of the bone is not the only determining factor for the fracture strength of the bone. In addition to the density, the structure, the arrangement, and the distribution pattern of the trabeculae are also important factors that influence the quality and the

overall stability of the implant.^[4,5] To achieve satisfactory results, it is a vital to have an overall assessment of the condition of the patient. This assessment usually starts with acquiring the patient's medical and dental history and continues with prosthesis evaluations (like occlusion and the edentulous area), and radiographic diagnosis (like panoramic and cone beam computed tomography).

Stability of Implant

Since the duration of tooth loss after the surgery depends on the stability of the implant, and the stability of the implant itself is related to the density of the bone, the assessment of the quality of the bone before the surgery is a key factor in the success of the surgery and the stability of the implant after the operation.^[6] As a rule of thumb, but not always, less success rates are expected for the implants positioned on the upper jawbone in comparison with the implants treatments on the mandible.^[2] This is likely related to the higher density of the bone in the mandible.^[3] Likewise, studies showed lower success rates in posterior region

in comparison with the anterior areas of the jaw. This could be due to the fact that in the posterior areas of the jawbone the quality and quantity of the bone is not coherent.^[7] Considering the direct correlation between bone density and bone strength, it can be induced that the bone density is a key factor for the long-term and secure stability of the implant inside the bone. In general, it is difficult to assess the bone density, because not only it may differ from one anatomical area to another but also the density may be incoherent in one region. Nevertheless, it shall be re-emphasized that the evaluation of quality of the bone is of utmost importance in sketching the treatment plan.^[8] The most important pre-requisite for an implant is its security and stability. Different implant systems with various designs can be arranged in different types of bones. In turn, these different systems, designs and bone types result in different degrees of stability. According to clinical findings, it appears that these degrees of stability determine the clinical success of the implant.^[9] The implant stability is one of the most important parameters that influence the successful osteointegration of the implant. It is particularly crucial in cases in which the implant is being loaded faster than usual. The stability of implant can be categorized into two classes: First, the initial stability that is gained during the implant installation; and then, the secondary stability that is gained after healing. Initial stability is a mechanical phenomenon; whereas, secondary stability is a biological phenomenon and is the result of osteointegration.^[10] The implants with little initial stability show an increase of stability during the healing process. On the contrary, the stability decreases during the healing process in implants with high initial stability.^[11] It should be noted that in fast loading, the stability of the implant does not follow the above-mentioned pattern of behavior.^[12] While the most studies suggest a correlation between bone density and implant stability, some other investigations show the opposite. For example, according to Markezan *et al.* study, the correlation coefficient between implant stability quotient (ISQ) and Hounsfield unit (HU) changes between 0.46 (medium correlation) and 0.88 (strong correlation). The differences in results are probably due to the different methods that these various studies employ. For instance, the method of measuring the quality of the bones is different in these studies. The concept of the quality of the bone has not been fully explained in most articles.^[13] The quality of the bone depends on the physiological and structural aspects of the bone and its degree of mineralization.^[14] Moreover, other factors such as bone metabolism, cell turnover, inter-cell matrix maturation and bone vascularity influence the quality of the bone.^[15] Meanwhile, it is not yet clear how much each of these factors is responsible for the quality of the bone.^[14] In implant dentistry, the most prevalent method for assessing the bone quality was proposed by Lekholm and Zarb. Their method evaluates the quality of the bone based on radiographic assessments, examining the quantity of the cortical and trabecular bone, and the amount of strength reported by the clinician. Based on these factors, Lekholm and Zarb's method identifies the type of bone. They define four types of bones.^[16] These types depend on the practitioner's judgment and his/her experience. Therefore, it is not objective or it is reproducible.^[17,18]

Nowadays, cone-beam computed tomography (CBCT) is vastly used in dentistry, as this technology provides a three-dimensional image of the structure of the bone. It does also allow users to measure the bone dimensions in different directions, and so makes it possible to measure the density of the bone using HU. Close examination of various articles reveals that one of the reasons for their contradictory results is related to their method for calculating HU in CBCT images. In fact, some of the studies have not distinguished between cortical and trabecular bones in their calculations.^[19,20] As a result of this miscalculation, the estimated amount for HU was larger than it should be in these studies. On the other hand, other studies^[14,21] only considered trabecular bones in their calculations. Therefore, they estimated a lower amount for HU. Meanwhile, those studies that based their HU calculations on both cortical and trabecular bones have reported a stronger correlation between bone quality and implant stability.

