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Original article

ASSESSMENT OF PRIMARY AND SECONDARY IMPLANT STABILITY BY RESONANCE FREQUENCY ANALYSIS IN ANTERIOR AND POSTERIOR SEGMENTS OF MAXILLARY EDENTULOUS RIDGES

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ABSTRACT

Purpose: The aim of this study was to analyze the implant stability quotient (ISQ) results of the resonance frequency (RF) during the first day of surgery and 3 months after dental implant placement in the maxilla.

Material and methods: This study was approved by 40 patients with total or partial edentulous maxillary jaws underwent with 85 dental implants. The ISQ values were measured from these 85 implants at baseline and 3 months after placement. Osttell Mentor device was invented to measure the RF value of the implant fixture through the transducer or pin. Measurements were taken 4 times in each direction of the inserted oral dental implant. OPG X-ray images were also obtained to evaluate the bone and neighbouring anatomical structures.

Results: The ISQ at baseline had a mean value of 58 (SD 5.91) for all implants placed in anterior and posterior sectors of maxillary ridges. The mean ISQ value on the 3rd month (secondary stability) after placement for all implants was 65 (SD 5.55). An ISQ value ≥65 was observed in 65 implants (78.82%) after 3 months of placement. Differences between primary and secondary mean ISQ values were statistically significant ($p < 0.001$). The one year cumulative success rate was 98.3% for tested and inserted oral implants.

Conclusion: The results of presented study demonstrates and suggests that the influence and reliability of Osstell ISQ values, measured immediately and 3 months after placement it's predictable for the oral implant outcomes, especially analyzing the sensibility of secondary RFA values.

Keywords: dental implants, maxilla, implant stability, implant stability quotient, resonance frequency analysis,

INTRODUCTION:

Oral implant treatment in the last 2 decades has been widely and increasingly used to provide support for prosthesis replacing missing teeth in edentulous and partially maxillary or mandible dentate patients.

Primary implant stability which is essential for osseointegration process has been firstable established by Branemark in 1985 [1, 2]. The main requirement of implant therapy depended on bone quality and quantity, dental implant design, and drilling protocol. Osseointegration (primary and secondary) is the main issue in the early days of the implant dentistry.

Primary stability of the implants mainly depends on bone-to-implant contact, press-fit structure into a bone cavity, mechanical engagement with cortical bone and belongs on the three major factors: bone quantity and quality, the mechanical shape of the fixture placed in the bone, and the surgical procedure [3-5]. Secondary stability involves initial healing process around the dental implant, and it's determined by primary stability process of osseointegration who developed from regeneration and remodeling of the

bone and tissue around the inserted dental implants [6, 7]. Also, implant interface and implant design with characteristics as most complex healing process plays an important role in the success of implant placement.

The main goal in oral implantology is to achieve and measure the fixation stability after implant placement at any time during the healing period by resonance frequency analysis (RFA) [8-10]. Early diagnosis of primary stability and micro mobility for dental implants (in the mandible and maxillary edentulous ridges) it may provide useful information for the next phase, or secondary stability of implants. RFA as widely accepted, the objective and noninvasive method might be reliable, easily predictable for quantifying implant stability [11-13].

The aim of this study was to measure, estimate and compare the ISQ results between primary and the secondary (after 3 months of placement) stability using an RFA device and to detect possible changes in stability.

MATERIAL AND METHODS:

This study included the implants placed for implant-supported rehabilitation of the anterior and posterior sectors of maxilla at the Private Dental Office Vita Dent, Tetovo, Republic of Macedonia. In the period between October 2010 and October 2013, stability measurements were taken on a total number of 85 consecutive MIS SEVEN implants placed in 40 (23 men and 17 women) partially or completely toothless patients. MIS SEVEN are implanted with the color-coded internal hexagonal connection, assuring proper implant abutment seating, anti-rotational engagement, resistance to lateral forces, and esthetic results. Patients were selected to meet the following inclusion criteria: collaborated patients between 37-79 years old with partial or total edentulism/toothless for at 3 least months from tooth loss, residual bone height ranging from 6 to 8 mm and sufficient bone width in the edentulous region (≥6 mm).

All patients were studied following our clinical-implantologic protocol for prosthetic rehabilitation. The systematic health condition of all the participants was recorded, and they fulfilled the following criteria. All procedures to be performed were explained verbally and in writing to the patients, and all patients signed an informed consent form for the implant placement procedure. OPG X-ray (preoperatively, postoperatively on the 1st day and 3rd month of insertion) images were also obtained to evaluate the bone and neighboring anatomical structures.

