Original article

ISQ (RFA) vs BIC and torque: a histomorphometric and biomechanical analysis in humans

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The aim of the present study is to clarify the controversy and to demonstrate in human implants if a statistically significant correlation exists between the ISQ values and measurement of osseointegration (degree of osseointegration), the Torque-Out values and histomorphometric data of bone implant anchorage. Twelve implants were removed from the superior and inferior maxillaries of 12 patients after a healing period of about 60 days, 3 3i™ Osseotite and 9 MK III implant Ti-Unite and machined surface. The Torque-In values were computed during the implant placement. The Torque-Out test was computed at the time of removal. The ISQ values were taken before the Torque-Out test and before retrieval of the implants. Subsequently, histological specimens were prepared, and bone volume (BV), bone-implant-contact (BIC), and the number of threads in contact with the compact bone (n.Tcb) were measured. A lack of statistical significance was found between the values of ISQ and torque-out values (ρ= 0.391552 r^2=0.1533 P=0.2081), the percentage of bone-implant-contact (BIC) (ρ= 0.222076 r^2=0.0493 P=0.4879) and the peri-implant bone volume (BV/TV %) (ρ= 0.431972 r^2=0.1866 P=0,1608). The ISQ values and the number of threads in contact with the compact bone (n.Tcb) (ρ= 0.634807 r^2=0.403 P= 0.0266) were statistically significantly related. After two months healing Torque-in values were still statistically significantly correlated with the values of ISQ (ρ= 0.669018 r^2=0.4476 P=0.0174), while there was a lack of statistical significance between the values of ISQ and the clinical bone density (bone type) (ρ=-0.2477 r^2=0.06133 P=0.4377). A statistically significant correlation was found between BIC and Torque-out values, (ρ=0.905561 r^2=0.82 P=0.0001). Within the limits of the present study, the results suggest that the development of osseointegration after a healing period of two months, measured through the percentage of BIC does not influence the values of ISQ. On the other hand, the ISQ seems to be related to the cortical anchorage of the implants at two months healing.
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Key words: dental implant, implant stability, resonance frequency analysis, histomorphometry, torque test.

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INTRODUCTION

It is thought that the development of a stable bone-implant interface is an indispensable requirement for the long and short-term correct function of an implant. The development and the characteristics of the bone-implant interface can be influenced by the different geometric shapes of the implant surface and the bone where the implant is anchored. Therefore, it is in the common interest to develop and evaluate methods capable to measure different biomechanical properties of the bone-implant interface, either experimentally or in clinical practice.

In the past, histological analysis was considered the gold standard to measure the degree of osseointegration. This method, along with a biomechanical Torque-Out test are still today credited as the most reliable and objective methods available. Nevertheless, both methods are limited since they have been used only in experimental studies and since the samples are destroyed after the experimentation, they cannot be followed-up or monitored in time. Recently, new methods were developed to measure the non-destructive implant stability, there are literature reports on percussion tests, radiographs (BMD), cutting resistance, torque-in, impact hammer method (Periotest) and even resonance frequency analysis (RFA).

Table 1. The values of each implant at the time of the placement.

Implant and surface	Torque- in (N cm)	Bone-Type	Position inthe Jaws
N° 1 Osseotite	40	3.5	Mand. post.
N° 2 Osseotite	30	2.0	Mand. ant.
N° 3 Osseotite	20	3.5	Maxilla post.
N° 4 Mk III Ti Unite	45	2.0	Mand. ant.
N° 5 MKIII Ti Unite	20	3.5	Maxilla post.
N° 6 MKIII Ti Unite	45	4.0	Mand. post.
N° 7 MKIII Ti Unite	30	2.0	Mand. post.
N° 8 MKIII Ti Unite	50	2.0	Mand. post.
N° 9 MKIII Ti Unite	30	3.0	Mand. post.
N°10 MkIII standard	30	2.5	Mand. post.
N°11 MkIII standard	40	3.0	Mand. post.
N°12 MkIII standard	40	2.5	Mand. post.
Mean and SD	35 ± 9.7	2.79 ± 0.72	

Among these, the RFA is the most used in experimental studies, as well as in clinical practice, but many aspects still need to be clarified.

Resonance Frequency Analysis developed by Meredith et al.[1] uses specified resonance characteristics of acoustically excited implants and utilises a small L-shaped transducer which is screwed onto an implant fixture or abutment. The transducer comprises 2 piezoceramic elements, one of which vibrates by a sinusoidal signal (5 to 15 kHz). The other serves as a receptor for the signal. Resonance peaks from the received signal indicate the first flexural (bending) resonance frequency of the measured object. The specific value that indicates the implant stability of a given situation is called the resonance frequency.[1,2] In vitro and in vivo studies have suggested that this resonance peak may be used to assess implant stability in a quantitative manner.[3,4]

Currently, 2 RFA machines are in clinical use: the Osstell[tm] device (Integration Diagnostics AB, Göteborg, Sweden) and Implomates (Bio Tech One,Taipei,Taiwan). Osstell combines the transducer, computerized analysis and the excitation source into one machine closely resembling the model used by Meredith. In the early studies, the Hertz signal was used as a measurement unit.[1-5] Later, Osstell created the implant stability quotient (ISQ) as a measurement unit in place of Hertz. Resonance frequency values ranging from 3500 to 8500 Hz are translated into an ISQ of 0 to 100. A high value indicates greater stability, whereas a low value implies instability. The manufacturer's guidelines suggest that a successful implant typically has an ISQ greater than 65. An ISQ < 50 may indicate potential failure or increased risk of failure.[6]

