# Primary Stability Determination by Means of Insertion Torque and RFA in a Sample of 4,135 Implants

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## ABSTRACT

*Objectives:* The aims of the present study are to evaluate the primary stability of a sample of 4,135 implants and to investigate the correlations between primary stability and mechanical characteristic of the implant and bone density at insertion time.

*Material and Methods:* The study was conducted from March 2002 to January 2009 at a private practice in Bologna (Italy). Patients were eligible for the study if they needed the insertion of single or multiple implants. Bone density, length, and diameter of each implant were recorded. During surgery for each implant, peak insertion torque (IT) was recorded; the resonance frequency analysis (RFA) values were also collected. Finally, it was recorded whether an implant was lost or removed at an early stage (within 6 months from insertion surgery).

*Results:* A total of 1,045 consecutive patients were included in the study. A total of 4,135 of implants were inserted. The sample presented 1,184 implants inserted in a postextractive site. The mean peak IT was 34.82 ± 19.36. The mean RFA was 71.57 ± 10.63 implant stability quotient. Spearman correlation analysis shows the presence of a weak positive correlation between IT and RFA. The statistical analysis shows a relevant dependency between IT and bone quality and a very weak dependency between RFA and bone quality. Again, the statistical analysis shows a quite weak correlation between length or diameter and IT, but it shows a relevant correlation between length and RFA. Postextractive implants presented a higher mean IT and a lower RFA compared with implants inserted in healed sites. Twenty-eight (0.7%) implants were considered to have failed and removed within 6 months.

*Conclusions:* The results show that the implants studied obtain a good primary stability with a standard protocol. The IT and RFA appear as two independent features of primary stability. Data show that only IT is influenced by bone density as well as only RFA is correlated to the length of implants used. Finally, it is possible to obtain a good primary stability also in postextractive sites.

KEY WORDS: dental implants, insertion torque, postextractive implants, primary stability, resonance frequency analysis

## INTRODUCTION

Primary stability was always considered a fundamental prerequisite to acquiring osteointegration and it is now even more important, whenever clinicians want to use immediate loading protocols: the reliability of this technique was demonstrated by a good number of papers, but the stiffness of the bone/implant/crown system has to be assured to obtain a good result.[1]

Different methods to evaluate primary stability were proposed[2]: in particular insertion torque (IT) and resonance frequency analysis (RFA) seem to be the most trustworthy. The determination of the first is done by a torque gauge incorporated within the drilling unit; on the other hand, RFA is measured by an electronic device and a transducer tightened to the implant by a screw. Even if these methods are not widely diffused among the clinicians, several papers have been written to assess what are the optimal IT and RFA values for a reliable use of immediate loading.[3] At the same time, very few data are available to understand what the most commonly

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encountered values during the implant insertion surgery are; furthermore, the available papers[4–7] report data from small samples.

The aims of the present study are to describe the primary stability of a sample of 4,135 Xive implants, by means of insertion torque and RFA values, and to understand the correlations between primary stability and mechanical characteristic of the implant and bone density at insertion time.

## MATERIALS AND METHODS

The study was conducted from March 2002 to January 2009 at a private practice in Bologna (Italy). Patients were eligible for the study if they needed the insertion of single or multiple implants and if they fulfilled the following inclusion criteria: no need for bone augmentation procedures prior to implant placement, minimum bone width and height necessary to insert an implant with at least 8 mm of length and 3 mm of diameter, good oral hygiene. 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.

The implants used were XiVE implants (Dentsply Friadent, Mannheim, Germany): these implants are based on a cylindrical core with a self-tapping thread; the thread depth increases from the crestal region to the apex with the thread pitch remaining equal; the external diameter remains constant (Figure 1).

