Correlation Between Implant Stability Quotient and Bone-Implant Contact: A Retrospective Histological and Histomorphometrical Study of Seven Titanium Implants Retrieved from Humans

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ABSTRACT

Background: Primary stability has a relevant role in the long-term success of dental implants. A quantitative method for the measurement of implant stability has been introduced (resonance frequency analysis [RFA]). Information about the significance of RFA measurements and about the relationship between RFA values and their association with implant osseointegration, success, or failure is important from a clinical point of view.

Purpose: The aim of the present histological and histomorphometric study was to see if a correlation existed between the bone-implant contact (BIC) percentage of retrieved human implants and RFA values.

Materials and Methods: Seven implants inserted in the posterior mandible, with a sandblasted and acid-etched surface and retrieved after a 6-month period, were evaluated in the present study. These seven implants had been retrieved for different causes. All these implants were submerged and were retrieved with a 5-mm trephine bur and immersed in 10% buffered formalin to be processed for histology.

Results: A statistically significant correlation could be detected between implant stability quotient and BIC ($p = .016$).

Conclusions: Even if the relationship between bone structure and RFA is still not fully understood, in our study, a statistically significant correlation was found between RFA and BIC values. Further studies are needed to evaluate a correlation of RFA and BIC in human implants retrieved after a range of healing periods.

KEY WORDS: bone-implant contact percentage, bone structure, histomorphometry, resonance frequency analysis

It is agreed that implant primary stability has a relevant role in the long-term success of dental implants.[1] Primary stability occurs at the time of implant placement and is related to the level of primary bone contact.[2] Clinicians need reliable and supporting objective guidelines to determine on an individual basis the prognosis of a given implant.[3] A quantitative method is needed for the measurement of implant stability and osseointegration.[1] One such method has been introduced in the past decade and has been reported to be evidence based and useful for determining implant stability.[4] Resonance frequency analysis (RFA) gives a clinical measure of stability and presumed osseointegration of implants.[2] RFA is related mainly to the height of the implant not surrounded by bone, and to the stability of the implant-bone interface.[4,5] There is still little information available about the significance of RFA measurements.[5] Moreover, several factors influence RFA: (1) stiffness of the implant-bone interface; (2) stiffness of the bone itself; and (3) stiffness of the implant components.[5]

Forces are produced through a piezo effect and the oscillation response is amplified, analyzed, and graphi-

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cally and numerically shown in a unit called *implant stability quotient* (ISQ).[5] In a study, RFA measurements showed a mean value of 68 ISQ indicating that high primary stability was achieved.[6] Subsequently, it was shown that the mean stability decreased to 60 ISQ in the first 2 months after implant insertion.[6,7] This initial decrease is probably related to bone relaxation following compression, biologic changes associated with early bone healing, and start of the marginal crestal bone resorption.[8] After a stabilization period, RFA started to increase again reaching at 12 months post-insertion a mean ISQ value comparable to the mean ISQ values observed at implant placement.[6,8] This increase in stability is most likely due to bone formation/remodeling and an increased stiffness of the bone.[3,9] On the contrary, failing implants showed a decreased stability until eventual loss of the implant.[1,6] A cutoff ISQ value for implant stability has been proposed at 47, meaning that an implant displaying an ISQ ≥47 should be considered as a stable implant.[3] ISQ values for successfully osseointegrated implants have been reported to vary from 57 to 82 ISQ, with a mean of 69 ISQ after 1 year of loading.[10]

RFA is then believed to be a potential useful clinical tool for the prevention, diagnosis, and prediction of implant failure and is helpful in the maintenance of viable implants.[11,12] Moreover, implants with a high primary stability might be loaded earlier than implants with a lower ISQ.[3]

Available data suggest that all implants reach a similar degree of stability with time, irrespective of the level of primary stability.[4] Zix and colleagues[5] found no differences in the values in not loaded implants, in implants loaded for less than 12 months, and in implants loaded for more than 12 months. Nkenke and colleagues[7] reported that immediately loaded implants and implants loaded after a healing period of up to 5 months showed a higher implant stability than implants loaded after 1 to 3 months. Da Cunha and colleagues[1] reported no overall correlation between placement torque and RFA. Also, Rocci and colleagues[13] found no correlation between any of the morphometric parameters and ISQ values.

Huang and colleagues[11] found that the highest RFA values were found in implants inserted into type I bone.

The ISQ values showed a high level of repeatability, with an accuracy of ±1%.[2]

Due to a lack of scientific data, no information is available to date on RFA values and their association with implant osseointegration, success, or failure.[14] Conclusive data on the bone-implant interface and RFA values are still lacking.[9]

The aim of the present histological and histomorphometric study was to see if a correlation existed between the bone-implant contact (BIC) percentage of retrieved human implants and RFA values.