So far, different methods have been used for calculating initial stability in the studies. Most studies prefer the objective and the non-aggressive methods for assessing stability. It is good to remind ourselves that these methods use Ostell and Periotest apparatuses. Ostell measures stability through radio-frequency analysis (RFA) based on ISQ index. ISQ index can vary between 0 and 100. The greater number for ISQ corresponds to a higher degree of stability. Periotest (PTV) is another equipment that measures the stability and reports it on scale of -8 to +50. The lower the amount reported by PTV, the higher is the stability of the bone. Another method for measuring stability is estimating insertion torque (IT) at the time of installing the implant. IT is measured in N/cm units and is only suitable for measuring initial stability.^[20]

Some clinical studies and studies on animals suggest medium to strong correlations between Periotest and Ostell results. Even some *in vitro* studies suggest linear correlations between these two methods.^[22,23] However, in a study conducted by Simunek *et al.*,^[24] a low correlation between ISQ (which relates to Ostell) and PTV (which relates to Periotest) was reported ($P > 0.001$ and $R^2 = 0.06$). In calculating IT with Ratchet, the maximum amount was 50 N/cm, which is much lower than it should normally be for implants with initial stability. One reason for the different results in the studies could be that they used different apparatuses to measure stability.

Sennerby and Meredith^[25] introduced RFA as a quantitative method for assessing implant stability. They evaluated implant behavior in various types of bones and introduced RFA as reliable method for assessing implant stability.^[26] Likewise, Friberg *et al.*'s study^[22] confirmed RFA as a suitable method for evaluating implant stability. Meanwhile, contradictory results disrupt any attempt to understand the changes in stability and the stability's relationship with bone density. Hence, a few researchers have introduced RFA as a debatable method for measuring stability. A very important study on this topic has been conducted by Rasmusson *et al.*^[27] He found that ISQ cannot be suitable criteria for assessing osteointegration. He depicted that implants with similar anchorages may show different ISQs. Despite the fact that

several researchers have questioned the reliability of resonance frequency as an index for evaluating implant stability, the method is still vastly in use due to its simplicity and non-aggressive nature. Other studies question the ISQ as an index for assessing osteointegration and speculate that employing this index could be the reason behind contradictory results in the studies.

For an osteointegrated implant, stability depends only on the biologic portion. Yet, for those implants that are exposed to fast-loading only mechanical stability is important. Previously, it was believed that the stability of implant increases during the healing process.^[28,29] We know today that it was a rather naïve view and a simplification of the actual process.^[11] What is proved today is that implant stability increases during the healing process only for implants with low initial stability. Unlike such implants, the ones with high initial stability lose strength during the healing process.^[11] There is no consensus on the parameters that affect implant stability after its installation. Some studies suggest that stability decreases between week 2 to 8 after installation.^[24] Other studies reported severe loss of stability from week 3 to 4.^[24] Yet, some other researchers have not observed any loss of stability at all.^[11] These various (and sometimes contradictory) results could be due to the variations in implant designs, particularly their surface properties.^[25,30,31] The increase of stability in time is related to the increase in the attachment between the implant and the bone. This quality is typically observable on bioactive surfaces such as fluoridated surfaces.^[32,33]

Bio surfaces can increase the activity of ions and amino acids around them. This, in turn, increases cell activity in the interface between bone and implant.^[32] On top of this, hydrophilic surfaces guarantee an effective connection between blood clots and the implant, and also lead to the absorption of calcium and phosphate ions over the implant's surface.^[32] This mechanism can accelerate the creation of stable surfaces at the implant site.^[32] Therefore, some scholars hypothesized that stability loss can be controlled and its effects can be minimized by using hydrophilic bio-surfaces.^[33,34]

