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Dental Implant Stability at Stage I and II Surgery as Measured Using Resonance Frequency Analysis

Linish Vidyasagar, Girts Salms, Peteris Apse, Uldis Teibe

SUMMARY

The aim of the present investigation was to evaluate the stability of implants using resonance frequency analysis (RFA) relative to length, diameter and arch location, at the time of implant placement and during second-stage surgery. A total of 102 implants in 43 patients had been measured for stability at the time of implant placement (49 implants), and during second-stage surgery (53 implants). Radiographic examinations were performed pre-operatively and following implant placement for Group 1 patients and at second-stage surgery for Group 2 patients. The implant stability for both groups was assessed by RFA (Osstell, Integration Diagnostics AB, Göteborgsvägen, Sweden). For each measurement, the transducer was placed perpendicular to the long axis of the implant location and then secured with a torque of 10 Ncm as per manufacturer instructions. The results showed implants at first-stage surgery to have a mean stability of 66 $\pm$ 6.2 ISQ (range 52 to 79), and implants at the second stage to have a mean stability value of 65 $\pm$ 6.2 ISQ (range 51 to 79). Mandibular implants appear to reach higher stability values than maxillary implants at both first and second stage surgery ($P \leq 0.05$). A direct relationship was observed between implant stability and implant diameter, however not between implant stability and implant length

Key words: implant-dental-stability-resonance frequency

INTRODUCTION

Primary implant stability appears to be important for successful bone integration of dental implants when using a two-stage approach [1]. The Brånemark protocol [2] favored a prolonged healing period to avoid premature loading of the implant. This was considered essential to avoid 'micromotion', which could lead to fibrous tissue formation around the implant, and the subsequent implant loss [3, 4, 5].

However, immediate or early implant loading is becoming recognized as an alternative method for restoring edentulous mandibles and single teeth [6, 7, 8, 9]. There is now evidence that only excessive micromotion during healing phase can cause failure of osseointegration [10, 11, 12]. Their findings suggest that, a range of micromotion exists, that is tolerable (perhaps desirable), and is in the order of 50-150 μm [12]. High primary stability reduces the risk of excessive micromotion, which is associated with fibrous tissue formation at the bone-implant interface during healing and loading. Primary implant stability is now generally accepted as an essential criterion for obtaining osseointegration [13].

The traditional clinical methods for evaluating osseointegration include radiographic evaluation [14], tapping the implant with a metallic instrument and assessing the emitted sound [15], stability measurement with the Periotest instrument [16], rotational stiffness produced upon impact [17], and reverse torque application [18]. However due to problems of invasiveness and accuracy, these methods have not been found suitable for long-term clinical assessment. The Periotest provides a relatively quantitative method of evaluating osseointegration, though there has been evidence [19, 20] that the reading maybe influenced by variables such as the vertical measuring point on the implant abutment, the hand-piece angulations and the horizontal distance of the hand-piece from the implant.

A recently developed apparatus (Osstell; Integration Diagnostics AB, Sweden) uses resonance frequency (i.e. tuning fork principle) to determine implant stability. The wave feed back is interpreted as a numerical value that is linearly related to the degree of micromotion of the implant. This device may be able to detect changes in micromotion that could be associated with increase or decrease in degree of osseointegration [21]. By means of RFA, initial implant stability can be quantitatively assessed and followed with time as a function of implant's stiffness in bone. The use of RFA may provide a possibility to individualize implant treatment with regards to healing periods, detecting failing implants, type of prosthetic construction, and if one- or two-staged procedures should be used [22]. Furthermore, it is likely possible that resonance frequency may detect failing implants earlier than the traditional clinical criteria [21].

The resonance frequency value obtained (in hertz) is translated into an index called the Implant Stability quotient (ISQ), with a scale from 1 to 100. Previous studies using RFA have reported resonance frequency in hertz as a parameter to describe implant stability [21, 23, 24]. However, to date little information is available in the literature reporting on ISQ levels that represent sufficient degree of primary or secondary stability.

The aim of the present study was to evaluate the stability of implants (ISQ) relative to length, diameter and arch location, at the time of implant placement and during second-stage surgery (implant-openings).

