Evaluation of Factors Influencing Resonance Frequency Analysis Values, at Insertion Surgery, of Implants Placed in Sinus-Augmented and Nongrafted Sites

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ABSTRACT

Background: The immediate loading technique requires a high primary stability. Resonance frequency analysis (RFA) has been proposed to assess this stability with a quantitative method.

Purpose: The aim of the present study was to evaluate if a good primary stability could be achieved in sites that had undergone a sinus augmentation procedure and also to evaluate the importance of different clinical factors in the determination of resonance frequency values at implant insertion.

Materials and Methods: In 14 patients, 80 implants were inserted. Sixty-three implants were inserted in a site previously treated with a sinus augmentation procedure, while 17 implants were inserted in healed or postextraction sites. For each implant, diameter, length, bone density, insertion torque, RFA value, and percentage of implant fixed to a nongrafted bone were recorded.

Results: Grafted sites showed high RFA values. A statistically significant positive correlation was found between resonance frequency values and implant diameter ($p = 0.007$), implant length ($p = 0.02$), diameter of the last bur used ($p = 0.01$). No statistically significant correlation between RFA values and all the other variables considered was found.

Conclusions: Sites treated with sinus augmentation procedures can offer good primary stability after 6 months of healing. The length and diameter of the implants, together with the geometry of the implant used, are important to obtain high RFA values.

KEY WORDS: dental implants, immediate loading, implant stability, insertion torque, resonance frequency analysis

Osseointegrated implants are today widely used for functional and aesthetic rehabilitations. According to the original protocol proposed by Brånemark, a healing period of about 4 to 6 months without loading is necessary to obtain mineralized bone tissue at the dental implant interface.[1] Nevertheless, in the last few years, several clinical and histological studies on immediate loading have been carried out, showing the high reliability of this technique.[2–4]

The immediate-loading technique requires a high level of primary stability[3] and a quantitative method to assess it, especially in grafted sites, where the risk of failure is higher. Resonance frequence analysis (RFA) has been proposed for this purpose.[5] However, clinical experience shows that RFA is very difficult to predict by means of insertion torque, bone quality, and other clinical characteristics generally considered by the operators. At the same time, very few studies[6–8] have tried to determine what clinical factors influence implant primary stability at the time of their insertion. At the moment, clinicians do not have sufficient information to improve implant primary stability by changing the normal protocol.

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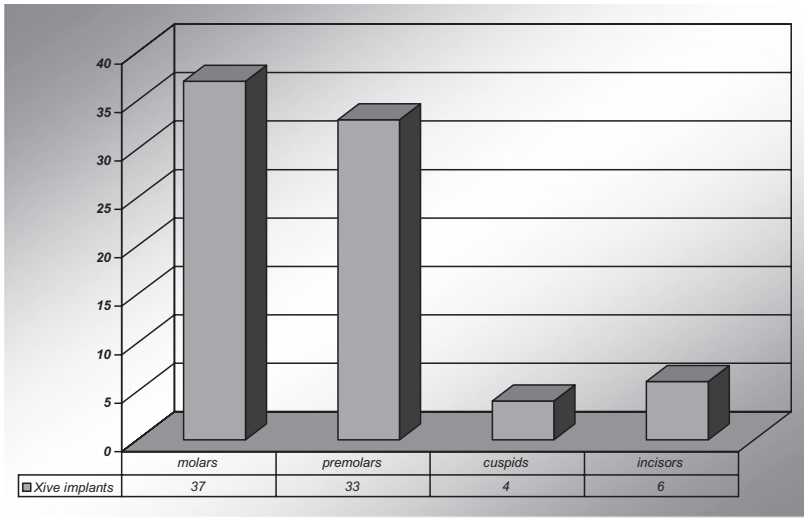

Figure 1 Implant distribution.

The aim of the present study was to evaluate if a similar primary stability could be achieved in augmented sinuses as in nongrafted sites and also to evaluate the importance of different clinical factors in the determination of resonance frequency values at implant insertion.

MATERIALS AND METHODS

Patients

In the period July 2003 and December 2004, 14 patients (5 males and 9 females, age ranging from 40 to 66) who needed an upper jaw rehabilitation were selected. Informed written consent to use their data for research purposes, approved by the Ethics Committee of the University of Chieti, Pescara, Italy, was obtained from the patients.

Exclusion criteria were as follows: a high degree of bruxism, smoking more than 20 cigarettes per day and excessive consumption of alcohol, localized radiation therapy of the oral cavity, antitumor chemotherapy, liver pathologies, hematic nephropathies, immunosupressed patients, patients taking corticosteroids, pregnant women, inflammatory and autoimmunity diseases of the oral cavity, and poor oral hygiene.

Implants

In 14 patients, a total of 80 XiVE implants (Dentsply-Friadent, Mannheim, Germany) were distributed as follows: 63 implants were inserted in a site previously treated with a sinus augmentation procedure (group A), whereas 17 implants were inserted in nongrafted sites (group B). In group B, 13 implants were inserted in healed sites and 4 in postextraction sites. Implant distribution is reported in Figure 1.