However, until today there are no literature reports describing any exact values on long-term implant osseointegration, or any value that can identify an implant failure. Only very wide ranges are hypothesized since there are many variables that come into play. More frequently there are literature data that help identify the numerous factors that can influence such measurements, as for example, the characteristics of the bone tissue (density and quality), mono and bicortical anchoring of the implant,[7] the inclination of the transducer,[8] the effective length of the implant above the bone crest, the diameter of the implant, the micro and macro geometry of the implant[9]. Not only, but in a recent study, some authors explain how the simplicity of the algorithm used from Osstell's software to determine values of resonance frequency could produce erratic results, consequently the authors suggest using more suitable and precise software.[10]

In the first European Osseointegration Association Consensus Conference held in 2006 [11], some authors sustained that a single measure using RFA does not define the characteristics of the bone-implant interface and does not offer any reliable quantitative evaluation of the degree of osseointegration. Not only that, but the RFA would not have any prognostic validity on the development of the instability. These authors assert that the validity and reliability of RFA, from a clinical point of view, still remain to be demonstrated, for every implant system, such as the ISQ values which indicate the stability or the risk of loss of stability of the precise implant system.

Research evidence demonstrates that elevated values of ISQ in a specific implant indicates that the implant is stable, and if in a follow-up the ISQ values remain high, it would indicate that the stability is maintained; while low values of ISQ, or a lowering of the values with time would indicate risk of instability of the implant.[12] These evidences could prove to be valid, however, there are still many aspects that need clarification. First of all, there are no literature reports that demon-

Table 2. The values of each implant after about 2 months of healing.

Implant and surface	ISQ	Torque-out (N cm)	BIC (%)	BV (%)	n. Tcb
N° 1 Osseotite	68	32	30.42	50.76	4
N° 2 Osseotite	65	30	16.27	26.58	0
N° 3 Osseotite	60	15	17.91	25.95	0
N° 4 Mk III Ti Unite	76	40	31.78	60.23	11
N° 5 MKIII Ti Unite	60	30	32.54	42.52	0
N° 6 MKIII Ti Unite	79	40	44.81	37.33	5
N° 7 MKIII Ti Unite	72	55	55.18	52.26	8
N° 8 MKIII Ti Unite	74	60	65.36	62.70	7
N° 9 MKIII Ti Unite	70	65	63.58	33.18	3
N°10 MkIII standard	81	30	11.52	45.37	4
N°11 MkIII standard	73	55	53.93	60.05	8
N°12 MkIII standard	71	60	47.38	69.04	10
Mean and SD	70.75 ± 6.68	42.67 ± 15.89	39.22 ± 18.51	47.16 ± 14.42	5 ± 3.86

strate a correlation between RFA and the micro-movements of an implant inserted in the bone. If such a measurement was demonstrated to indicate the rigidity of the bone-implant interface, it could be expected that the results could be correlated with the density of the peri-implant bone volume, or the percent bone-implant contact, or at least with the necessary force to insert or remove the implant from the bone site. In the literature, this non destructive measuring method (RFA measuring) has been compared to radiograms, mechanical tests and histomorphometric tests giving contradictory results.[13-27]

The aim of the present study is to clarify the controversy and to demonstrate in human implants if a statistically significant correlation exists between the RFA values and measurement of osseointegration (BIC %), the Torque-Out values and histomorphometric data of bone implant anchorage, the percentage bone volume round the implant (BV) and the number of threads in contact to the compact bone (n.Tcb).

MATERIALS AND METHODS

Subjects and dental implant history

From 2002 to 2007, 12 patients (8 males and 4 females) have had necessity of implants removal for different reasons: pain, psychological and prosthetic difficulties. The subjects had no specific documented medical problems. The patients agreed to participate in the study and gave their informed written consent after receiving a thorough explanation of the surgical procedures. The study was performed in accordance with the Helsinki Declaration of 1975.

Twelve implants were removed from the superior and inferior jaws of 12 patients after about two months unloaded healing. (n=3 3i™ Osseotite [Implant Innovations Inc., Palm Beach Gardens, FL, USA], (n=3 MK III Standard and n=6 MK III TiUnite [Nobel Biocare AB, Goteborg, Sweden]). All the implants had a diameter of 3.75 mm and a length of 8.5 mm. The implants were inserted in the maxillary bones of subjects without the addition of any bone regeneration. The bone quality of each implant was measured by the operator during the standard surgical procedure, basing themselves on the manual perception of the cutting resistance and classifying them according to Misch system described in 1999.[28] The bone types were from the most dense (D 1) to the least dense (D 4). For the statistical analysis, the intermediate types (1-2, 2-3, 3-4) were classified as type 1.5 - 2.5 - 3.5. The preparation of the implant site was carried out with a conventional method. All the implants were submerged up to the crest and for each implant, a maximum torque measurement using a manual surgical torque wrench was made (Torque-In). The cover screws were placed and all the implants were submerged. The implant site placement into the jaws (mandible or maxillae, anterior or posterior) is shown in table 1.