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MATERIALS AND METHODS

The study was conducted at the Department of Oral and Maxillofacial Surgery, Institute of Dentistry (affliated to the Riga Stradina University). The study subjects were randomly selected and were between the age group of 26-47 years. All participating patients were carefully informed about the treatment procedure and their consent obtained. A total of 102 implants (Semados Implant systems, BEGO Semados, Germany) in 43 patients (14 males and 29 females) had been measured for stability at the time of implant placement (49 implants), and during second-stage surgery (4-6 months following first-stage)(53 implants). Forty-nine implants were measured for primary stability using resonance frequency (Osstell, Integration Diagnostics AB, Göteborgsvägen, Sweden) at the time of implant placement (Group 1), and 53 implants at second stage (Group 2). The bone quality [25] at the implant sites was determined by radiographs, and during surgery. The lengths and diameters of the implants used in the study are presented in Table 1.

All implants measured have been inserted according to manufacturer instructions and by one of the authors (G.S.). The implants placed in Group 1 patients were inserted with an insertion torque of > 35 Ncm. The seating of the implants was further checked with a hand wrench. Radiographic examinations were performed pre-operatively and following implant placement for Group 1 patients and at second-stage surgery for Group 2 patients. The implant stability for both groups was assessed by RFA (Osstell, Integration Diagnostics AB, Göteborgsvägen, Sweden). For each measurement, the transducer was placed perpendicular to the long axis of the implant location and then secured with a torque of 10 Ncm as per manufacturer instructions. Each reading was repeated twice and if any difference was observed, the lesser of the two was registered. The implant stability values obtained are given in ISQ units that range in a scale from 1 to 100. Statistical analysis was performed using t-test ($P \leq 0.05$). Differences were evaluated between:

- stability of mandibular and maxillary implants at initial placement
- stability of mandibular and maxillary implants at second stage,
- stability of anterior and posterior implants at initial placement,
- stability of anterior and posterior implants at second stage,

The following relationships were evaluated between:

- implant diameter and implant stability at initial placement,
- implant diameter and implant stability at second stage,
- implant length and implant stability at initial placement,
- implant length and implant stability at second stage

RESULTS

All implants at first-stage surgery had a mean stability of 66 ± 6.2 ISQ (range 52 to 79), and 65 ± 6.2 ISQ (range 51 to 79) at the second-stage.

Group 1 (at time of implant placement)

The mandibular implants were found to be significantly more stable than maxillary implants with means of 70.7 ± 4.4 ISQ (range 58 to 79) and 61.7 ± 3.8 ISQ (range 53 to 67) respectively (Table 2, Figure 1). There was no statistical

Table 1. Lengths and diameters of the implants used in the study.

Length (mm)	10	11.5
Diameter (mm)	3.25	3.75

Table 2. Statistical analysis correlating ISQ levels of maxillary with mandibular implants at time of implant placement.

Location	Number (N)	Mean	SD	SE
Upper	27	61,67 (M_1)	3,79	0,73
Lower	22	70,71 (M_2)	4,39	0,96

t-test for Equality of Means						
t	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
					Lower	Upper
7.649	47	0,001	9,05	1,18	11,43	6,67

SD = Standard Deviation SE = Standard Error

$$t = \frac{M_1 - M_2}{\sqrt{SE_1 + SE_2}}$$

Table 3. Statistical analysis correlating ISQ levels of anterior with posterior implants at time of implant placement.

Location	Number (N)	Mean	SD	SE
Anterior	13	66,08 (M_1)	5,22	1,45
Posterior	36	65,08 (M_2)	6,70	1,12

t-test for Equality of Means						
t	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
					Lower	Upper
0.483	47	0,631	0,99	2,06	3,14	-5,13

Table 4. Statistical analysis correlating ISQ levels with implant diameter (Group 1)

Diameter (mm)	Number (N)	Mean	SD	SE
3,25	24	60,58 (M_1)	4,07	,83
3,75	25	69,54 (M_2)	4,30	,84

t-test for Equality of Means						
t	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
					Lower	Upper
7,543	47	0,001	8,96	1,19	11,34	6,57

Table 5. Statistical analysis correlating ISQ levels with implant length (Group 1).