Surgical Technique

Where needed, a sinus augmentation procedure was performed with a combination of 50% autogenous bone and 50% deproteneized bovine bone mineral (Bio-Oss®, Geistlich Söhne AG, Wolhusen, Switzerland). The implants were inserted in grafted sites after 6 months of uneventful healing time; 52 of the group A implants were inserted according to a two-stage procedure and 11 with a one-stage procedure.

In group B, nine implants were inserted with a two-stage procedure, whereas eight implants were inserted using a one-stage procedure.

Antimicrobial prophylaxis was obtained with 500 mg of amoxicillin twice daily for 5 days starting 1 hour before surgery. Local anesthesia was induced by infiltration with articaine/epinephrine, and postsurgical analgesic treatment was performed with 100-mg nimesulid twice daily for 3 days. Oral hygiene instructions were provided.

After a crestal incision, a mucoperiosteal flap was elevated. All the implants were inserted according to a strict protocol following the manufacturer's instructions. The sutures were removed 14 days after surgery.

Data Collection

Before surgery, radiographic examinations were carried out with the use of periapical radiography, orthopantomographs, and computerized axial tomography scans. During surgery for each implant, the following data

were collected: implant diameter, implant length, bone density: assessed using preoperative radiographs, and during drilling, according to the classification by Lekholm and Zarb.[9] The insertion torque was recorded by an electronic instrument (Frios® Unit E, Dentsply-Friadent) during low-speed insertion. The RFA values were recorded with the implant stability quotient (ISQ) scale by means of a transducer attached to the implant via a screw and a frequency response analyzer (Osstell™ device, Integration Diagnostics AB, Sävedalen, Sweden). According to the procedure described by Meredith and colleagues,[5] the transducer had a perpendicular orientation to the alveolar crest, and its upright beam part was placed on the palatal side.

For the implants inserted in augmented sites, the percentage of implant fixed to nongrafted bone was also recorded. For this purpose, a periapical radiograph was taken before the sinus augmentation procedure, after 6 months, and immediately after the implant placement. The highest level of the recipient bone and the length of the implant that lay in the bone were then calculated. The measurement was rounded off to the nearest 0.1 mm. A Peak Scale Loupe (GWJ Company, Hacienda Heights, CA, USA) with a magnifying factor of 7× and a scale graduated in 0.1 mm was used. Finally, the percentage was calculated.

All the measurements were made by three independent examiners.

Statistical Analysis

A matrix of nonparametric correlation was used to explore possible association between the whole set of quantitative variables.

Qualitative analyses were carried out by means of the Mann–Whitney *U* test.

A further nonparametric model (linear regression or analysis of variance) was used to better explore the association between RFA values and any single variable of interest. A p value < .05 was considered significant.[10,11]

RESULTS

Analyses of individual sites were performed to correlate resonance frequency values with the most important variables at implant placement (Table 1).

Variables Related to the Surgical Site

The average ISQ value was 62.12 + 10.62 for group A and 61.41 + 10.14 for group B. Grafted sites presented RFA values slightly higher than group B sites at insertion time, but the difference was not statistically significant. No statistically significant correlations were found between RFA values and the percentage of the implant fixed to nongrafted bone.

No significant correlations between bone quality and RFA were found at implant insertion.

TABLE 1 Correlation between Resonance Frequency Analysis Values and All the Variables Considered

	$p \leq 0.05$ (significant)	$p > 0.05$ (nonsignificant)
Implant-related variables	Diameter Length	
Surgical site-related variables		Sinus lift after 6 months Bone quality Percentage of implant fixed in native bone
Surgical technique-related variables	Diameter of the last bur used	Insertion torque One- or two-stage technique

Variables Related to the Implant

At implant placement, statistically significant positive correlations were found between RFA and (1) implant diameter ($p = 0.007$) and (2) implant length ($p = 0.02$).

Variables Related to Surgical Technique

No statistically significant correlations were found between RFA values and insertion torque.

A positive statistically significant correlation ($p = 0.01$) between RFA values and the diameter of the last bur used was found at implant insertion.

No significant correlations between RFA values and the one- or two-stage technique were found.

DISCUSSION

According to Meredith and colleagues,[12] RFA indicates the stiffness of the transducer/implant/tissue system, and it can be influenced by the distance between the transducer and the first bone contact. The objective of this study was to establish if it was possible to obtain a good primary stability in sites that had undergone a sinus augmentation procedure 6 months earlier.

Moreover, the study tried to establish which clinical factors could affect RFA values and so the stiffness of this system at the implant insertion. In order to simplify the analysis, the variables considered were divided into three groups. The first group is represented by surgical site-related variables. No differences were found between normally healed, postextraction, and grafted sites after 6 months of healing, with the latter showing slightly higher RFA values. This finding seems to show that a site that underwent a sinus lift with the reported technique can offer to the implant the sufficient conditions to achieve a good primary stability, indicating a proper maturation of the graft. The lack of correlation between RFA values and the percentage of implant fixed to non-grafted bone seems to point to the same conclusion, indicating a substantial similarity between grafted and recipient bone after 6 months of healing. According to the study by Friberg and colleagues,[13] this result could be explained by the nature of the RFA technique, wherein the crestal third of the implant site seems to be the most important for the determination of ISQ values at least in machine paralleled walled implants. XiVE implants present different design and surface, so a further study should be conducted to confirm this hypothesis. On the other hand, these results suggest that, given the calibration with all the other influencing variables, RFA can be used to monitor and assess the maturation of the grafted bone after implant installation. Again, more studies have to be carried out to support this conclusion.