Before removal ISQ measurement was performed according to Osstell. Subsequently, the Torque-Out test was measured using a dynamometric wrench. After the implants were all repositioned in the same position before the Torque-Out test, all implants were extracted using a trephine cutter of 4.5 mm and immersed in 10% formalin for histological studies.

Torque test

To measure the maximum resistance of insertion (Torque-In) a manual surgical torque wrench (NobelReplace™ Manual Torque Wrench – Surgical, [Nobel Biocare AB, Goteborg, Sweden]) was used. The Torque-In values were computed during the positioning of all the 12 implants. To measure the maximum removal torque (Torque-Out) a customized digital hand torque wrench was used to measure the peak reverse torque. In addition, electronic equipment consisting of a digital hand operated torque wrench,

Fig. 1.

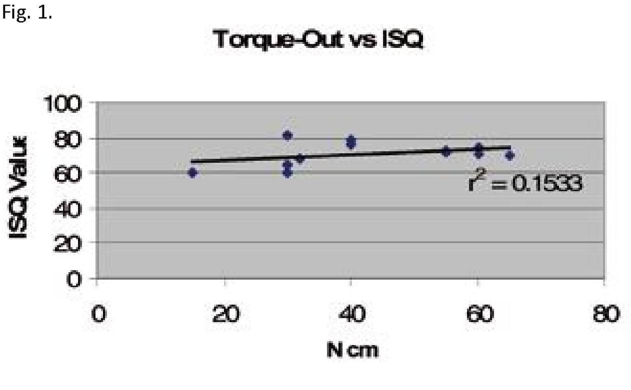


Figure 1. Scatter plot compares data points for values BIC vs Torque-out, Test-1. Positive liner trend line show that correlation could be found between bone implant contact percentage values and Torque-out values (Pearson coefficient of correlation ρ=0.905561; r^2=0.82) P=0.0001, is statistically significant

Fig. 2.

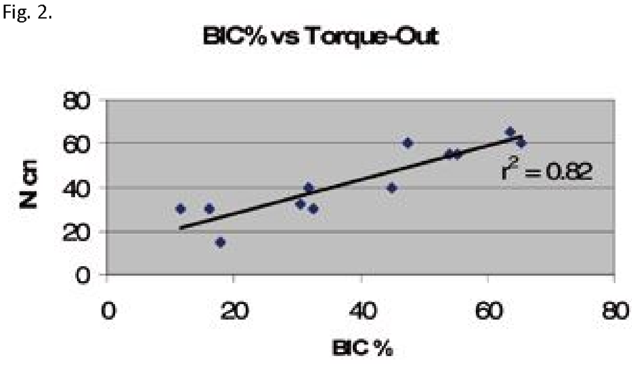


Figure 2. Scatter plot compares data points for values Torque-out vs ISQ, Test-2. Positive liner trend line show that no correlation could be found between torque-out values and ISQ values (Pearson coefficient of correlation ρ= 0.391552; r^2=0.1533) P=0.2081, is not statistically significant.

Fig. 3.

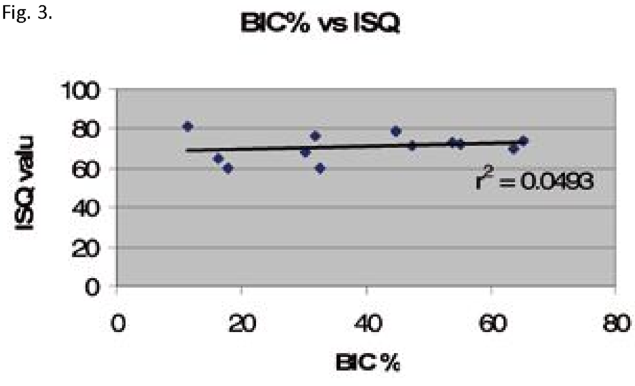


Figure 3. Scatter plot compares data points for values BIC vs ISQ, Test-3. Positive liner trend line show that no correlation could be found between BIC values and ISQ values (Pearson coefficient of correlation ρ= 0.222076; r^2=0.0493) P=0.4879, is not statistically significant.

Fig. 4.

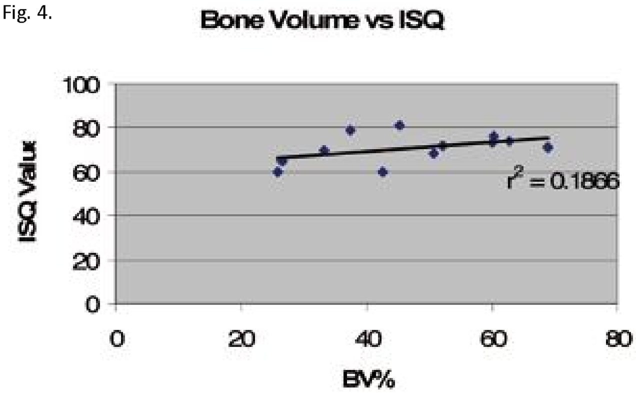


Figure 4. Scatter plot compares data points for values BV vs ISQ, Test-4. Positive liner trend line show that no correlation could be found between bone volume percentage values and ISQ values (Pearson coefficient of correlation ρ= 0.431972; r^2=0.1866). P=0.1608, is not statistically significant.

equipped with a calibrated strain gauge and connected to a PC reading the peak insertion torque value every 0.5 ms, was customized for this study. To obtain the peak extrusion torque, the signal was subsequently evaluated by the MECO-DAREC software (ATech s.r.l., Bergamo, Italy). When an implant was unscrewed, the peak torque value fell quickly when the rupture between bone and implant occurred; up to this moment no macroscopic movement of the implant was evident. After interface breakage the implant was repositioned as precisely as possible into the initial position. This tissue was fixed and processed to obtain a readable interface under histomorphometric analysis. In the past a similar procedure to study the morphology of the bone-metal rupture was used by Sennerby et al.[29] For both tests the peak values were taken to the closest numerical unity and calculated as Ncm.

