Insertion torque and resonance frequency analysis (ISQ) as predictor methods of implant osseointegration

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ABSTRACT

Aim Determining appropriate primary stability at time of implant placement is a key therapeutic decision. The aim of the study was to compare insertion torque and implant stability quotient (ISQ) obtained at the time of implant placement, as predictors of osseointegration.

Methods There were 31 implants evaluated in the maxilla and 29 in the mandible. A "High Torque Indicating Ratchet Wrench" was used for the measurement of insertion torque and a "Osstell Mentor®" to register the ISQ value at the end of each surgery. At 6 weeks counter-torque was performed on each implant using a "Low Torque Indicating Ratchet Wrench" applying 20 to 32 Ncm. Successful osseointegration was appropriately obtained with torque insertion of 35 or more and an ISQ of 60 or more without mobility, as well as torque insertion less than 35 and an ISQ less than 60 with mobility. The results, contrary to those described above, were considered to be failure. The use of ROC (Receiver Operating Characteristic) curves establishes differences between the two methods. Contingency tables and Kappa statistics were used to analyze the coincidence results between methods. Insertion torque was used as the Gold Standard. The significance level used is $\alpha \leq 0.05$.

Results In the ROC curve analysis, the area of value was 0.611 ($p > 0.05$). The Kappa statistic value was 0.208 ($p > 0.05$) and there are no discrepancies between success and failure between the two methods compared.

Conclusion Both methods tend to have the same results in relation to the studied variables.

INTRODUCTION

Dental implants require proper osseointegration for lasting aesthetic and functional rehabilitation. Stability is one of the requirements to achieve adequate osseointegration (1) in implants, and is divided into two phases. The first, primary stability is clearly mechanical and consists in the strength and stiffness of the bone implant bonding by pressure at the time of insertion, determining whether or not it is subject to load. This stability reduces with time, as remodeling of the surrounding bone occurs. Subsequently the secondary phase occurs, also called biological, when new bone formation in direct contact with the implant surface forms (2-4).

Various devices and techniques for measuring this variable have been developed such as, for example, insertion torque, which is the force used to insert the dental implant, the reverse torque based on unscrewing the implant bone and resonance frequency analysis (RFA), a noninvasive method that measures the frequency of oscillation, inside the bone tissue (5-7). In the RFA method, the implant is subjected to a slight lateral force causing lateral displacement of the implant due to the elastic deformation of the bone. This resonant frequency is expressed as an electromagnetically implant stability quotient (ISQ) in units ranging from 1 to 100. Low values indicate instability and higher values greater stability, as well as representing the stiffness of the implant-bone interface. ISQ levels for successfully osseointegrated implants fluctuate in a range of 57 to 82, with an average of 69; whereas implants with ISQ values less than 50 indicate high risk of failure (5, 8-9). Single implants immediately loaded or following standard protocol, have equally resulted successful in respect to survival and marginal bone loss, when they have been placed with a minimum torque between 20 and 45 Ncm or ISQ values of a minimum between 60 and 65 (10). Other studies have established that a value of 35 Ncm or an ISQ of 60 or more establishes adequate primary stability when the implant is subjected to load (11,12). The reverse torque test has also been proposed for evaluating the stability of the implant at the time of connection. Reverse torque of 20 Ncm, appears to be a safe and reliable method for verifying osseointegration (13). The aim of this study was to compare insertion torque and implant stability quotient (ISQ) obtained at the time of implant placement, as predictors of osseointegration.

FIG. 1 High Torque Indicating Ratchet Wrench® Biomet3i.

FIG. 2 Ostell Mentor® of third generation.

FIG. 3 Low Torque Indicating Ratchet Wrench® (Biomet3i).

METHODOLOGY

Case selection (admission criteria)

Data was obtained from 60 implant surgeries using 3i Biomet Osseotite units, 31 placed in the maxilla and 29 in the mandible. Pre-operative evaluation included clinical examination, panoramic and CBCT X-ray in the area of intervention.

Inclusion criteria: Men and women over 18 years. Patients that are in need of implant rehabilitation of one or two teeth, and are physically able to tolerate conventional surgical procedures and rehabilitation.