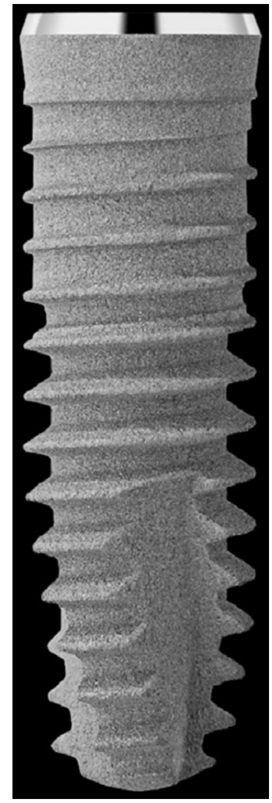

**Figure 1** Xive implant.

The surgical procedure was the following: 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. After a crestal incision, a mucoperiosteal flap was elevated. All the implants were inserted by a single oral surgeon according to a strict protocol following the manufacturer's instructions: in particular, the crestal twist drill was used with a 2-mm depth in D3 and D4 bone, with a 4-mm depth in D2 bone and with a 6-mm depth in D1 bone. The crestal twist drill was not used in postextractive sites.

Postsurgical analgesic treatment was performed using 100 mg of nimesulid twice daily for 3 days. Oral hygiene instructions were provided. The sutures were removed 14 days after surgery. Bone density was determined before surgery by means of panoramic and periapical radiographs and it was confirmed by the evaluation of the drilling resistance during implant bed preparation.[8]

In order to determine primary stability, for each implant peak IT was recorded by means of an electronic instrument (FRIOS Unit E, W&H Dentalwerk GmbH, Buermoos, Austria) during low-speed insertion. Immediately after insertion, implant stability was also measured by a single trained dentist using the RFA technique: implant stability quotient (ISQ) values were collected by means of a transducer attached to the implant via a screw and a frequency response analyzer (Osstell Mentor Device, Integration Diagnostic AB, Goteborg, Sweden).

Finally, it was recorded whether an implant was lost or removed at an early stage (within 6 months from insertion surgery). Implants were considered failed and thus removed according to the clinical criteria of mobility, pain, and gingival inflammation.

The protocol was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000. The subjects provided informed consent to participate in the study.

## STATISTICAL ANALYSIS

After a descriptive data analysis, Kolmogorov–Smirnov test was used to test the distributive normality. Mann–Whitney and Kruskal–Wallis tests were used to compare mean values. Spearman tests and Eta index were used to explore possible association between the studied variables. A further analysis with chi-squared test was performed to better investigate the significance of the variables studied in the failed implants group. A $p$ value <.05 was considered significant.

## RESULTS

Altogether, 1,045 patients (368 males, 677 females, age ranging from 18 to 93) were included in the study. A total of 4,135 of implants were inserted. The implants were distributed as follow: 606 in the anterior maxilla, 1,486 in the posterior maxilla, 280 in the anterior mandible, and 1,763 in the posterior mandible. The sample presented 1,184 implants inserted in a postextractive site. All range of lengths (8–9.5–11–13–15–18) and diameters (3.0–3.4–3.8–4.5–5.5) was used.

The mean peak IT was 34.82 ± 19.36. The mean RFA was 71.57 ± 10.63 ISQ. Figures 2 and 3 show the IT and RFA values distribution; the solid line shows the normal distribution. Spearman correlation analysis shows the presence of a statistically significant ($p$ = .0001) positive correlation between IT and RFA, even if this appears quite weak (0.218, where –1 means perfect negative correlation and 1 perfect positive correlation).

The mean peak IT and RFA with standard deviation of the implants divided by bone quality, length, and diameter are presented in Tables 1–3.

The distribution of the implants inserted in healed sites by bone density is as follows: 270 in D1 bone (9%), 944 in D2 bone (32%), 1,371 in D3 bone (46.5%), and 366 in D4 bone (12.5%). The distribution of the postextractive implants by bone density is as follows: 86 in D1 bone (7.3%), 766 in D2 bone (64.7%), 308 in D3 bone (26%), and 24 in D4 bone (2%).

The ETA analysis shows a relevant dependency between IT and bone quality, even if this appears not particularly strong (0.339, where 0 means no correlation and 1 means very strong dependency). The same analysis shows a very weak dependency between RFA and bone quality (0.140).