Resonance frequency analysis

Resonance Frequency Analysis was calculated using Osstell (Integration Diagnostics, Göteborg, Sweden). The RFA measurements were performed on all 12 removed implants, and the values were registered in ISQ units (Implant Stability Quotient). This test was performed before the Torque-Out test and before removal of the implants. The transducers were specific for the implants and were screwed in the implants without the specific abutment. The screw-fixation of the transducer was obtained with 10 Ncm torque, even if some authors have demonstrated that the degree of screw-in transducer torque does not influence the measurement.[30] RFA values were meas-

Fig. 5.

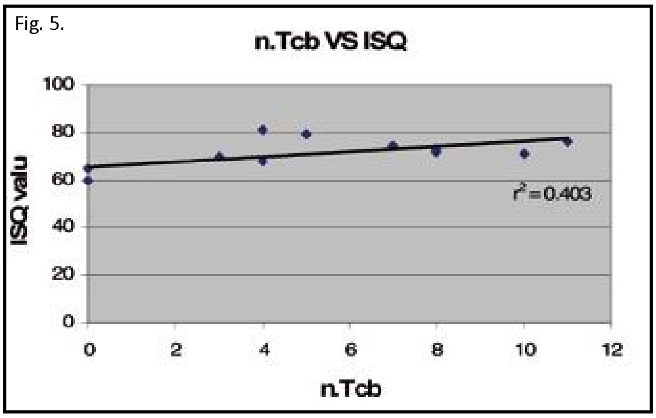


Fig. 6.

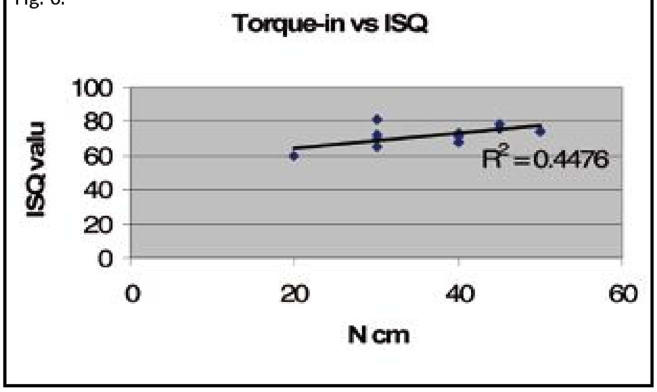


Fig. 7.

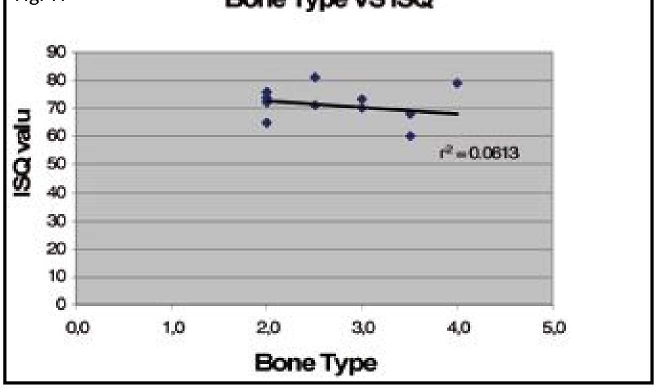


Figure 5. Scatter plot compares data points for values n.TCB vs ISQ, Test-5. Positive liner trend line show that correlation could be found between number of the threads in contact to the compact bone (n.Tcb) and ISQ values (Pearson coefficient of correlation ρ= 0.634807; r^2=0.403). P=0.0266, is statistically significant.

Figure 6. Scatter plot compares data points for values Torque-in vs ISQ, Test-6. Positive liner trend line show that correlation could be found between Torque-in values and ISQ values (Pearson coefficient of correlation ρ= 0.669018; r^2=0.4476). P=0.0174, is statistically significant.

Figure 7. Scatter plot compares data points for values Bone Type vs ISQ, Test-7. Negative liner trend line show that no correlation could be found between Bone type (clinical density) and ISQ values. (Pearson coefficient of correlation ρ=-0.2477; r^2=0.06133). P=0.4377, is not statistically significant.

ured in each implant.

Histologic and Histomorphometric Procedure

The evaluated specimens were infiltrated in methacrylate resin from a starting solution of 50% ethanol resin and subsequently 100% resin. Each step in this process required a 24-hour period. Photopolymerization was obtained using a 48-hour blue-light exposure, and the implants were oriented longitudinally to display the opposing surfaces. After polymerization, the blocks were ground to remove excess resin and expose the tissue and then glued on plastic slides using a methacrylate-based glue. A Micromet high-speed rotating- blade microtome (Remet, Bologna, Italy) was used to separate the section from the block to obtain a 250-µm-thick section. The section was ground down to about 40 µm using an LS-2 grinding machine (Remet, Bologna, Italy) equipped with waterproof grinding paper. After grinding, each section was polished with polishing paper and a 3-µm polishing cream. Two different staining procedures were used for these sections. Toluidine blue was used to analyze the different ages and remodeling patterns of the bone, and basic fuchsin was used to distinguish the fibrous tissue and for better contrast.