MATERIALS AND METHODS

The archives of the Implant Retrieval Center of the University of Chieti-Pescara were searched for implants that had been retrieved from humans for different causes in the last 4 years (2002–2005). It was decided to evaluate only the implants that had been inserted in the posterior mandible, had a sandblasted and acid-etched surface, and had been retrieved after a 6-month period. Seven implants (XiVE®, DENTSPLY Friadent, Mannheim, Germany) had these characteristics. These seven 3.8 × 8 mm implants had been retrieved for pathology of the nerve (1), psychological reasons (1), malalignment (2), hygienic problems (1), and difficulties in the restorative phase (2). The radiographical and surgical evaluation of the bone density at the moment of the insertion was, for all implants, D2-D3 bone quality. All these implants were submerged, and after 6 months, all implants were retrieved with a 5-mm trephine bur and immersed in 10% buffered formalin to be processed for histology.

Before implant retrieval, the implant stability was evaluated with Osstell™ (Integration Diagnostics AB, Göteborg, Sweden). The transducer had a perpendicular orientation to the alveolar crest and its upright beam was placed on the palatal side. For the determination of the device measurement repeatability under identical experimental conditions, three measurements were done for each implant.

Processing of Specimens

The implants and the surrounding tissues were stored immediately in 10% buffered formalin and processed to obtain thin ground sections with the Precise 1 Automated System[15] (Assing, Rome, Italy). The specimens were dehydrated in an ascending series of alcohol rinses and embedded in a glycolmethacrylate resin (Technovit® 7200 VLC, Kulzer, Wehrheim, Germany). After polymerization, the specimens were sectioned longitudinally, in a mesio-distal direction, along the major axis of the implant with a high-precision diamond disk at about 150 μm and ground down to about 30 μm. Three slides were obtained for each implant. The slides were stained with basic fuchsin and toluidine blue. A double staining with von Kossa and acid fuchsin was done to evaluate the degree of bone mineralization, and one slide, after polishing, was immersed in $AgNO_3$ for 30 minutes and exposed to sunlight; the slides were then washed under tap water, dried, and immersed in basic fuchsin for 5 minutes, then washed and mounted.

Histomorphometry

The histomorphometry of BIC percentage was carried out using a light microscope (Laborlux S™, Leitz, Wetzlar, Germany) connected to a high-resolution video camera (3CCD, JVC KY-F55B®; JVC, Yokohama, Japan) and interfaced to a monitor and PC (Intel® Pentium® III 1200 MMX, Intel Corporation, Santa Clara, CA, USA). This optical system was associated with a digitizing pad (Matrix Vision GmbH, Oppenweiler, Germany) and a histometry software package with image-capturing capabilities (Image-Pro® Plus Version 4.5; Media Cybernetics Inc., Silver Spring, MD, USA and Immagini & Computer Snc, Milano, Italy).

Statistical Analysis

The means of ISQ values and mean values of BIC of these seven implants were compared by the Friedman test at 95% confidence level, in order to determine whether a statistically significant correlation could be established between RFA and BIC. Spearman's rho was determined for each combination.

RESULTS

All the implants were clinically osseointegrated and were stable, and no mobility was present. Radiographically, no bone loss was observed around the implants. Histologically, the bone resorption was comprised between 0.2 and 0.4 mm. The mean ISQ values were 69 (±2.7) in one implant, 71 (±1.4) in one implant, 74 (±0.7) in three implants, 79 (±1.2) in one implant, and 81 (±1.3) in one implant.

Implant with an ISQ Value of 69

Many marrow spaces were observed directly on the implant surface. Only in a few areas of the implant surface was it possible to observe a rim of osteoblasts actively producing osteoid matrix. In the coronal portion of the implant, a few Haversian canals and newly formed bone trabeculae were present; these were mainly composed by woven bone, and only a small quantity of preexisting lamellar bone was present. This newly formed bone was in tight contact with the implant surface. The quality of the bone around the apical portion of the implant was poor. This preexisting bone was completely surrounded by the newly formed bone. Histomorphometric evaluation showed that the BIC percentage was 58.6% (±2.7%).

Group of Three Implants with an ISQ Value of 71

In the coronal portion of the implants, compact bone was present; only a few bone trabeculae were present. This bone filled the screw threads. No inflammatory infiltrate was present around the implants. No gaps or dense fibrous connective tissue were found at the bone-metal interface. No apical epithelial migration was found. In the apical portion, many bone trabeculae undergoing remodeling were present; no Haversian canals were present close to the implant surface. Histomorphometric evaluation showed that the mean BIC percentage for the three implants was 68.1% (±3.7%).

Implant with an ISQ Value of 74

Mature bone with many Haversian systems was present in close contact to the implant surface, and a few marrow spaces were also present. Remodeling bone areas were present with osteoblasts that were producing osteoid matrix. Histomorphometric evaluation showed that the BIC percentage was 73.2% (±4.7%).

