



ORIGINAL ARTICLE

Assessment of primary implant stability of self-tapping implants using the resonance frequency analysis



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Abstract *Objective:* The objective of this study was to determine the influence of implant surface modification and implant length on primary implant stability using resonance frequency analysis (RFA).

Materials and methods: Twenty-seven patients with bilateral free end mandible were treated with 162 dental self-tapping implants (72 implants with sandblasted and acid-etched surface (SLA) with 8 and 10 mm length, respectively; 90 implants with chemically modified SLA surface (modSLA) and a length of 8 mm). Implant stability quotient (ISQ) values were determined and were compared in between the implant types using statistical analysis (*t*-test).

Results: Mean ISQ value for all 162 implants was 79.09 (5.97). Statistically significant differences were noted between mean ISQ value of SLA and modSLA implants (76.92 vs. 80.80). Also significantly lower mean ISQ values have been recorded for 8 mm length implants compared to 10 mm length implants in the SLA group (74.15 vs. 79.57).

Conclusion: All ISQ values indicate the high primary stability for tapper implants inserted in the posterior part of the mandible. Self-tapping implant design provides sufficient initial stability even for implants with nonstandard length. Further investigations are necessary to define the influence of surface chemical modification on primary implant stability.

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1. Introduction

Primary implant stability is believed to play an essential role in successful osseointegration.¹ This initial implant stability is defined as stability at the time of implant placement. It is a prerequisite for direct bone formation on the surface of the implant. Primary implant stability is only a mechanical phenomenon and depends on the contact between the implant and the bony bed. Failure rates of as much as 32% have been

reported for implants, which did not show adequate implant stability.² During the healing period, the primary implant stability is replaced by the secondary implant stability, which is a biological phenomenon.¹ Secondary stability is the result of the formation of new woven and lamellar bone onto the implant surface.¹ Micro-motion beyond a certain degree has been shown to prevent secondary implant stability to occur. Sufficient primary stability prevents micro-motions between the surface of the implant and the surrounding bone to reach a degree detrimental to bone formation. Several authors suggested that primary stability might be a useful predictor for osseointegration.^{3,4} In addition, it may provide information for proper decisions regarding loading protocols.^{5,6}

Different factors may contribute to initial implant stability. The degree of primary stability after the implant placement has been related to local factors, implant factors, patient characteristic and surgical technique. Initial stability of implants can be significantly less in bones of low density or insufficient volume.^{7,8} Larger bone-to-implant contact fractions have been reported in bone sites of higher density.⁹ The length of the dental implant, its diameter, its design, as well as the micro-morphology and the type of implant surface are considered key factors influencing primary stability.¹⁰ Previous data have presented correlations between implant length and primary implant stability.¹¹ Implants of higher length provide greater contact surface between bone and implant compared with implants with smaller length.¹¹ Impact of implant geometry on primary stability has not been fully investigated and described yet. It has been observed that tapered implants lead to higher insertion torque values than cylindrical implants, which was considered to be due to the greater frictional surface of the tapered implants.¹² Furthermore, implants exhibiting threads and implants with self-tapping threads have been reported to exhibit higher primary bone-to-implant contact.^{13,14}

It has further been demonstrated that medium rough implant surfaces lead to improved osseointegration and thus may be amenable to shorter healing times before loading (Wennerberg EAO consensus 2009). In addition, recent data described the potential of chemical modification of rough implant surfaces to speed up the biological events during the osseointegration process.¹ Finally, the preparation of the implant bony bed has been shown to influence primary implant stability. Thus condensing of bone, under preparation of the implant bed, and avoiding tapping for threaded implants have all been demonstrated to improve primary implant stability.^{15–17}