A further analysis was conducted, putting together the implants inserted in bone qualities D1, D2 in a group and the implants inserted in bone qualities D3 and D4 in

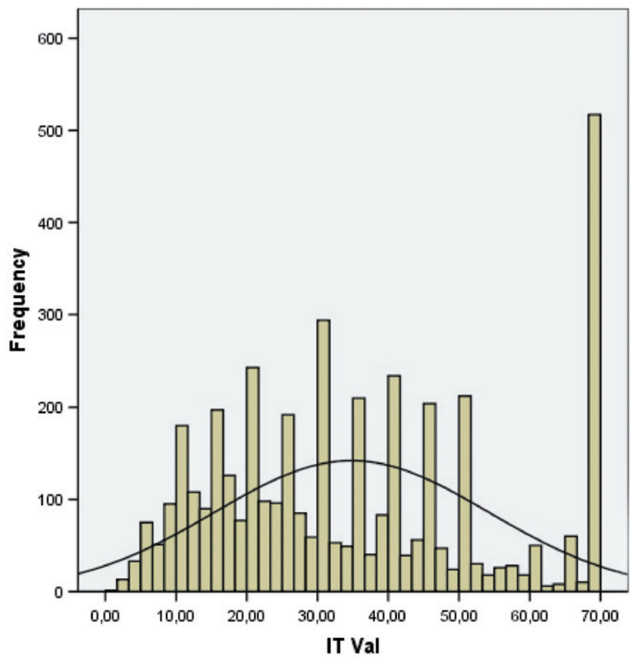


**Figure 2** Peak insertion torque (IT) distribution.

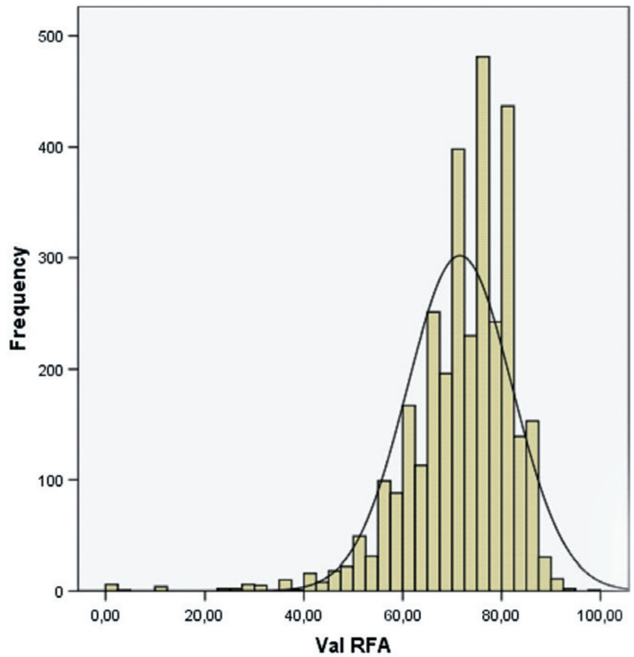


**Figure 3** Resonance frequency analysis (RFA) distribution.

**TABLE 1 Distribution and Mean Peak IT and RFA of the Implants by Bone Quality**

| Bone Quality | Number of Implants | Mean Peak IT | Mean RFA |
|---|---|---|---|
| D1 | 360 | 48.07 ± 17.66 | 73.19 ± 9.84 |
| D2 | 1,710 | 38.45 ± 19.02 | 72.04 ± 10.60 |
| D3 | 1,679 | 31.44 ± 18.08 | 71.86 ± 9.90 |
| D4 | 386 | 21.08 ± 15.56 | 65.93 ± 13.25 |

IT = insertion torque; RFA = resonance frequency analysis.

**TABLE 4 Distribution and Mean Peak IT and RFA of the Implants by Grouped Bone Quality**

| Bone Quality | Number of Implants | Mean Peak IT | Mean RFA |
|---|---|---|---|
| D1-D2 | 2,070 | 40.12 ± 19.13 | 72.22 ± 10.49 |
| D3-D4 | 2,065 | 29.50 ± 18.09 | 70.91 ± 10.73 |

IT = insertion torque; RFA = resonance frequency analysis.

a second group. The mean peak IT and RFA with standard deviation of the implants divided in this way are shown in Table 4. The Mann–Whitney test showed that the differences of IT and RFA in the groups were statistically significant ($p = .0001$ and $p = .001$, respectively).

The ETA analysis does not show a strong correlation between length or diameter and IT (respectively 0.072 and 0.199); on the other hand, a weak correlation was shown between diameter and RFA (0.097), but a relevant correlation was present between length and RFA (0.343).