Diameter (mm)	Length (mm)	Number	Mean	SD	SE
3,25	10,0	7	62,29	4,39	1,66
	11,5	17	59,88	3,85	,93
3,75	10,0	21	69,86	4,30	,92
	11,5	4	67,75	4,43	2,21

Diameter (mm)	t-test for Equality of Means						
	t	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
						Lower	Upper
3,25	1,336	22	0,195	2,40	1,80	1,33	-6,14
3,75	,901	23	0,377	2,11	2,35	2,73	-6,96

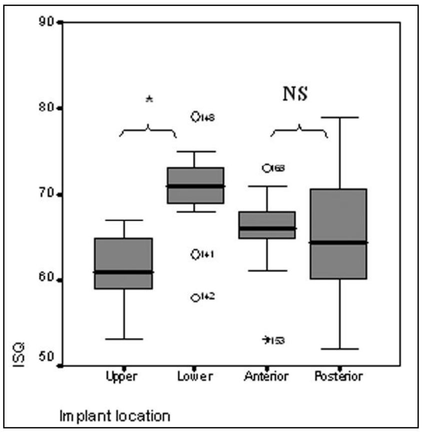

Figure 1. ISQ levels set against implant location (Group 1). There was significant correlation between maxillary and mandibular implants (p = 0.001) but not between anterior and posterior implants (p = 0.63).
p ≤ 0.05 (Statistically significant); NS Not statistically significant

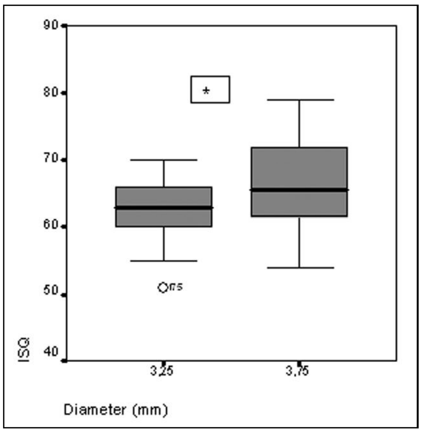

Figure 2. ISQ levels set against implant diameter (Group 1). There was a significant correlation (p = 0.001).

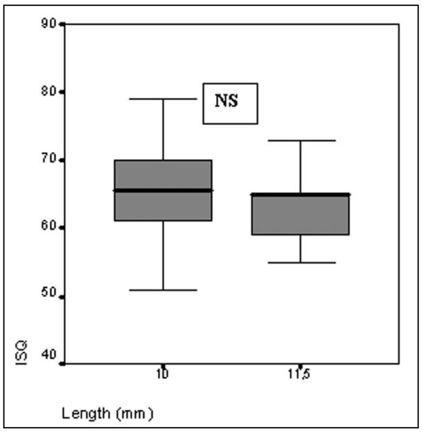

Figure 3. ISQ levels set against implant length. No significant correlation observed (p = 0.195 and 0.377).

Table 6. Statistical analysis correlating ISQ levels of maxillary with mandibular implants at time of implant opening.

Location	Number (N)	Mean	SD	SE
Upper	30	63,20 (M_1)	6,53	1,19
Lower	23	67,29 (M_2)	4,47	0,98

t-test for Equality of Means						
t	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
					Lower	Upper
2,484	51	0,016	4,09	1,64	7,39	0,78

Table 7. Statistical analysis correlating ISQ levels of anterior with posterior implants at time of implant opening.

Location	Number (N)	Mean	SD	SE
Anterior	9	63,33 (M_1)	7,37	2,46
Posterior	44	64,98 (M_2)	6,22	0,94

t-test for Equality of Means						
t	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
					Lower	Upper
0.701	51	0,487	1,64	2,35	6,35	-3,07

Table 8. Statistical analysis correlating ISQ levels with implant diameter (Group 2).

Diameter (mm)	Number (N)	Mean	SD	SE
3,25	24	62,62 (M_1)	5,20	1,13
3,75	29	66,39 (M_2)	6,66	1,26

t-test for Equality of Means						
t	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
					Lower	Upper
2,150	51	0,037	3,77	1,76	7,30	0,24

Table 9. Statistical analysis correlating ISQ levels with implant length (Group 2).