Exclusion Criteria: Patients: a) Infection and/or inflammation at the surgical site; b) Heavy smokers (more than 10 cigarettes a day); c) Uncontrolled Diabetes Mellitus; d) Metabolic bone diseases such as osteomalacia, primary or secondary hyperparathyroidism, renal osteodystrophy, or Paget's disease; e) A history of radiation treatment for the head and neck; f) In need of bone graft at the site intended for implant rehabilitation; g) Being pregnant at the time of the pre-surgical evaluation; h) Evidence of parafunctional habits such as bruxism or clenching. In patients requiring extraction of teeth after rehabilitation with implants, it is necessary to wait a period of 3 months, for healing.

All participants were orally informed about the characteristics of this research, its benefits and absence of any harm. In addition, these characteristics were also explained by an informed consent, in accordance with the rules of Helsinki, which was signed in order to participate in the study.

MATERIALS AND METHODS

Implants 3i Osseotite parallel with diameters of 4.0 and 5.0 mm were used with lengths of 10, 11.5 and 13 mm that were positioned by two calibrated operators (specialist in oral implantology) according to standard drill sequence by the manufacturer. In all cases access was made using a full thickness flap exposing the surgical area. All implants were placed in a single surgery (one or two single implants according to the case) and were in an epicrestal position. Patients were not considered if a bone graft was needed, but in those cases during surgery if it was evident that lateral undercuts were needed to help regenerate the implant after placement, it was acceptable to add particulate bone.

A high torque indicating ratchet wrench (Fig. 1) was used to measure the insertion torque and an analysis device of resonance frequency Osstell Mentor® (Fig. 2) to register the ISQ value at the end of each surgery. The implants were connected to the oral cavity by a healing abutment. At 6 weeks counter-torque was conducted to each implant using a low torque indicating ratchet wrench (Fig. 3) by applying a force from 20 Ncm up to 32 Ncm, when there was no mobility.

TORQUE 35Ncm or more at the surgery	Valid n (according list)
Positive	45
Negative	15

TABLE 1 Summary of the case process in the Gold standard method.

The following criteria were considered to define success or failure in predicting osseointegration, after applying counter-torque at 6 weeks:

Success, when:

- With insertion torque of 35 or more, no mobility.
- With ISQ of 60 or more, no mobility.
- With torque less than 35, there was mobility.
- With less than ISQ of 60, there was mobility.

Failure, when:

- With torque 35 or more, there was mobility.
- With ISQ of 60 or more, there was mobility.
- With torque less than 35, no mobility.
- With ISQ less than 60, there was no mobility.

According to the criteria proposed, Success (1) or failure (0) was recorded when comparing the torque and ISQ data obtained at baseline, with mobility or not at the counter-torque test at 6 weeks.

Statistical analysis

The observed data of the above-explained methods were compared using ROC curves for nonparametric distributions in order to determine the discriminatory ability to observe true positives with respect of one method to another (14,15). It estimates, by the contingency table and Kappa statistic, in order to analyze the coincidence of the results between the compared methods (16). The significance level in all cases was $\alpha \leq 0.05$.

RESULTS

In Table 1, the results of the positive and negative values in the method chosen as the Gold standard (Torque 35 Ncm) are presented, considering that the value of 1 was chosen as success. In Figure 4, the results in the graph showing the area of the ISQ of 60 method in relation to the diagonal that determines the same area between true positives (susceptibility) and false positives (1-specificity) are presented. Table 2 shows that the value of the area was 0.611; a value observed as not significant (p <0.05). The value of this area does not reach 0.7, considered the critical minimum to determine discrepancies between the methods in relation to the finding the proportion of true positives greater than false positives in absolute and statistical terms. The value of standard error determines that the lower range limit is practically equal to 0.087.