The histomorphometric analysis was performed by digitizing the images from the microscope via a JVC TK-C1380 color video camera (JVC Victor, Yokohama, Japan) and a frame grabber. Subsequently, the digitized images were analyzed by image-analysis software (IAS 2000, Delta Sistemi, Rome, Italy). The images were acquired with a 50 magnification of the implant and surrounding bone. For each implant the two most central sections were analyzed. The BIC percentage was expressed by considering the total length of the implant interface. The parameters calculated using the IAS 2000 software were:

- Bone volume % (BV/TV): the amount of bone matrix measured over the entire microscopic field. This measurement was accomplished by outlining the bone islands and surfaces to determine the surface area of bone in each particular microscopic field, representing in clinical terms "bone quality".
- Bone-to-implant contact % (BIC): the linear surface of the implant directly contacted by the bone matrix and expressed as a percentage of the total implant surface.
- n.Tcb: the number of threads in contact

Figures 8. (a: original magnification X 100; b: original magnification X 75) A space (arrow) is present between the implant surface and tissue, which indicates that the rupture has occurred between the implant surface and the bone. No fractures are visibile in the bone.

to the compact bone, both in crest and along the whole bone-implant interface. At times the compact bone was finded to the apex or along the implant surface.

Stastistical analysis

All 12 samples were incuded in the study. The linear Pearson coeficient of correlation (*ρ)* was used for the 7 items each one composed of 2 variables. For the first hypothesis the BIC % vs Torque-out values were included (Test-1); for the second hypothesis Torque-Out vs ISQ values were included (Test-2); for the third hypothesis BIC % vs ISQ values were evaluated (Test-3); the fourth hypothesis BV % vs ISQ values were included (Test 4); for the five hypotheses the number of threads in contact to the compact bone (n.Tcb) vs ISQ values were included (Test-5); for the six hypotheses Torque-In vs ISQ values were included (Test-6), and finally clinical bone density (bone type) vs ISQ values were included (Test-7). For each function an r^2 value was also calculated and graphed (scatter plots) where the linear trend line was shown to better explain the relevance of such a correlation. Significance testing was also made for each correlation (*P*-value).

RESULTS

All implants were regarded as clinically osseointegrated and stable, not one was mobile. Radiographically there was no appreciable peri-implant bone resorption. Table 1 shows, the torque-in (N cm), the clinical bone density (bone type) and the position in the jaws, at the time of the placement (Table 1). Table 2 shows for each implant, the ISQ values, the torque-out (N cm), the bone-implant contact (BIC %), the bone volume (BV/TV %), the number of threads in contact to the compact bone (n.Tcb) (Table 2).

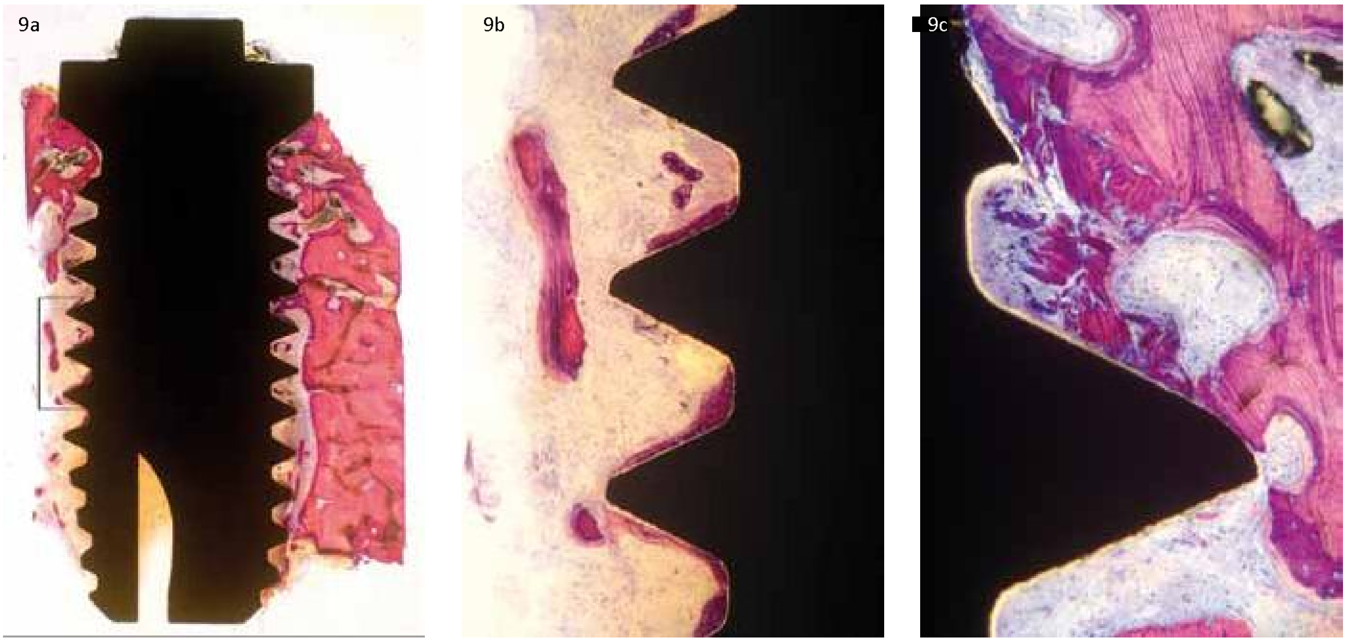
The linear Pearson Coeficient of correlation (*ρ)* and (r^2) values for each items (Test1-7) was: Test-1 (BIC vs Torque-out) ρ=0.905561 r^2=0.82 P=0.0001, the variables are correlated and test is statistically significant (Fig.1); Test-2 (Torque-Out vs ISQ) ρ= 0.391552 r^2=0.1533 P=0.2081, the variables are not correlated and the test is not statistically significant (Fig.2); Test-3 (BIC vs ISQ) ρ= 0.222076 r^2=0.0493 P=0.4879, the variables are not correlated and the test is not statistically significant (Fig.3); Test-4 (BV vs ISQ) ρ= 0.431972 r^2=0.1866 P=0,1608, the variables are not correlated and the test is not statistically significant (Fig.4); Test-5 (n.Tcb vs ISQ) ρ= 0.634807 r^2=0.403 P= 0.0266 the variables are correlated and test is statistically significant (Fig.5); Test-6 (Torque-In vs ISQ) ρ= 0.669018 r^2=0.4476 P=0.0174 the variables are correlated and test is statistically significant (Fig.6); Test-7 (Bone Type vs ISQ) ρ=-0.2477 r^2=0.06133 P=0.4377 the variables are not correlated and the test is not statistically significant (Fig.7).