Several devices are available to assess implant stability.¹⁸ These devices can be used at various time points during the healing and the loading phase of implants. These procedures can be separated into invasive and non-invasive methods. In the past the quantitative measurement of primary stability has been limited to invasive methods such as pull out and push out attempts and the assessment of removal torque.^{3,19,20} These invasive tests used in animal studies to determine the level of osseointegration are not suitable for clinical use.²¹ Vibration analyses of implants are non-invasive methods and allow the assessment of implant stability under clinical settings.³ They either use transient or continuous excitation. In 1996 a new method called resonance frequency analysis (RFA) was introduced for the measurement of implant stability.²² This RFA method is an easily applicable method of measuring quantitative stability and it can be used in a surgical and a non-surgical setting.^{23–25} The Hertz waves resulting from the RFA measure-

ment are converted into numeric values on a scale from 1 to 100, which is called the implant stability quotient (ISQ). Classically, ISQ values have been found to vary between 40 and 80. Higher ISQ values generally represent higher implant stability. It has been reported that ISQ values for successfully integrated implants typically range from 57 to 82 and that ISQ values of < 50 are associated with higher implant failure rates.^{26,27}

Recently, new implant designs have taken into account the various factors described above for improving primary stability. One such implant consists of a cylindrical and conical implant body, higher density of threads on the implant surface, a self tapping profile of these threads, and a medium rough surface (TE implant, Straumann Dental Implant System[®], Basel, Switzerland). This implant was developed for placement into extraction sockets or into bone of low quality.²⁸ In addition, it may be assumed that due to its design features this implant may successfully be used in conjunction with immediate loading protocols.

The aim of the present investigation was to determinate the values of primary implant stability applying a conical, self tapping implant with a medium rough surface. Furthermore, the study aimed at assessing the influence of implant length and implant surface activation on primary implant stability.

2. Materials and methods

The present investigation was conducted at the Department of Oral Surgery, Faculty of Dentistry, University of Belgrade. Ethical approval was obtained from the Belgrade University Ethics Committee (Nr. 165/2, 2004) and participants gave informed consent.

2.1. Patient data

Twenty-seven consecutively treated patients (15 women, 12 men) with a mean age of 47.7 years (range 20–62 years) were included in this study. All patients were in need of dental implant treatment bilaterally in their partially edentulous mandible. The following inclusion criteria had to be met:

- (a) Patients with unremarkable medical history;
- (b) Patients with bilaterally terminal edentulous space distal from the first premolar in the mandible (Kennedy 1st class);
- (c) Presence of natural teeth or prosthetic rehabilitation in the posterior maxilla to provide occlusal contact with the prosthetic units on the implants in the mandible;
- (d) Patients with the same type of antagonists on both sides of the mandible;
- (e) Adequate oral hygiene;
- (f) Surgical sites with bone density type I–III (Lekholm and Zarb)^{29,30};
- (g) Patients with dimensions of the alveolar bone measured 1 mm from the top of the crest in bucco-oral direction of ≥ 6 mm in order to provide bone wall thickness of at least 1.0 mm on the facial and the lingual side.

2.1.1. Exclusion criteria

- (a) patients with oral parafunctions (bruxism);
- (b) heavy smokers (more than 10 cigarettes a day);

(c) self-declared pregnancy or intention to become pregnant.

2.1.2. Preoperative procedures

The preoperative planning was based on radiographic (cone beam computer tomograms) examination. Preoperative radiograph with a radiograph guide was used to determine the bone quantity and quality for each implant site.³⁰

2.2. Clinical procedures

A total of 162 implants (TE implants, Straumann Dental Implant System®, length 8 or 10 mm, diameter 4.1 mm, Straumann AG, Basel, Switzerland) were placed bilaterally in the position of the second premolar, and the first and second molars according to the manufacturer's recommendations (same sequence of implant drills for each implant site). Implant beds have been drilled with: pilot drill Ø 2.2 mm; pilot drill Ø 2.8 mm; twist drill Ø 3.5 and finally with tapered effect profile drill Ø 4.1 mm. Implants were mechanically inserted using an insertion torque of 40 Ncm. Twelve patients were included in Group I and received implants with an SLA surface. In subgroup 1a the implants measured 8 mm in length, in subgroup 1b they measured 10 mm. Another 15 patients made up Group 2 and received modSLA implants all with a length of 8 mm. All 27 patients were part of comparative studies which will be published elsewhere. Equal numbers of implants ($n = 81$) were subjected to immediate or early loading protocols. Follow up period for all these implants was 5 years and implant success rate has been determined.³¹