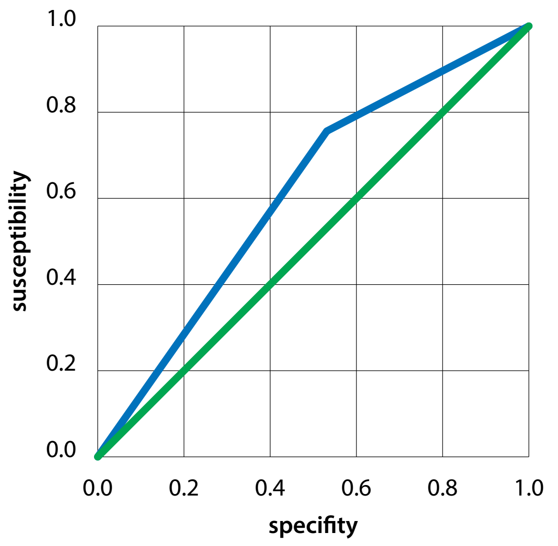

FIG. 4 ROC Curves Graphic. Results of the graph of the estimated area under the curve that estimates the degree of the difference between the two methods studied.

In Table 3, a two by two contingency table shows the observed and expected value for each method and Table 4 shows the results of the Kappa statistic, which had a value of 0.208 with a standard error of 0.135. This statistic was not significant (p> 0.05), indicating that there are no discrepancies between successes and failures between the two methods compared. However, the significance level is close to 0.05 which shows that there is a possibility an increase of the sample could show different trends from those found in this work.

DISCUSSION

The implant stability is a critical factor to consider in the prosthetic rehabilitation, since all loading protocols

Area	Typical error	Asymptotic significance	Asymptotic confidence interval at 95%	
			Lower limit	Upper limit
0.611	0.087	0.20	0.44	0.782

TABLE 2 Value of the area.

			ISQ of 60 or more in surgery		Total
			0	1	
TORQUE 35 Ncm or more in surgery	0	Count	7	8	15
		Expected frequency	4,5	10,5	15,0
		Count	11	34	45
Total	1	Expected frequency	13,5	31,5	45,0
		Count	18	42	60
		Expected frequency	18,0	42,0	60,0

TABLE 3 Contingency table. TORQUE 35 Ncm or more in surgery * ISQ of 60 or more in surgery.

		Value	Typical Asymptotic error	Approximate T	Approximate significance
Measure of agreement	Kappa	0.208	0.135	1.627	0.104

TABLE 4 Kappa statistic estimation between the two methods studied.

require a stable mechanical connection between the implant and bone (7,10,11). This study intended to establish which method between insertion torque and RFA, is more predictive of osseointegration when performing counter-torque at 6 weeks. Despite that the result was close to showing statistical differences, there were no differences between the methods to demonstrate success or failure in osseointegration. This is in agreement with *in vitro* experiments of Trisi et al. (17), who found a positive correlation between insertion torque and ISQ. As well as clinical studies of Turkyilmaz et al. (18) that found a positive correlation between insertion torque and ISQ values ($r = 0.853$; $p < 0.001$).
A strong correlation was observed between insertion torque and RFA methods for evaluating primary stability, by meta-analysis (3). These results coincide with the findings in this paper.
It has also been shown that there is positive correlation between insertion torque and RFA when evaluating the stability of implants positioned in the maxilla and mandible and in bones of different densities. Both values of insertion torque and RFA obtained were significantly greater in denser bone, such as the mandible (19).
Several studies have shown the evaluation of stability of implants through RFA as noninvasive method proven to be efficient and with a high degree of reliability (20-22). Its advantage lies with the possibility to assess stability over time, making this method a good choice for establishing primary stability and thus predicting the osseointegration of implants.
However, a meta-analysis of Momen et al. (23) found that measuring RFA upon implant placement is not sufficiently accurate to determine the stability of implants and osseointegration during immediate loading protocols. This study leads us to conclude that RFA is just a method of assessment and the ability to establish when to submit an implant load depends on multiple factors that must be evaluated by the clinician.

CONCLUSION

There were no differences found when comparing both methods as predictors of osseointegration. However, the differences of values between the methods compared have a relatively low probability of rejecting the null hypothesis and the probability that the value could possibly change with increasing the sample size. As a result, to confirm this lack of differences between the methods studied, the study needs to be repeated with a larger sample in order to obtain more conclusive results.
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