Histologic Results

Ground sections of this samples, clearly showed that the rupture occurred close to the implant surface and not within the bone. Sometimes, a gap was present between the implant surface and the bone and no tissue remained on the implant surface. (Figs. 8)

- Osseotite implants

The osseotite implants showed a certain degree of osseoconduction. Since the three most coronal threads are machined surface few degree of bone implant contact was found in this region of the implant. Conversely, the more apical threads show higher level of bone conduction in the typical flowing pattern. Nevertheless in cancellous bone the new trabeculae formed on the titanium surface were very thin and made of woven bone. In the crest bone was still incompletely remodelled and microc-



Figures 9. The osseotite implants showed a certain degree of osseoconduction. *(a: original magnification 8 X; toluidine blue-basic fuchsine)* Since the three most coronal threads are machined surface few degree of bone implant contact was found in this region of the implant. Conversely the more apical threads show higher level of bone conduction in the typical flowing pattern. *(b: original magnification X 25)* Nevertheless in cancellous bone the new trabeculae formed on the titanium surface were very thin and made of woven bone. In the crest bone was still incompletely remodelled and microcracks, lamellar delamination and bone debris were still visible. *(c: original magnification X 100)* Large osteoid bands coupled with osteoclastic resorption lacunae testify the active on going remodeling.

racks, lamellar delamination and bone debris were still visible. Large osteoid bands coupled with osteoclastic resorption lacunae testify the active on going remodeling. (Figs.9)

- Ti Unite implants

Ti unite implants showed a high level of osteoconduttivity. Both in cortical crestal regions and in cancellous areas these implants had large amount of implants surface covered by new bone. The trabeculae facing the implant surface were quite thick made of composite bone. Remodeling fenomena were evident in all samples. (Figs.10)

- MkIII standard implants

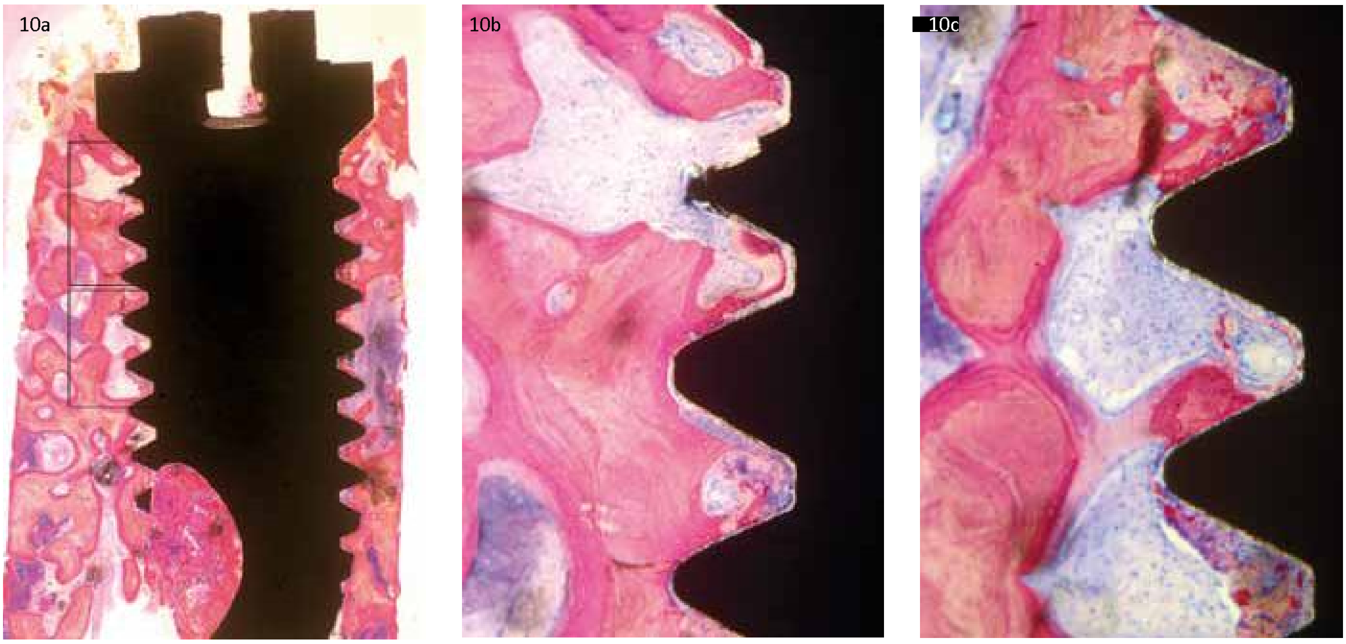
These implants showed the typical pattern of machined implant. The bone contacted implant surface in dense bone while in cancellous bone few contact points were evident. Dense fibrous tissue was facing the titanium-machined surface in marrow areas. This could represent the initial stage of bone formation due to the early stage of implant retrieval. (Figs.11)