**TABLE 2 Distribution and Mean Peak IT and RFA of Implants by Length**

| Implant Length | Number of Implants | Mean Peak IT | Mean RFA |
|---|---|---|---|
| 8.0 | 201 | 36.31 ± 20.78 | 71.53 ± 10.93 |
| 9.5 | 491 | 35.53 ± 19.98 | 73.97 ± 9.89 |
| 11.0 | 1,031 | 35.75 ± 19.43 | 73.84 ± 10.54 |
| 13.0 | 769 | 34.73 ± 19.23 | 70.61 ± 10.97 |
| 15.0 | 1,202 | 32.82 ± 18.04 | 69.93 ± 10.68 |
| 18.0 | 441 | 36.75 ± 21.08 | 70.18 ± 9.67 |

IT = insertion torque; RFA = resonance frequency analysis.

**TABLE 3 Distribution and Mean Peak IT and RFA of Implants by Diameter**

| Implant Diameter | Number of Implants | Mean Peak IT | Mean RFA |
|---|---|---|---|
| 3.0 | 417 | 27.55 ± 15.83 | 70.32 ± 11.63 |
| 3.4 | 1,406 | 32.27 ± 18.79 | 71.59 ± 10.03 |
| 3.8 | 1,269 | 35.80 ± 19.35 | 71.15 ± 10.47 |
| 4.5 | 761 | 39.33 ± 19.64 | 71.94 ± 11.29 |
| 5.5 | 282 | 41.67 ± 20.66 | 74.02 ± 11.28 |

IT = insertion torque; RFA = resonance frequency analysis.

The mean IT and RFA with standard deviation of the implants divided by surgical area are presented in Table 5. The ETA index shows a relevant correlation between IT and surgical area (0.306), but a weaker correlation between surgical area and RFA (0.252).

Postextractive implants presented a mean peak IT of 36.64 ± 19.47 Ncm versus a mean peak IT of 34.09 ± 19.27 Ncm of implants inserted in a healed site. The difference is statistically significant ($p = .0001$). Postextractive implants presented on the other hand a mean RFA of 71.12 ± 9.90 ISQ versus a mean RFA of 71.78 ± 10.96 ISQ of healed sites. Again, the difference is statistically significant ($p = .002$).

Twenty-eight (0.7%) implants were considered to have failed and removed within 6 months: Table 6 shows the details of failed implants. No statistically significant correlation was found between any of the variables considered and the implant failure.

## DISCUSSION

The achievement of a good primary stability is a prerequisite for implant success and different efforts were made to obtain its objective measurement. At the moment, IT and RFA seem to be the parameters most commonly recorded for this purpose; nevertheless, so far very few studies were conducted on large implant samples to understand what the IT and RFA value distribution is at the moment of implant insertion and how important the biomechanical properties of bone and implant are. The present study tried to answer these questions collecting primary stability data of a considerable number of dental implants.

The mean values of peak IT and RFA primarily show that the implants used are able to obtain a good primary stability with a standard insertion protocol. Mean peak IT found is similar to values reported by three different studies conducted by Turkyilmaz and colleagues[5,6,9]: the authors report mean values between 39.4

**TABLE 5 Distribution and Mean Peak IT and RFA of the Implants by Surgical Area**

| Surgical Area | Number of Implants | Mean Peak IT | Mean RFA |
|---|---|---|---|
| Posterior maxilla | 1,486 | 27.68 ± 17.72 | 69.06 ± 11.29 |
| Anterior maxilla | 606 | 33.56 ± 18.39 | 69.23 ± 9.50 |
| Posterior mandibula | 1,763 | 40.03 ± 18.79 | 74.68 ± 9.85 |
| Anterior mandibula | 280 | 43.42 ± 19.80 | 72.76 ± 8.82 |

IT = insertion torque; RFA = resonance frequency analysis.

and 41.5 Ncm on, respectively, 142, 158, and 60 Brånemark System implants. In the same studies, the authors reported mean ISQ values consistent with those measured in the present study (RFA values between 70.5 and 74.1 ISQ). Lower ISQ values were recorded by a study[7] on 905 Brånemark dental implants (67.4 ± 8.6). All these studies proposed a modified surgical protocol in order to achieve a higher primary stability.