Diameter (mm)	Length (mm)	Number (N)	Mean	SD	SE
3,25	10	13	63,91	5,70	1,72
	11,5	11	64,80	5,57	1,76
3,75	10	23	65,13	6,77	1,41
	11,5	6	68,40	5,64	2,52

Diameter (mm)	t-test for Equality of Means						
	T	df	p (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
						Lower	Upper
3,25	0,361	22	0,722	0,89	2,46	6,05	-4,27
3,75	1,003	27	0,325	3,27	3,26	9,97	-3,43

significance between primary implant stability of anterior (66.1 ± 5.2 ISQ) and posterior implants (65.1 ± 6.7 ISQ) (Table 3, Figure 1).

There appeared to be a direct relationship between implant diameter and implant stability (p = 0.001)(Table 4, Figure 2). However, no direct relationship was observed implant length and ISQ values (p = 0.195 and 0.377) (Table 5, Figure 3)

Group 2 (At second-stage surgery)

The mandibular implants (67.3 ± 4.5 ISQ) were again found to be significantly more stable than maxillary implants (63.2 ± 6.5 ISQ), though the difference was lesser than observed in Group 1. There was however no significant difference observed between stabilities of implants placed in anterior versus posterior sites (63.3 ± 7.4 ISQ and 65 ± 6.2 ISQ respectively) (Table 6, 7; Figure 4).

A direct relationship was observed between implant stability and implant diameter, however not between implant stability and implant length (Table 8, 9;Figure 5,6).

DISCUSSION

Initial implant stability obtained after implant insertion is regarded as critical for the prognosis of the implant [1]. It has been reported that implants with better initial stability would result in a higher secondary stability and require reduced healing periods than those fitted with a lower initial stability [26]. At placement, knowledge of primary stability may also serve as a guide to making a decision regarding the choice of treatment protocol; immediate-, early or

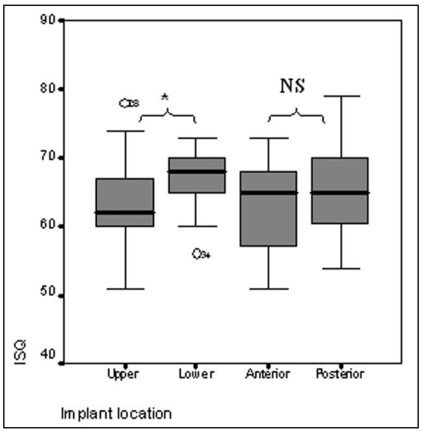

Figure 4. ISQ levels set against implant location (Group 2). Significant correlation observed between maxillary and mandibular implants (p = 0.016) and not between anterior and posterior implants (p = 0.487).

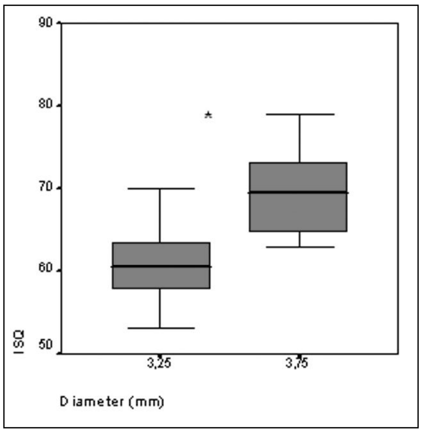

Figure 5. ISQ levels set against implant diameter (Group 2). Significant correlation observed (p = 0.037).

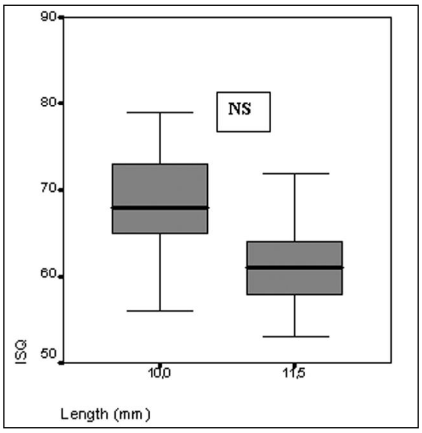

Figure 6. ISQ levels set against implant length (Group 2). No significant correlation observed (p =0.72 and 0.33).

delayed loading. Thus a quantitative method of assessing osseointegration becomes essential for serving as a baseline and to be able to follow the measurement with time. The measurement of secondary stability, after initial healing, may confirm a successful healing and facilitate decision-making with implants that demonstrate low stability.