DISCUSSION

The results of the present study showed that the ISQ is not statistically related to the percentage of osseointegration (BIC%), contrarily a statistically significant correlation was found between BIC and Torque-out values.

The calculation of the percentage of the bone-implant-contact is considered one of the best methods to analyze the bone-implant interface and therefore infers the biomechanical properties of the interface. Osseointegration may only be measured by destructive methods such as histomorphometric analysis of percentage bone-implant contact (BIC) or by mechanical measurements of torque removal.[31] Also in the present study the values of the percentage of bone-implant contact and the values of torque-out were directly correlated and showed an elevated statistical significance (Fig.1 ρ=0.905561 r^2=0.82 P=0.0001).

No statistically relation between the values of ISQ and torque-out values was found (Fig.2 ρ= 0.391552 r^2=0.1533 P=0.2081). To our knowledge, there are no studies that are similar to the present one. Akkocaoglu et al. in a human cadaver study, show that there is no correlation between the values of ISQ and the values of torque removal for implants placed into freshly prepared extraction sockets without healing.[19] In the present study the removal torque was performed after about two months of unloaded healing.



Figures 10. Ti unite implants showed a high level of osteoconduttivity. *(a: original magnification 8 X; toluidine blue-basic fuchsine)* Both in cortical crestal regions and in cancellous areas these implants had large amount of implants surface covered by new bone. The trabeculae facing the implant surface were quite thick made of composite bone. *(b: original magnification X 25)* Remodeling fenomena were evident in all samples. *(c: original magnification X 25)*

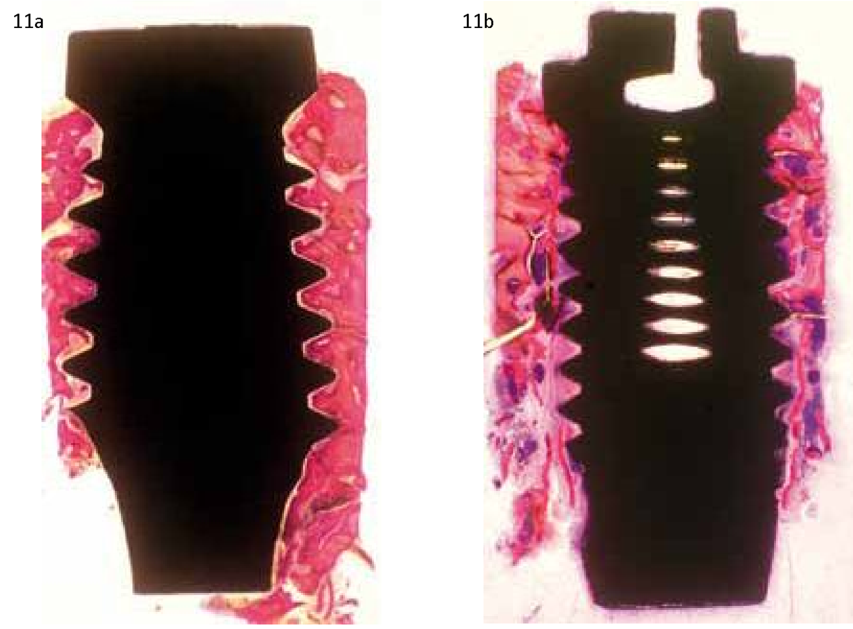
No correlation between the values of ISQ and the percentage of bone-implant-contact was found (% BIC) (Fig.3 ρ= 0.222076 r^2=0.0493 P=0.4879) and the peri-implant bone volume (% BV/TV) (Fig.4. ρ= 0.431972 r^2=0.1866 P=0.1608), but only between the values ISQ and the number of threads in contact with the compact bone (n.Tcb) (Fig.5 ρ= 0.634807 r^2=0.403 P=0.0266, the correlation was statistically significant). Rocci et al. in a human study, could not establish a correlation between ISQ values and BIC % for implant placed in the posterior mandible and retrieved after 2 months healing and 5-7 months of prosthetic load.[23]

The results of the present study are also confirmed by studies performed on living dogs[22] and in pigs[24] at different times of healing. No correlation was found between the percentage of BIC and the values of ISQ in both the studies, analyzed implants after a healing period of 1 and 3 months in dogs, and of 1, 2 and 4 weeks in pigs. However, in pig tibias Ito et al. [24] underline that BIC vs ISQ values are not correlated, but if the percentage of the bone-implant contact is analyzed at the level of the implant crest the correlation increases.