The RFA and IT distribution graphs show that the values collected in the present sample do not follow a

**TABLE 6 Details of Failed Implants**

| Implant | Sex | Age | Position | Diameter | Length | Postextraction | Bone Density | Peak IT | RFA |
|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 66 | 27 | 3,4 | 18 | N | D2 | 8,4 | 66 |
| 2 | F | 67 | 13 | 4,5 | 18 | Y | D2 | 16,8 | 55 |
| 3 | F | 55 | 14 | 3,4 | 15 | N | D2 | 18 | 79 |
| 4 | M | 51 | 15 | 4,5 | 15 | N | D4 | 20 | 50 |
| 5 | F | 64 | 14 | 4,5 | 15 | N | D3 | 20 | 77 |
| 6 | M | 51 | 15 | 5,5 | 9,5 | N | D2 | 23,8 | 70 |
| 7 | M | 64 | 45 | 3,4 | 15 | N | D2 | 25 | 71 |
| 8 | M | 36 | 36 | 3,4 | 11 | N | D3 | 30 | 77 |
| 9 | F | 49 | 47 | 3 | 15 | N | D2 | 31,5 | 77 |
| 10 | F | 59 | 36 | 3 | 11 | N | D3 | 32,9 | 82 |
| 11 | F | 44 | 35 | 3,4 | 11 | N | D2 | 38 | 80 |
| 12 | F | 41 | 35 | 3,4 | 11 | N | D2 | 38 | 80 |
| 13 | M | 64 | 32 | 3,4 | 15 | N | D2 | 39 | 80 |
| 14 | F | 67 | 23 | 4,5 | 15 | Y | D3 | 40 | 73 |
| 15 | M | 36 | 47 | 3,4 | 11 | N | D3 | 40 | 80 |
| 16 | M | 36 | 46 | 3,4 | 11 | N | D4 | 40 | 80 |
| 17 | F | 49 | 36 | 3 | 13 | N | D2 | 42,7 | 70 |
| 18 | M | 53 | 24 | 3,8 | 15 | N | D3 | 44 | 81 |
| 19 | F | 71 | 44 | 3,8 | 13 | N | D3 | 49,7 | 87 |
| 20 | M | 68 | 31 | 3,4 | 18 | Y | D1 | 50 | 71 |
| 21 | M | 42 | 25 | 5,5 | 9,5 | Y | D2 | 50 | 79 |
| 22 | F | 54 | 45 | 3,4 | 13 | N | D1 | 50 | 81 |
| 23 | F | 48 | 11 | 3,8 | 15 | Y | D2 | 60 | 71 |
| 24 | F | 49 | 36 | 5,5 | 11 | N | D2 | 60,2 | 85 |
| 25 | F | 56 | 26 | 5,5 | 11 | N | D2 | 70 | 58 |
| 26 | M | 45 | 41 | 3 | 15 | Y | D3 | 70 | 65 |
| 27 | M | 53 | 34 | 3 | 13 | N | D1 | 70 | 74 |
| 28 | F | 41 | 26 | 4,5 | 11 | N | D2 | 70 | 77 |

F = female; IT = insertion torque; M = male; N = no; RFA = resonance frequency analysis; Y = yes.

normal distribution, presenting peaks of frequency between 70 and 85 ISQ for the RFA, and 70 Ncm for the IT. This second peaks of frequency is easily explained by the usual settings of the drill units that automatically stop when they reach 70 Ncm to avoid an excessive mechanical stress to the bone.

The correlation between RFA and torque, even if statistically significant, is very low, showing that the two variables are practically independent. This evidence seems to confirm that RFA and insertion torque represent two different features of primary stability, the first indicating the resistance to bending load, the latter indicating the resistance to shear forces.[3] Data presented by Turkyilmaz and colleagues[6] are in contrast with the results of the present study: analyzing 142 Brånemark implants, the authors report Spearman correlation of 0.583 that is very far from 0.218 reported here. The reason for this difference appears unclear, but it could be explained by the different design of the implants studied, as well as the smaller number of the sample.