In one study, Geckili *et al.* measured the stability of Titanium implants over a 24-week period. They used two types of titanium implants in his experiment: One with fluoridated surfaces, another without such surfaces.^[35] They observed a decrease in ISQ index by an average of 4.9 within the first 2 weeks after the implant installation in the ones without fluoridated surfaces. He also observed that the decrease in ISQ index was negligible in implants with fluoridated surfaces. He concluded that using fluoride over implant surfaces improves osteointegration.^[35] Geckili's results were confirmed by Sim and Lang study,^[28] in which implants with fluoridated surfaces were used. Yet, studies on implants with SLA surfaces reported contradictory results.

Sim and Lang have reported a constant increase in ISQ index (with no period of decrease in stability) in implants with SLA surfaces during the first 12 weeks after installation.^[28] Valderrama *et al.* found similar results in his study,^[36] but Schatzle *et al.* reported a decrease of stability within the first few weeks after installation of implants with SLA surfaces.^[36] According to Simunek *et al.*'s study, the ISQ index decreased by 3 units during

the healing process and reached the lowest level in the third week. After that, ISQ has increased constantly up until week 12.^[24]

Likewise, Lai *et al.* reported a decrease in stability of implants with SLA surfaces during week 2 to week 6. This decrease was quite notable and reached 12 ISQ unit.^[37] Abrahamson *et al.*^[38] observed a loss of stability between week 1 and 4 after the installation of the implant. This decrease was about 2.2 on average and was not a constant decrease (i.e. it would decrease and increase). However, no changes were observed after week 5. It can be concluded from these studies that the decrease in stability is not very notable and in most cases the stability level returns to its original state very fast.

In addition to the above-mentioned factors, the loading time is also influencing the stability index. For instance, Zhou *et al.*^[12] compared changes in ISQ in normal and immediate implants and found that maximum stability is achieved 2 weeks after the surgery in immediate implants and 4 weeks after it in normal ones. Some other studies scrutinized the effects of initial stability on the stability of the implant during the healing process. The findings of these studies suggest a correlation between stability and initial stability.^[28]

In Nedir's study, ITI implants with ISQ indexes below 60 show an increase in stability; whereas, in implants with stabilities between 60 and 69 in the first 8 weeks after surgery, a loss of stability was observed. Interestingly, for all the implants in this study, the stability index returned to their initial stability levels after week 12. Implants with ISQs above 69 show a decrease in stability in the first 4 weeks, and after that, the stability level remained at the same level.^[10] In another study, Qatez separated the implants into those with initial stability index over 56 and those below 56 and measured their stability along follow-up period. According to this study, implants with initial stabilities below 56 show less stability compared to the ones with initial stabilities over 56 in the first 16 weeks. But after week 16, the difference becomes less so that it was almost statistically negligible.^[39]

Similarly, Simunek *et al.*'s study revealed that implants with low stability (ISQ < 68) present a considerable increase in stability. On the contrary, their study showed that implants with high stability (ISQ > 72) lose it in time.^[11] Blashi's study confirmed Simunek *et al.*'s results. Blashi *et al.* showed that the changes in stability are the least in implants with ISQ indexes between 68 to 72.^[40] This confirmed Simunek *et al.*'s results which showed that when implants with different initial stabilities were compared, those with the least initial stabilities presented noticeable increase in ISQ (with an average increase of 5.5, $P < 0.001$). In contrast, in the implants with the highest initial stability, notable stability loss was observable (average loss of stability 1.8, $P < 0.001$). Those implants with medium initial stability presented a medium yet notable increase in ISQ (average increase of 1.3, $P < 0.001$). According to this study, the implants that were installed in type IV bones showed much less stability than those installed in type I, II and III.^[24]

In some studies, a correlation between bone quality and stability (initial stability and secondary stability) parameters has

been observed.^[41] Turkyilmaz *et al.* showed in his study that there is a strong correlation between density and IT, also between density and ISQ index, and between IT and ISQ. In other words, the outcomes of this study suggested a strong relation between bone density, CT parameters and stability parameters.^[19]