The present study demonstrates that there is a correlation between the values of ISQ and the number of threads in contact with the compact bone, both in the crest and along the entire bone-implant interface; in some samples compact bone was found at the apex or along the lateral surface.

Similar results were found in a experimental study on cadaver jaws[18] in which the histomorphometric analysis was performed at the time of implant placement. The authors found that the BMD values, TBPf (trabecular bone pattern factor), BV/TV (density of trabecular bone) were not related to ISQ, while the BIC measured on the lingual aspect of the implants gave a positive correlation with ISQ values; this correlation increased only when implants were in contact with the cortical bone. A similar positive correlation (the height of the cortical passage implants vs ISQ) was found by Miyamoto et al.[25], who digitally measured (Computed Tomography) the thickness of the cortical bone at the implant sites (mesial and distal). In another human study a micro-CT was used for measurements of the BVD (bone volume density) and BCT (bone trabecular connettivity) of the implant site before the insertion of the implant, no significant correlation was found with values of ISQ.[26]

These data lead us to hypothesize that RFA measures the rigidity of the bone-implant complex only within the com-



Figures 11. MkIII standard implants showed the typical pattern of machined implant. The bone contacted implant surface in dense bone *(a)* while in cancellous bone few contact points were evident *(b)*. Dense fibrous tissue was facing the titanium machined surface in marrow areas. This could represent the initial stage of bone formation due to the early stage of implant retrieval. *(a,b: original magnification 8 X; toluidine blue-basic fuchsine)*

pact bone, while it does not account for osseointegration in cancellous bone.

The insertion torque measures, in Ncm, the maximum torque of insertion obtained during implant placement until it is totally lodged in its site. Such a procedure may be influenced by the preparation of most bone sites, the bone density and the type of implant (self-tapping or not, cone-shaped or cylindrical). High insertion torque values correspond to a high degree of primary stability of an implant [32]. It has also been demonstrated that insertion torque values is correlated with bone mineral density (BMD) of the receiving bone site, obtained by measuring TC or micro TC[33-35], or by the sensitivity of the operator during the preparation of the surgical site[36]. Such measurements have therefore been considered valid instruments for the determination of the quality of the implant site, and can foresee good primary stability of the implant.

With regard to measuring RFA, there are human studies that assert a correlation between the values of RFA (ISQ) measured at the time of implant placement and the values of insertion torque[13-15]. In other studies this correlation is confirmed for Hounsfield values of the implant site calculated using TC[16,17].

In the present study the ISQ value was measured about 60 days after implant positioning, while torque-in test and clinical bone density (bone type) was executed during implant placement. It was found that torque-in values were still statistically related to the values of ISQ (Fig.13: ρ= 0.669018 r^2=0.4476 P=0.0174, statistically significant correlation), and this data could lead to hypothesize that such correlation could have been found at the time of implant placement similarly to the previously mentioned studies[13-15].

There are, however, literature reports that demonstrate a lack of correlation between the Torque-In test and ISQ values measured at implant insertion on cadavers[18,19], in humans[15,20,21] and in dogs[22].

In the first studies[15] finding a correlation between RFA and cutting-torque, only the cutting-torque at the crest (first third of implant insertion) was correlated, while the overall insertion torque values were not related to the ISQ.

Unlike the torque-in, the clinical bone density was not correlated to the values of ISQ measured two months later (Fig.7 ρ=-0.2477 r^2=0.06133 P=0.4377); this may be questionable, but at the time of ISQ measurement a correlation between the values of ISQ and the percentage of bone volume (% BV/BT) was not found.

The only humans study in the literature which found a correlation between the ISQ and the %BIC is from Scarano et al. [27] In this study[27] seven implants were evaluated while in the present study 12 implants were analized. The reason for the different results from the present study could be due to the particular statistical analysis performed, or to the different healing time and number of implants. In that humans study [27] the implants were unloaded and retrieved after a healing period of six months. It is also possible that a longer healing period may allow for a more reliable results of the ISQ values accounting for the BIC %.

In conclusion, the degree of osseointegration can be measured only through mechanical test of removal torque or through the histomorphometric analysis of the % of BIC, which are highly statistically related. The ISQ values were statistically significant related to the number of threads in contact to the compact bone and after two months from the implant placement such values were related to the torque-in values.

Within the limits of the present study , these results can imply that the development of the osseointegration after a healing period of two months, as measured through the percentage of BIC, does not influence the values of ISQ. The ISQ depends, strongly on the quantity of cortical bone and does not account for the osseointegration in cancellous bone, it does not measure the % of osseointegration, but only the cortical anchorage. Further studies in humans implants are need to better clarify these aspects of the ISQ values.

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