Antimicrobial prophylaxis (Amoxicillin® 1 g) was given orally 1 h before each surgery and post-operative pain and edema were controlled with a corticosteroid (Dexason®, 4 mg i.m. 1 h before and 8 h after surgery) and a non-steroidal anti-inflammatory drug (Nimulid®, 100 mg tablet for subsequent 3 days). Patients were asked to use 0.12% chlorhexidine diglicomat mouth-rinses twice daily for a period of 1 month following surgery.

Following prosthetic reconstruction the patients were enrolled in a maintenance care program until the final examination of the present study at 6 years of loading. RFA measurements were performed at implant insertion and during the follow up period. Additional clinical study parameters (radiographs, modified bleeding index, and modified plaque index) were assessed at 3, 6 months, 1, and 5 years.

2.3. RFA measurement

Resonance frequency analysis (RFA) measurements were performed immediately following implant placement using (Osstell™ mentor, Integration Diagnostics AB, Göteborg, Sweden) according to the manufacturer's recommendations. The measuring devices (Smartpeg™) were attached to the implant using 10 Ncm of torque. All measurements were

performed with the probe (Osstell™ mentor Probe II) aiming from the buccal directions. The probe was held at a distance of 2–3 mm until the instrument displayed the implant stability quotient value (ISQ). Two ISQ values were recorded and used as a mean value for statistical analysis.

2.4. Statistical analysis

First, data were subjected to descriptive statistical analysis (SPSS, Chicago, IL, USA). The difference in resonance frequency values between SLA and SLActive implants as well as between implants with different lengths was tested for significance using student's *t*-test with a significance level of 5%.

3. Results

According to Lekholm & Zarb²⁹ classification, all surgical sites were of bone density type II.

Out of the 162 implants placed in this study 72 implants exhibited an SLA surface whereas 90 exhibited an modSLA surface (Table 1). One-hundred and twenty-seven implants exhibited a length of 8 mm and 35 a length of 10 mm.

The same number of implants were inserted in the position of the 2nd premolar, 1st and 2nd molars ($n = 54$). According to the gender 9 women and three men were in Group I and 6 women and 9 men were in Group II.

At the 5-year loading control, implant success rate of all implants was 100%.

Comparing the values for primary implant stability between the different sites of implant placement, i.e. 2nd premolar, 1st and 2nd molar, no statistically significant differences were found (Table 2).

The difference in primary stability between all SLA (mean value 76.92) and modSLA (mean value 80.80) implants reached statistical significance (Table 3).

At implant placement, the ISQ values for the SLA implants (Group I) ranged from 60 to 85. The average value of primary implant stability for 8 mm long implants was 74.15 (SD 7.26) and for the 10 mm long implants was 79.57 (SD 5.17). This difference was statistically significant.

At implant insertion, the individual ISQ values for the 90 modSLA implants ranged from 65 to 86 with a mean value of 80.80 (SD 4.67). Statistical analysis revealed a significant

Table 1 Distributions of the implants based on implant surface and implant length.

	Group I (SLA)	Group II (modSLA)
Length: 8 mm	37	90
Length: 10 mm	35	
Total n	72	90

Table 2 Mean ISQ values (standard deviation) for different implant positions.

	2nd premolar ($n = 54$)		1st molar ($n = 54$)		2nd molar ($n = 54$)		Significance
	Mean	SD	Mean	SD	Mean	SD	
Primary stability	78.72	5.73	79.14	6.23	79.33	5.96	$P > 0.005$
Range	60–85		62–85		61–85		

Table 3 Mean ISQ values (standard deviation) of the two groups at the time of implant placement.