The important prerequisite for the success of an osseointegrated dental implant is achievement and maintenance of implant stability. We measured 85 inserted MIS Seven dental ISQ values during the osseointegration period. A device called Osttell Mentor™ (Osttell AB, Gothenburg, Sweden) was invented to measure the resonance frequency value of the implant fixture through the transducer or pin (Smartpeg type 32 with maintain a distance of approximately 1-3 mm, angle of 90 degrees, and 3 mm above the soft tissue) which is mounted directly to the fixture with a screw.

The USB-cable was used to connect the Osstell ISQ instrument to a computer with ISQ Data Manager (Windows based software) who enabled viewing, printing of measurements made with Osstell ISQ, and patient data. The measurements were repeated four times in the mesial, distal, buccal and palatal/lingual directions, for each inserted dental implant in residual maxillary alveolar ridges. Follow-up was scheduled for the first day of surgery and 3 months after implant placement for data collection. All implants were not functionally loaded during the follow up period. The value of ISQ scale for analyzing the results stars from 1-100, and high stability means >70 ISQ, 60-69 is medium stability and <60 ISQ is considered as low stability. The higher the ISQ, the more stable the implant.

Dental implant torque is normally measured in *newton centimeter* (N-cm). 10 Ncm corresponds to having a 10 cm lever attached to the implant, and pushing it at the end, with the force of 1 N (0.1 Kgf). We used traditional dental implant placement which typically requires two phases: surgical insertion of the implants and placing the restoration (i.e., dental crown, bridge, or denture).

Exclusion criteria were conditions requiring the chronic routine prophylactic use of antibiotics, medical conditions requiring prolonged use of steroids, history of leukocyte dysfunction and deficiencies, neoplastic diseases, radiation and chemotherapy, renal failure, uncontrolled metabolic diseases and endocrine disorders. The definitive restorations were made in a period between 4 and 6 months after surgery.

Statistical analysis Data analysis was completed with software package SPSS Statistics 7.1 for Windows. Data from this clinical study was pooled and calculated with Statistics 7.1 for Windows using Pearson Chi-square, McNemar Chi-square, Descriptive Statistics (Mean; Std. Deviation; ±95,00%CI; Minimum; Maximum). Distribution of ISQ values during the primary and secondary osseointegration period was calculated and obtained with Kolmogorov-Smirnov test; Lilliefors test; Shapiro-Wilks test. Statistical data was calculated with analysis of variance with $P < 0.05$ considered statistically significant.

RESULTS:

Eighty-five implants w measured and registered in maxillary edentulous ridges. 40 patients were studied to follow up the implant stability, and 78.31% of implants were placed in the posterior segments/section of maxillary edentulous ridges, while 21.68% were inserted in anterior maxillary segments/section. The study group comprises 57.5% males and 42.50% females. Male: female ratio was 1.35:1. The patient's age ranges from 37 to 79 years, and the mean age was 52.15 ± 9.08 years old. All dental implants were examined using Osstell mentor device on the first day of surgery (immediately) and 3 months later to determine and compare ISQ values. When we measured the value of primary stability of inserted dental implants in the maxilla, no implant showed early osteointegration failure. The mean values and standard deviations were calculated. The overall average values for primary stability obtained for all dental implants at each time point in the different groups (anterior and posterior maxillary segments) ranged

from 52 to 65.33 ISQs, with mean values of 58.061 ISQ (5.91 SD), and confidence interval at +95% (61.02-98.97). Likewise, the medical data unit for secondary stability (on the 3rd month) of all inserted dental implants in maxilla in both segments, ranged from 58 and up to 71.67 ISQ. The mean values for ISQs were 65.351 and 5.554 SD with a confidence interval at +95% (67.72-81.58).

The comparison of the results of changes in the implant stability quotient parameters obtained in the primary and secondary stability of maxillary dental implants, analyzed using Spearman Rank Order Correlations registered a significant statistical distinction with monotonic relationship R=0.89 ($p<0.05$)

Based on the tests that we used and ISQ values, we found the important statistical distinction between the primary and secondary stability of inserted dental implants in anterior (p=0.000) and posterior edentulous segments/ sectors of maxillary rigdges. (Table 1; Table 2).

Table 1. Diferences between the primary and secondary stability of dental implants in the anterior segment of the maxilla.

Osseointegration	Mean	**Std. Dev**.	N	Diff.	Std. Dev. Diff.	t	df	**p**
Primary	**59,75**	5,72	20					
Secondary	**66,35**	7,82	20	-6,60	3,78	-7,81	19	**0,000**

Mean - mean obtained values expressed in ISQ units, **SD -** Standard Deviation, **N** - valid number of inserted dental implants, **Diff** – difference, **Std. Dev. Diff.** - *standard deviation* of the *difference* between sample means, **t-value** - ratio of the departure of an estimated parameter from its notional value and its standard error, **df** - degrees of freedom.