Implant with an ISQ Value of 79

Mature bone with many Haversian systems was in close and tight contact with the implant surface; few marrow spaces were present. A few remodeling bone areas were present with osteoblasts and osteoid matrix. In other portions of the implant perimeter, a very high bone contact was present and the bone presented many marrow spaces. Newly formed bone trabeculae with large osteocyte lacunae were present.

Histomorphometric evaluation showed that the BIC percentage was 78.2% (±3.2%).

Implant with an ISQ Value of 81

Mature bone with many Haversian systems was present in close contact with the implant surface; few marrow spaces were present. An area of bone remodeling was present with osteoblasts and osteoid matrix. In other portions of the implant perimeter, a high BIC percentage was present. Newly formed bone trabeculae with large osteocyte lacunae were present.

Histomorphometric evaluation showed that the BIC percentage was 87.5% (±3.4%).

Statistical Evaluation

A statistically significant correlation could be detected between ISQ and BIC ($p = .016$) (Table 1 and Figure 1).

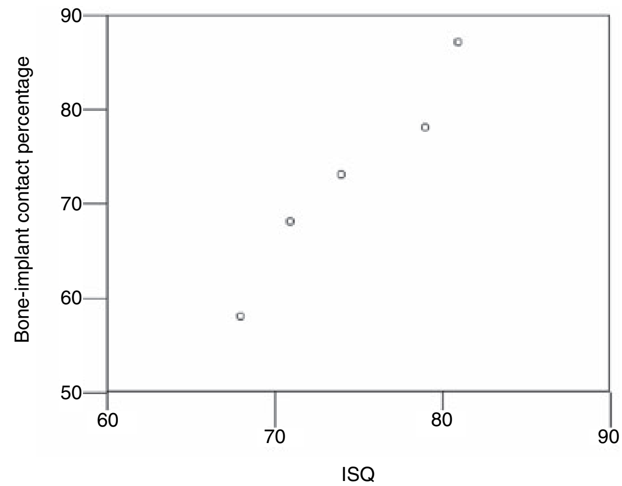

Figure 1 Curve correlation of bone contact and implant stability quotient (ISQ) values.

DISCUSSION

Several methods have been proposed to evaluate the initial bone quality and osseointegration of dental implants, including histology and histomorphometry, removal torque value (RTV) analysis, pull and push-through tests, and X-ray examination.[11] Due to problems of invasiveness and accuracy, these methods are, however, not suitable for long-term clinical assessment.[11] An adequate stability of a dental implant into the surrounding bone plays a relevant role in the undisturbed healing of the peri-implant bone and seems to be a prerequisite for a favorable long-term clinical outcome.[16,17] Two main factors have been said to be important in influencing the primary stability of an implant at placement: the BIC percentage and the role of compressive stresses at the implant-bone interface.[16] Histomorphometry has been widely used as a quantitative method for establishing the percentage of bone contact.[16] It has been shown that bone formation at the implant surface results in an increase in stability.[18] Stability is then related also to the amount of bone in contact with the implant.[17] An increase in implant stability with time has been demonstrated by using RTV which could be correlated with an increasing degree of BIC.[17,19] Histological and histomorphometrical assessment is the most accurate method of observing morphological changes at the implant-bone interface.[17] It has been suggested that RFA is related to the stiffness of the implant in the surrounding tissues corresponding to histological results.[20] More bone contact with the implant surface is believed to imply higher implant stability.[20] It is evident that RFA increased with time following implant placement, and these results suggest that there may be merit in attempting to correlate BIC percentage with RFA from specimens taken at a range of different healing periods.[17] The relationship between bone structure and RFA is not fully understood.[21] Different results on a possible relationship between RFA and BIC have been reported; Gedrange and colleagues[20] and Nkenke and colleagues[7] in human cadaver studies, reported on the existence of such a correlation, while other researchers[13] failed to show this correlation. Accocaoglu and colleagues,[22] in a human cadaver study, could not establish a correlation between ISQ values and RTVs. The relationship between bone structure and RFA is still not fully understood.[21]

In our study, a statistically significant correlation was found between RFA and BIC values. Further studies are needed to evaluate a correlation of RFA and BIC in human implants retrieved after a range of healing periods.

TABLE 1 Implant Stability Quotient (ISQ) and Percentages of Bone-Implant Contact

	Mean Bone Contact (%)	Standard Deviation	Standard Error	*p* Value
Implant with ISQ 69	58.6	2.7	0.089	.016*
Implant with ISQ 71	68.1	3.7	0.077	
Implant with ISQ 74	73.2	4.7	0.085	
Implant with ISQ 79	78.2	3.2	0.054	
Implant with ISQ 81	87.5	3.4	0.077	

*Significant at 95% (according to the Friedman test).

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