The use of RFA may provide an objective approach to measuring initial implant stability and detecting failures by being able to follow-up the acquired stability [27]. However, the literature does not reveal the ''normal ISQ stability values'' observed at the time of first and second surgery when using a two-stage approach. The only other study of this nature [28] reports on ISQ values for successfully integrated implants following one year of loading.

The results from the present study reveal mean ISQ levels of 66 ± 6.2 ISQ (range 52 to 79) at the time of implant placement, and 65 ± 6.2 ISQ (range 51 to 79) at the second-stage surgery. This is in support with the results of Bailleri et al [28] which reports ISQ values of 69 ± 6.5 ISQ for successfully integrated implants following one year of loading.

The data from the current study appears to demonstrate a direct relationship between implant diameter and stability in both groups. Friberg [29] suggested using wider diameter implants in low density bone to gain higher primary stability. In the current study, wider diameter implants were used when bone volume and quantity permitted. It has been suggested that incorporating wider diameter implants may increase the bone-metal contact not only to the crestal cortical layer, but also to the lateral cortical walls [30]. The results from our study support this observation.

The comparison of ISQ data obtained in different regions of the mandible and maxilla for both the groups failed to demonstrate a direct relationship between implant length and stability. The consensus on the use of endosseous dental implants is that long implants are necessary for success to ensure sufficient surface area for bone contact [31, 32, 33, 34, 35, 36]. The majority of failed implants were either 7 or 10 mm in length, confirming the earlier statements by Lekholm and colleagues [37], that there was an increased risk of failure with implant lengths less than 10 mm in the mandible or less than 13 mm in the maxilla [31]. Thus the trend has been to place longer implants whenever possible assuming that longer implants result in higher stability. However, the implants used in these studies have been machined-surface implants. Higher failure rates after loading have been reported for implants with relatively smooth surfaces [37, 38, 39, 40, 41, 42], in comparison with rough-surfaced implants [43, 44, 45, 46]. Deporter et al [47, 48] reported high cumulative survival rates using porous-surfaced implants with mean length of 8.7 mm. Glauser et al [49] reported surface-modified implants to maintain implant stability during the first 3 months of healing in contrast to the machined surface implants. It may be that although surface texturing of implants do not directly contribute to initial implant stability, it may reduce the risk of stability loss and consequently facilitating wound healing (secondary osseointegration). The implants used in this study (Semados Implant systems, BEGO Semados, Germany) incorporate a microstructured osteoconductive surface, which may explain the results observed in Group 2. For Group 1 however, it appears unlikely that surface texturing of the implants may have contributed to the higher values. It is plausible that the use of wider diameter implants and implant design-related factors may have influenced the stability values.

The data from the current study also reveal higher stability values for the mandibular implants in comparison with the maxillary ones. This may be explained by the good bone quality observed in the mandible (Type 1/ 2 of Lekholm and Zarb classification [25]). Implants seem to more stable in cortical bone as compared to trabecular bone [50]. However the difference between the upper and lower implants was less in Group 2 patients, which may suggest that following a 4-6 month bone healing period, implants placed in different bone densities approach towards a similar level of secondary density [51]. It seems that implants inserted in low density bone ''catch up'' over time with those placed in bone of medium and high density [30]. The differences in stability however were not significant between the anterior and posterior sites for both groups, possibly due to less distinct difference in bone densities. Reports from investigators have been contradictory in regard to the relative effectiveness of dental implants in the anterior versus posterior sites. Bahat [34] reported more failures to occur in the posterior than in the anterior maxilla for machined-surface implants. Similar results in the posterior maxilla were reported by Nevins and Langer [38] and Becker and Becker [52]. In contrast, other studies have reported better results with fixtures placed posteriorly [53, 54, 55]. Our data is in support with the results of Bailleri et al [28], where the fixtures placed in posterior areas were found to be as stable as the ones placed anteriorly.

CONCLUSION

The RFA readings showed mean stability values of 66 ± 6.2 ISQ (range 52 to 79) during first-stage, and 65 ± 6.2 ISQ (range 51 to 79) at the second-stage surgery. Mandibular implants reached higher stability values than maxillary implants at both first and second stage surgery. A direct relationship was observed between implant stability and implant diameter, however not between implant stability and implant length. Further investigations using resonance frequency analysis are required to study stability in relationship to conditions that predispose to implant failure. In this way, it may be possible to identify ''at risk" implants and lengthen the healing period until sufficient stability is achieved.

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