Table 2. Descriptive statistic / Posterior segment of maxillary dental implants/ ISQ. CI (confidence interval, type of interval estimate of a population parameter); Minimum and the maximum values are the first and last order statistics (values of the greatest and least elements of a sample used in descriptive statistics).

Osseointegration	N	Mean	CI -95,00%	CI +95,00%	Minimum	Maximum	Std.Dev.
Primary	65	58,15	56,47	59,83	41,00	77,00	6,78
Secondary	65	65,52	64,00	67,03	51,00	83,00	6,11

Regarding the location and position of the oral implants, the ISQ values measured on the 3rd month (secondary stability) after surgery were found to be higher than primary stability in the posterior upper edentulous jaw segments. Significant differences were recorded between the primary and secondary stability of inserted implants in the posterior sector of maxilla $p<0.001$ (p=0.000). (Table 3).

Table 3. Diferences between primary and secondary stability of dental implants in posterior segment of maxilla

Osseointegration	Mean	Std.Dev.	N	Diff.	Std. Dev.Diff.	t	df	p
Primary stability	**58,15**	6,78	65					
Secondary stability	**65,52**	6,11	65	-7,37	3,68	**-16,13**	64	**0,000**

No significant differences were determined in RFA values between anterior and posterior maxillary segments in primary stability $p>0.05$ (p=0.34). Subsequently, secondary measurements applied after 3 months show that there were no significant differences between the same segments $p>0.05$ (p=0.62). (Table 4).

Table 4. Diference between anterior and posterior segment of maxilla in primary and secondary implant stability / Measurements and Diferences of ISQ parametars between anterior and posterior sectors of maxilla in primary and secondary stability of inserted dental implants

Stability of dental implant	Mean Anterior segment of maxilla	Mean Posterior segment of maxilla	t-value	df	p	Valid N Anterior segment	Valid N Posterior segment
Primary stability	**59.75**	**58.15**	**0.96**	83	**0.34**	20	65
Secondary stability	**66.35**	**65.52**	**0.50**	83	**0.62**	20	65

Two (1.7%) implants were considered failure, because of poor oral hygiene by the patient in accordance with smoking more than 3 cigarettes per day, registered with severe bone loss and diabetes mellitus type 2 who was not under control. The other 83 (98.3%) implants were stable, and no mobility was present at the time of prosthesis delivery (4 to 6 months after implant placement). In 98.3% marginal bone levels (followed and observed with OPG X-ray) were found in accordance with normal biologic width requirements.

After osseointegration and normal recovery process, in 65% of patients were made implant supported partial fixed dentures (a bridge supported by several implants which will restore function and looks) with cemented-implant crown (95%) for long-term treatment planning.

DISCUSSION:

Primary and secondary implant stability is an important clinical parameter and plays an important role in the success of osseointegration of implants especially when there are anatomical limitations such as nasal cavity and cavity of the maxillary sinus in the upper jaw.

The Resonance Frequency Analysis (RFA) as the noninvasive intraoral method is constructed to assess based bone-implant contact and it may use therefore to provide clinical evidence of implant stability [12, 14].

Numerous studies have proven to *have* predictive validity using the RFA analysis system. The first authors who proposed to use the RFA as effective qualitative nondestructive test method are Meredith, Sennerby and Meredith [11, 15]. They concluded that quantitative methods, including RFA for clinical measurements of implant stability and osseointegration, can yield valuable information.

When we measured the ability of the resonance frequency for detecting outcome of implant stability, the process was established by analyzing the ISQ results at the time of placement of the implant and in a period of three months after. The results were expressed as an implant stability quotient (ISQ), and the value on a scale indicates the level of stability and osseointegration in dental implants. RFA has been widely used, and many authors have reported their ISQ values to detect the immediately-on the first day of surgery or early loading implant-prosthetic rehabilitation and changes in stability over the time.

Kang YH et al., [16] studied the ISQ values of implant stability using RFA of simultaneously placed dental implants with two autologous bone grafts and found high reproducibility with favorable clinical results.

Bornstein and colleagues [17] recommended further and additional recovery before implant-prosthetic rehabilitation of edentulous alveolar ridge when ISQ values of inserted dental implants are less than 65.

Rodrigo et al., [18] when assessed the predictability of implant stability, they concluded that there was no significant association between primary stability and implant survival (P<0.753) on the first day of surgery, but there is a significant distinction (P<0.001) at the day of restoration placement.

The effect of laser on dental implants in rabbits was investigated by Blay et al.,[19]. Results of applied investigations of two laser groups in their study showed that there is a significant difference between RFA values analyzed on the baseline, after three and six weeks (p>0.05).