Bone quality does not appear to be important to obtain high ISQ values. This finding is consistent with other clinical studies.[6,8] Nevertheless, a recent study by Östman and colleagues[14] on 905 Brånemark implants showed a significant positive correlation between RFA and bone quality. This conclusion could be explained by the use of a completely different surgical protocol: The implants were placed in either mandibular and maxillary sites with an underpreparation that increased with poor bone quality; when the bone quality was considered particularly poor, a tapered implant instead of a parallel walled implant was used. In our study, all the implants were inserted in the upper jaw where the cortical bone is more uniform; moreover, the same implant design and a standard surgical protocol were used for all the implants. Another study by Huang and colleagues[15] based on a three-dimensional finite model reported that the calculated frequencies decreased when the implant's surrounding bone quality was reduced. The different typology of this study can probably explain the different results.

The second group is represented by the implant-related variables: XiVE implants showed high average RFA values; moreover, the results show that the length and especially the diameter of the implants present a significant positive correlation with RFA values. The first finding is easily explained by the XiVE implant geometry and characteristics particularly designed to achieve a high primary stability: These implants are cylindrical screws based on a core with a self-tapping thread. The thread depth increases from the crestal region to the apex with the thread pitch remaining the same and as a result, the external diameter remains constant, but the shallower threads in the crestal part result in a condensation of the cortical bone. In particularly dense bone, this condensation is avoided by means of a special drill that slightly overprepares the first 6 mm of the implant site (Figures 2 and 3). The importance of the implant design was already reported by Meredith[16] and again by Da Cunha and colleagues[7] in a study carried out with TiUnite and standard Brånemark systems showing the higher RFA values of the latter. The importance of implant diameter and length is more controversial: Several authors have already suggested the use of wide implants to achieve a better primary stability,[17,18] and data from this study seem to confirm this clinical

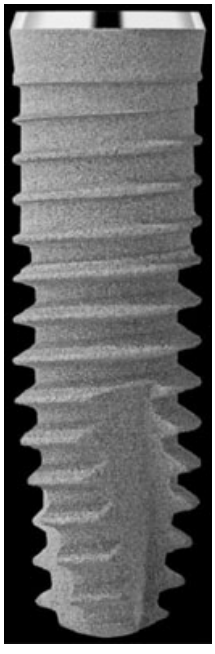

Figure 2 XiVE implant.

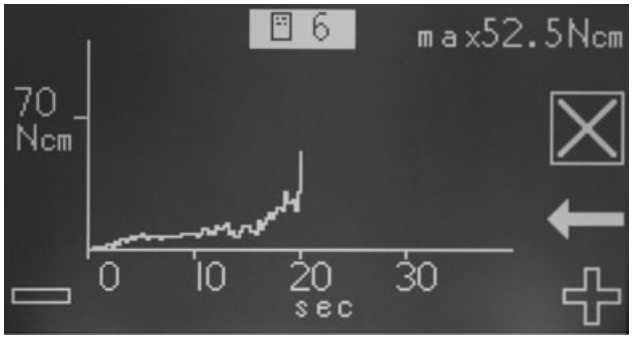

Figure 3 Curve from the insertion torque measurement.

assumption with higher RFA values for wide-diameter implants. Opposite results come from a recent study carried out on ITI implants placed both in the maxilla and mandible by Bischof and colleagues,[6] who reported a lack of influence of implant diameter on RFA values. The same study denies the importance of implant length for RFA values; again, data from the present study are different and implant length seems to be important for the primary stability at least at the time of implant insertion.

The third group is represented by surgical technique-related variables. The lack of correlation between RFA values and insertion torque found in this study is very similar to the results reported by the already cited study of Da Cunha and colleagues[7] about the correlation between RFA and cutting torque. On the other hand, Friberg and colleagues[13] reported that with TiUnite MKII implants (Nobel Biocare AB, Göteborg, Sweden), a significant relationship existed between cutting torque and RFA at implant placement in the upper/crestal third of the implants. Nevertheless, the same authors' final results show that there was no overall correlation between the two variables.

The positive statistically significant correlation between RFA values and the diameter of the last bur has to be attributed more to the diameter of the implant than to the use of a final bur with a diameter smaller than the implant: In fact, analyzing the data, nearly always the diameter of the last bur used was the same diameter of the implant.

CONCLUSIONS

Within the limitation of the present study, the results show that in a site that has undergone a sinus lift, a good primary stability can be assured after 6 months of healing. At implant insertion, very few factors seem to influence the RFA values. In particular, implant length and diameter, together with the geometry of the implant used, are important to obtain a good primary stability. Finally, the surgical technique used (one- or two-stage), the bone quality, and the insertion torque do not seem to be related to the primary stability of the implant measured by means of RFA values.

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