The independency of RFA and IT makes the interpretation of the data recorded very difficult: analyzing Tables 1 and 4, the standard deviation reported shows that the implants inserted in D3 and D4 presented good ISQ values in nearly all the cases, but at the same time a bigger range of IT records, with also low Ncm values. Nevertheless, the very low incidence of early failures and the analysis of Table 6 corroborate the clinical impression that a high IT is not mandatory for osseointegration of the implants.

The analysis of Tables 1 and 2 shows also a weak correlation between bone density and ISQ values, even if, putting together the implants placed in D1 and D2 bone in one group and the implants placed in D3 and D4 bone in another, this second group showed significantly lower ISQ values than the first. A previous study in grafted and nongrafted sites[10] reported similar findings. On the other hand, the results of the present study are not consistent with already cited studies by Turkyilmaz and Östman, where the authors report a strong positive correlation between ISQ values and bone densities; the difference can be explained by several reasons.[1,5] First of all, the implant geometry was different: in the studies of Turkyilmaz and colleagues, parallel-walled Brånemark MKIII implants were used; in the other study both MKIII and tapered MKIV Brånemark implants were inserted. Again, in the first series of studies, bone density was assessed by means of a software incorporated in the CT machine and recorded in Hounsfield Units; furthermore, the number of records was quite small. Finally, both authors used a modified surgical protocol in order to achieve a higher primary stability, using a final bur smaller than the implant diameter or changing the implant geometry from a parallel-walled to a tapered implant in poor density bone.

The same tables show a stronger correlation between bone quality and IT, confirmed by a higher level of statistical significance when grouping implants placed in D1 and D2 bone density. These findings are consistent with the cited series of studies by Turkyilmaz and colleagues, even if the method to assess the bone density is different, as already discussed. Nevertheless, the results are similar to those reported by a paper of Johansson and colleagues[11] that shows an inverse linear relation between IT values and Lekholm and Zarb bone quality index.

The different importance of the bone density in the determination of IT and RFA is confirmed by the results reported in Table 5: the distribution of peak IT mean values shows that higher primary stability can be achieved in the areas where a better bone density is typically encountered and the correlation revealed by statistical analysis is relevant even if not extremely strong; on the other hand, the same table shows a more homogeneous distribution of the ISQ mean values and a weaker correlation with bone density.

Diameter and length of the implants do not seem to influence primary stability: in fact, only a quite weak correlation between RFA values and length was found. These results are consistent with a study conducted on ITI implants by Bischof and colleagues[12] who denied the importance of implant diameter and length in the determination of RFA values. On the other hand, the results are in contrast with other studies that reported a lower stability with increased implant length[7] or an importance of wider implant diameter for the achievement of a better primary stability.[4,7] It is quite probable that these controversial results are because of an absence of homogenity in the implants used, insertion surgery protocol, and dimension of the sample examined.

The primary stability data in postextractive implants show that XiVE implants are able to obtain good RFA and peak IT values even in this clinical situation: mean values are higher than those recently reported by Turkyilmaz and colleagues[13] on a cadaver study. A possible explanation for this difference can be the geometry of the implant used and the variability of vertical defect around the implants studied in the cadavers. More difficult to explain is the higher mean values of peak IT in the implants placed in the postextractive sites compared with the healed sites: considering the correlation reported between IT and bone density, a possible explanation can be found in the higher number of postextractive implants placed in D1 and D2 bone (72%) compared with the implants placed in a healed site with similar bone densities (41%). Furthermore, it is probable that the clinical situation drove the surgeon to a slight modification of the implant insertion protocol to always obtain good primary stability, for example avoiding the use of the crestal drill.

The very small number of failures found (0.7%) suggests that the use of cylindrical cored, parallel walled implants in healed and postextractive sites, without the need for bone augmentation prior to the insertion surgery, is an extremely reliable procedure, especially when an accurate selection of the patients and a precise surgical protocol are followed.

## CONCLUSIONS

Within the limitations of the present study, the results show that XiVE implants obtain a good primary stability with a standard protocol. The IT and RFA appear as two independent features of primary stability. Data show that only insertion torque is influenced by bone density as well as only RFA is correlated to the length of implants used. Finally, it is possible to obtain a good primary stability also in postextractive sites.

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