Likewise, Friberg *et al.* showed a noticeable correlation between initial and secondary stabilities.^[22] According to da Cunha *et al.*'s study, there is a notable linear relationship between placement torque and secondary stability in implants that are installed at maxilla.^[42] In his study, Friberg *et al.* found that the implants that are installed in bones with lower density reach higher levels of stability during the time in comparison with the implants that are installed in bones of higher densities.^[22] According to Zhou *et al.* study implants which were installed in bones of type I and II presented higher stabilities when compared with those installed in type III and IV.^[12]

Some of the studies on animals show medium to high correlation between initial and secondary stabilities.^[23,12,43] However, according to the findings of Cornelini *et al.*, who has installed 40 implants in mandibular molars, the ultimate stabilities were between 72 to 74.5 ISQ, and after a year the ultimate stabilities of all the implants were almost the same.^[44] Nevertheless, Cahrel *et al.*^[45] concluded in a study that there is no correlation between these two indices.

Simunek *et al.*^[24] found a relation between the bone type and initial stability and also between initial and secondary stability. As it can be seen, there seems to be no unifying view among the scholars that confirms or refutes the relationship between bone quality initial and secondary stabilities.^[22,28,38,45-49] Martinez *et al.*^[50] suggested in his study that the implants installed in bones with low density have less stability in comparison with those installed in higher-density bones. His study also suggested that secondary stability is the same for various types of densities. Farré-Pagés *et al.*^[51] observed higher stabilities in regions with high density like anterior and posterior regions of the mandible. He concluded that higher densities with higher HU index corresponds to higher estimated initial stability with higher ISQs. Yet, his study did not find a meaningful correlation between HU and IT. He also found a noticeable correlation between density (based on Zarb and Lekholm's classification) and ISQ index, so that the ISQ level of the implants installed in type I bones were notably higher than the other types. Turkyilmaz *et al.*,^[19] Ikumi and Tsutsumi,^[52] and Friberg *et al.*^[53] also found a considerable relationship between bone density (based on HU), initial stability (IT) and secondary stability (ISQ). In contrast, Beer *et al.*^[54] reported no correlation between bone quality and initial stability.

It seems that initial stability is more sensitive to clinical parameters and has less accuracy.^[16,17] Initial stability is influenced by various factors such as surgery technique, morphology of the surface of the implant, the implant's diameter, bone compaction, and cortical anchor. Larger diameters lead to higher initial stability. This is because implants with larger diameters have a larger connection area between the implant and the bone. Likewise, from the morphological perspective, the implants

of taper quality present more initial stability in comparison with cylindrical ones, since taper-shaped implants have larger diameters in their crystal area.^[50]

Although the correlation between initial stability and secondary stability is very much debatable, it can be said that if the initial stability be less than a critical limit, an appropriate secondary stability cannot be achieved, and the implant plan will fail. Different studies propose a diverse range of numbers for this critical limit. The widespread belief is that for initial stability with low ISQs, the limit should be considered 50.^[47] In Degigi's study,^[52] all the implants with an initial stability (ISQ) below 46 failed, while in those with ISQs over 60 osteointegration was successful.

Conclusion

Implant stability is one of the most important factors for the success of implant treatments. Although most studies showed a correlation between bone density and implant stability, some studies suggest the opposite. These discrepancies in results are most likely because of the differences in the methods used in these studies. For instance, the method of assessing bone quality is different across these studies. The term "bone quality" is not usually well-explained in papers. Moreover, the aforementioned studies have adopted different methods for measuring initial stability. In addition, the inconsistent results of these studies could be the result of using different tools. It was conventionally believed that the stability of the implant increases during the healing process. However, recent studies suggest that implant stability during the healing process only increases for implants with low initial stabilities. Meanwhile, loss of stability during the healing can be observed in implants with high initial stabilities. This paper scrutinizes and critically compares the results of different studies on the changes in stability and the correlation between initial and secondary stability.

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