Analyzing the primary RFA results of implants, Ostman et all., [20] presented that mean ISQ values were 67.4 (higher in man) with a standard deviation of 8.6. In contrast to our study, the mean values of primary stability results were 58.06 ISQ with a standard deviation of 5.91. The minimal ISQ value in our study was 52, and the maximal 65.33. Granic M et al., [21], demonstrate that the mean ISQ value of primary (immediate) implant placement was 61.43, and was detected the statistical significant difference between primary and secondary (after few weeks) measurements.

Valente et al., [22] analyzed the influence of implant shape on primary stability using three kinds of methods with two types of dental implants, showed that the primary stability of tapered implants presents positive and better scores.

Treatment with implants in edentulous ridges in maxillary bones are commonly faced and dictated with great challenges due to the limited residual bone-high and width, bone quality, bone volume, implant design, the absence of implant movement, including micro-motions, immediately after insertion, and surgical techniques (relation between drill size and implant size).

Barikani H et al., [23] registered that the regular and wide platform of implants is also preferred in ticker bone. They found that there is no significant difference between these two types of implants. On the other hand, some studies have reported results that conical implants show higher implant stability in low quality bones [24, 25].

Monje A et al., [26] showed that ISQ values didn'*t allow for any predict of implant failure and* worked proven by the RFA analysis system is not useful to obtain an objective assessment of clinical implant stability or mobility. The *poor* and quantify reliability in clinical measurements of the sensitivity RFA *predictive* failure in immediately inserted dental implants was also obtained and it has been recommended in a study by Atieh MA et al. [27].

Tang YL et al., [28] included a method for assessment of inserted oral dental implants and osseointegration called torsional resonance frequencies. They found that *these* advantages have direct application for investigation represented with high reliability and sensibility which alleviated the same process for detecting the degree of stability-osseointegration and will approve the benefit in the diagnostic process of stability.

Bilhan H et al.,[29] used element model-Periotest to detect the reliability and evaluation of dental implants stability. The results of Periotest were compared with ISQ values observed for the same implants, and they found that there is no significance, but the method with Periotest *can show* a high degree only for measurements conducted

and applied at buccal directions because mesial showing poor results. Nienkemper M et al., [30] suggest that between using these two types or methods, RFA is more recommended and feasible to predict the implant failure.

Regarding implant position between maxilla and mandible Monje A et al.,[31] was found higher implant ISQ stability values in the mandible than maxilla ($P < 0.001$). The results of posterior upper aspects of the maxilla in the same study were greater than anterior which is similar to our results. In our study, on relating the location and the position of the implants, the ISQ values of secondary stability were found to be greater in the upper posterior and anterior sector than primary implant stability in both maxillary sectors.

Clinical analysis of the stability of the dental implants after two types of bone preparation was observed by da Silva Neto UT et al. [32]. Placing dental implants using piezosurgery in edentulous maxillary ridges have been shown with very good or satisfactory stability values than conventional protocol. The study of Baker JA et al. [33] indicates that there are similar primary stability values of dental implants when have been used the Piezoelectric or conventional method.

In accordance with the reliability of scores measured with RFA to have valid analyzes Herrero-Climent M et al., [34] suggested that one measurement with this method proves enough. Some authors preferable to measure ISQ values in the early stages of dental implant fixation in bones or residual alveolar ridges [35].

Careful planning and case selections are needed to ensure implant success and final aesthetic outcomes, because bone quality and bone resorption followed by remodelling of the maxillary ridges after tooth loss, often results with residual ridge process where primary stability can't be obtained. Successful osseointegration (primary and secondary stability) process of placed dental implants depends and related to their stability.

CONCLUSION

Analysis of the resonant frequency with Osstell Mentor device as a standard instrument parameter for evaluating the non-invasive stability of dental implants might be a successful diagnostic tool (method) in assessing the stability of the implant and the outcome of the survival by monitoring the osseointegration progress. Our results observed for primary and secondary stability indicates and suggests that the influence and reliability of ISQ values could predict the survival rate and outcome of placed oral dental implants in maxillary edentulous ridges. In our study, there was a good correlation between RFA and the proposed clinical measurements of primary and secondary stability to predict successful bone-contact osseointegration or dental implant failure. The analysis of inserted dental implants showed a better secondary (mean ISQ 65.351) than primary (mean ISQ 58.061) stability in all jaw regions, measured immediately after insertion and 3 months later. A significant difference was observed between primary and secondary stability, while no significant differences were noted in the case between anterior and posterior sector of maxillary edentulous ridges in secondary stability. After the completed period of osseointegration, only 2 dental implants have been lost. Patients who *have been* missing *dental implants* require control the metabolic disease, access normal oral hygiene with turn off and less use of cigarettes before they can get *implants*.

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