	SLA (<i>n</i> = 72)		modSLA (<i>n</i> = 90)		Significance
	Mean	SD	Mean	SD	
Primary stability	76.92	6.68	80.80	4.67	0.000

ISQ, implant stability quotient.

Table 4 Mean ISQ values for 8 mm length implants with different implant surfaces (SLA and modSLA).

	Ia		II		Significance
	Mean	SD	Mean	SD	
Primary stability	74.15	7.26	80.80	4.67	0.000
Range	60–83		65–86		

difference between Group Ia (8 mm long SLA implants) and Group II (8 mm long modSLA implants) with higher values for Group 2 (Table 4).

4. Discussion

The results of this study have shown implants with a rough and activated surface to exhibit higher primary stability than implants with a rough but non-activated surface. In addition, implant of 10 mm length showed higher primary implant stability than implants with a length of 8 mm. No difference was found, when the primary stability of implants placed in different sites in the posterior mandible was compared.

It is well known that initial implant stability depends on local bone quality and quantity, the geometry of the implant and the placement technique.³ Implant configuration is an important factor for implant success. Screw implant designs allow obtaining sufficient mechanical stability, which is the principal requirement for immediate loading.³² In the present study, the lowest ISQ value found for an individual implant was 60. This value is similar to recently published data.³³ In previous studies using the same implant design lower values have been reported.¹³ In a human cadaver study, the mean value for primary stability for 12 mm long rough surface implants inserted into extraction socket of lower premolars was 69 ISQ (range 64–73).²⁸ In the present study, the average value of primary stability for implants with the same surface and 10 mm in length amounted to 79 ISQ (range 60–85) and for 8 mm in length it was 74 ISQ (range 60–83). The lower mean value of primary stability in the human cadaver study may be due to the fact that the implants were inserted into fresh extraction sockets.

In the current study, identical designs of the implants were used for all sites, with the exception of implant surface and implant length. The object of many investigations has been to assess the influence of different implant surfaces on early bone healing. The results from recent studies failed to document significant differences in ISQ values between rough and rough and activated titanium surfaces immediately after implant insertion.^{1,31} In the present study, 44% of the patients were treated with rough and 56% with rough and activated implant surfaces. The type of implant surface (activated or non-acti-

vated) revealed significant differences in ISQ values with the activated surfaces showing higher values. Although, group 1 encompassed 8 and 10 mm long implants, the mean values for primary stability were higher in group 2, where only 8 mm long implants were included but with an activated surface. Taking into account that all surgical procedures were performed under the same conditions and that they had been done by the same operator and the activation of the surface only influences the establishment of the secondary stability, there is no obvious explanation for the difference obtained. Clearly, further investigations with a higher number of implant sites distributed equally in analyzed groups are necessary to elucidate this issue.

The influence of implant length on primary and secondary stability has been the subject of many studies. One study has reported higher primary implant stability for 10 mm standard implants compared with 8 mm long ones (70 vs. 59).³⁴ Owing to high standard deviations, this difference did not reach statistical significance. The present study revealed a positive influence of implant length on ISQ values. Ten millimeter long implants exhibited higher primary implant stability than 8 mm long implants. This higher implant stability with longer implants may translate into higher survival rates of long implants subjected to immediate loading. In this context a 50% failure rate has previously been reported with immediate loading for implant lengths < 10 mm.³²

5. Conclusion

In this clinical study, self-tapping rough-surfaced implants achieved high values of primary stability. Longer implants exhibited higher primary implant stability than shorter ones. Interestingly, implants with a rough and activated surface showed higher values for primary implant stability compared with implants with a rough but non-activated surface. Implants exhibiting lengths of 8 and 10 mm reached values for primary stability generally considered sufficient for immediate loading protocols.

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