

# Estimation of dental implant stability: comparison between resonance frequency analysis and a quantitative ultrasound technique

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**Abstract.** Dental implant primary stability is determined by the biomechanical quality and quantity of bone tissue around the implant. Radiofrequency analyses (RFA) and quantitative ultrasound (QUS) methods have been suggested to assess implant stability. The purpose of this study was to compare the results obtained using both techniques applied to dental implants inserted in various synthetic block mimicking bone tissue. Different values of trabecular bone density (#10, #20, #30 PCF) and cortical thickness (1 and 2 mm) were considered to assess the effect of bone quality on the ultrasonic indicator (UI) and on the ISQ values. The effect of the implant insertion depth and of the final drill diameter was also investigated. UI values decrease and ISQ values increase when i) the bone density increase, ii) cortical thickness increase, and iii) the implant is screwed in the phantom. When the implant diameter varies, the UI values are significantly different for all final drill diameters (except for 2.8 and 2.9 mm), while the ISQ values are similar for all final drill diameters lower than 3.2 mm and higher than 3.3 mm, respectively. The error on the estimation of the trabecular density (respectively cortical thickness and insertion depth) with the QUS device is around 4 (respectively 8 and 4) times lower compared to that made with the RFA technique. The results show that ultrasound technique provides a better estimation of different parameters related to the implant stability compared to the RFA technique.

## Introduction

Dental implant stability, which is determinant for the surgical success [1], is determined by the quantity and biomechanical quality of bone tissue around the implant [2]. Dental implant stability remains difficult to be assessed clinically because it depends on the implant properties (geometry, surface properties...), on the patient behavior and bone quality as well as on the surgical protocol. Accurate measurements of implant biomechanical stability are of interest since they could be used to improve the surgical strategy by adapting the choice of the healing period in a patient-specific manner.

Assessing the implant stability is a difficult multiscale problem because of the complex heterogeneous nature of periprosthetic bone tissue and to remodeling phenomena [3, 4]. Different approaches have been used to assess the implant stability in vivo. So far, most surgeons still rely on their proprioception because it remains difficult to monitor bone healing in vivo. Accurate quantitative methods capable of assessing implant stability are required to guide the surgeons and eventually reduce the risk of implant failure.

The most commonly used biomechanical technique is the resonance frequency analysis (RFA), which consists in measuring [5] the first bending resonance frequency. The RFA technique allows to assess the implant anchorage depth into bone, marginal bone level and the stiffness of the bone-implant structure. However, the RFA cannot be used to identify directly the bone-implant interface characteristics. No correlation between the implant stability quotient (ISQ) and bone implant contact (BIC) nor between ISQ and cortical thickness has been evidenced so.

An alternative method has been developed by our group and consists in using a quantitative ultrasound (QUS) method [6] to investigate the properties of the bone-implant interface. The principle of the measurement lies on the dependence of ultrasonic propagation within the implant on the boundary conditions given by the biomechanical properties of the bone-implant interface [7].

The comparison of the experimental results obtained in a controlled configuration using the QUS and RFA techniques would be of interest in order to better assess the performance of the different approaches. The aim of the present study is to compare these two different methods (i.e. RFA and QUS approaches) that have been evoked to assess dental implant stability.

## Material and Methods

Dental implants were inserted in bone mimicking phantoms made of polyurethane because it allows to work under standardized and reproducible conditions. Different parameters related to the implant stability (such as the density of the bone phantom, the thickness of cortical bone, the insertion depth and the drill diameter) were investigated and the related variations of different quantities such as i) the RFA response and ii) the ultrasonic response at 10MHz were investigated.

## Results

The values of the ISQ are shown to increase when i) trabecular density increases, ii) cortical thickness increases, and iii) the insertion depth increases. These results are in agreement with previous studies [8-11] and can be explained by the higher rigidity of the block-implant system induced by an increase of trabecular density, of cortical thickness and of implant insertion depth.

The values of the UI are shown to decrease when i) trabecular density increases, ii) cortical thickness increases, iii) the final diameter drill decreases and iv) the insertion depth increases. These results are in agreement with previous papers by our group [12-16]. The aforementioned results can be explained by the fact that the UI is related to the amplitude of the echographic response of the implant, which depends on the boundary conditions applied to the implant external surface. When bone quantity and quality increase around the implant surface, the gap of mechanical properties between the implant and its environment decreases, which induces an increase of the transmission coefficient. Therefore, the ultrasound energy decreases faster since ultrasound may propagate in the surrounding medium, resulting in a faster decrease of the implant echographic response.

## Conclusion

This study allows to compare the results obtained with two different approaches aiming at estimating primary dental implant stability, which are realized with the same implants under various configurations. Namely, we considered a variation of the following parameters: i) trabecular bone density, ii) cortical thickness, final drill diameter and iv) penetration depth. All results are consistent and can be explained by physical analyses of the biomechanical phenomena occurring in and around the implant. Moreover, we found that ultrasound technique provides a better estimation of different parameters related to the implant stability compared to RFA techniques. The present study paves the way for the development of an ultrasonic device to estimate dental implant stability that could be used in the clinic provided further in vivo investigations.

## References

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