Comparison of Reliability of 3 Resonance Frequency Analysis Devices: An In Vitro Study

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The purpose of the present study was to investigate the intraobserver and interobserver reliability of 3 resonance frequency analysis (RFA) devices and to compare the implant stability quotient (ISQ) values according to implant macro design and diameter in 2 different bone densities. A total of 64 implants (Neoss ProActive; Neoss; Harrogate, UK) of varying diameters (3.5 and 4.0 mm) and implant macro design (tapered and straight) were placed in 2 artificial bone blocks (the density of type 2 and 3). The implant primary stability was measured using Osstell IDx (Osstell; Göteborg, Sweden), Osstell Beacon and Penguin RFA (Integration Diagnostics; Göteborg, Sweden). The ISQ value of each implant was measured by 2 observers and recorded 5 times in 2 directions. The intraobserver and interobserver reliability of RFA devices were evaluated. In addition to that, mean ISQ values were calculated for each RFA device to evaluate the effect of implant diameter, implant macro design, and bone density on ISQ values. ISQ values were significantly higher for implants placed within the type 2 bone than for the type 3 bone. The 4.0-mm diameter implants presented higher ISQ values than 3.5-mm diameter implants. The intraclass correlation coefficient (ICC) values for intraobserver reliability were above 0.85 for each observer and the ICC values for interobserver reliability were 0.94, 0.93, and 0.98 for Osstell IDx, Osstell Beacon, and Penguin RFA, respectively. Although there was excellent interobserver reliability with 3 RFA devices, the intraobserver reliability of Osstell Beacon and Penguin RFA were slightly better than Osstell IDx. Bone density and implant diameter were parameters affecting the primary stability of implants.

Key Words: dental implants, resonance frequency analysis, primary stability

INTRODUCTION

Dental implant placement is becoming a first-choice option for the rehabilitation of partially or completely edentulous patients. The number of patients who had undergone implant-based rehabilitation has gradually increased over the last years.[1] Additionally, due to patients' increasing expectations in esthetic and shorter treatment periods, immediate implant placement and immediate loading have gained popularity. Primary implant stability can be defined as the biomechanical stability upon implant insertion, influenced by several factors, such as bone quantity and quality, implant macro design, and surgical technique.[2] The primary stability of an implant is known to be one of the key factors for success associated with placement and loading protocols, especially for immediate loading where implant face with functional load before osseointegration. It has been shown that micromotion beyond 150 μm should be avoided, which may cause the wound to undergo fibrous repair instead of osseous regeneration.[3] Therefore, it is important for clinicians to evaluate the primary stability before immediate implant loading to achieve appropriate osseointegration while meeting the expectations of patients.

There are different methods for evaluation of implant stability such as dental mobility checker, Periotest, resonance frequency analysis (RFA) and cutting torque resistance analysis.[4,5] RFA is known as a noninvasive, reliable, easily predictable, and objective method of quantifying implant stability.[6] This method determines the implant stability quotient (ISQ), which has values ranging from 1 to 100; 100 shows the highest degree of stability. The value of ISQ 70 is considered the threshold for inserting the dental prosthesis and for immediate loading.[7] Different devices in the market such as Osstell (Göteborg, Sweden)and Penguin RFA (Integration Diagnostics; Göteborg, Sweden) use this method. Both systems use magnetic frequencies between the RFA and the transducer (peg). Several generations of Osstell products have been produced over the years and Osstell Beacon is the latest version. Osstell IDX is the version that was introduced before Beacon and has a probe with cable and a touch screen. Osstell Beacon and Penguin RFA devices are small pen-like battery-driven instruments that have small screens to show measured ISQ values. For easy interpretation, Osstell IDx and Osstell Beacon use color coding depending on measured ISQ value. The SmartPegs using for Osstell devices are single use and made from a soft aluminum with a zinc-coated magnet mounted on top. The wear and tear of aluminum is fast and visible after only a few inserts, the manufacturer informs.[8] However, the MulTipegs used for Penguin RFA are made in titanium with sealed magnets, which makes them reusable. Also, they are autoclavable at least 20

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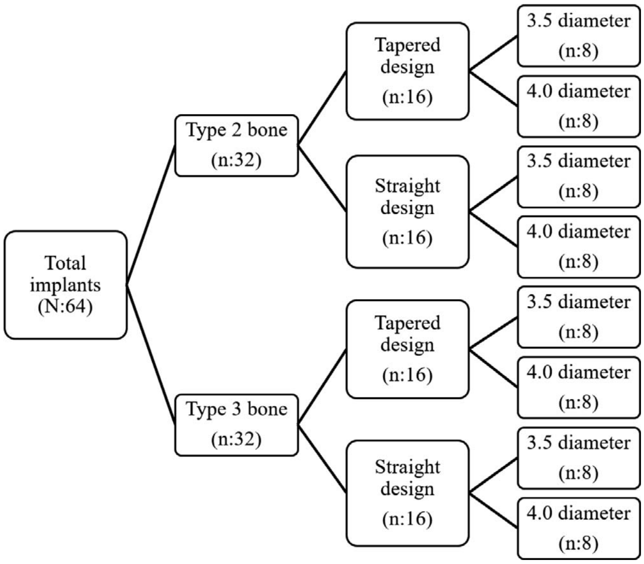

Figure 1. Schematic diagram of the study design.

times according to the manufacturer.[9] To date, many studies are available comparing RFA devices with various other noninvasive and invasive methods in measuring implant stability.[10,11] However, it is still unclear whether there is a difference in intraobserver and interobserver reliability of recently commercialized RFA devices. It is also important to find out whether different RFA devices in the market have similar ISQ values in the same implant conditions. The purpose of the present study was to investigate intraobserver and interobserver reliability of three RFA devices and to compare the ISQ values according to implant design and diameter in 2 different bone densities.

Materials and Methods

Implants and surgical procedures

A total of 64 implants (Neoss Proactive, Neoss Ltd., Harrogate, UK), with a length of 10 mm were used for the present study. Implants were subdivided into groups according to implant diameter (3.5 mm and 4.0 mm), implant design (tapered and straight body) and bone density (type 2 and type 3) (Fig. 1).

Implants were placed in two artificial bone blocks (100 mm x 50 mm x 17 mm), which had bone densities similar to type 2 (A-JT D2, Frasaco, Tettnang, Germany) and type 3 (A-JT D3, Frasaco) respectively according to the bone quality classification from Lekholm and Zarb.[12] The implants were placed in the bone blocks with the inter-implant distance of 5.75 millimeters. Standardization of implant position and interimplant distance were ensured with the help of the 3D surgical guide (Figure 2a). Guided preparation of implant bed was based on the instructions given in Neoss-guided surgery manual using the complete sequence of drills for each implant design. After implant bed preparations, each implant was inserted until its rough surface was completely inserted in the bone block (Figure 2b).

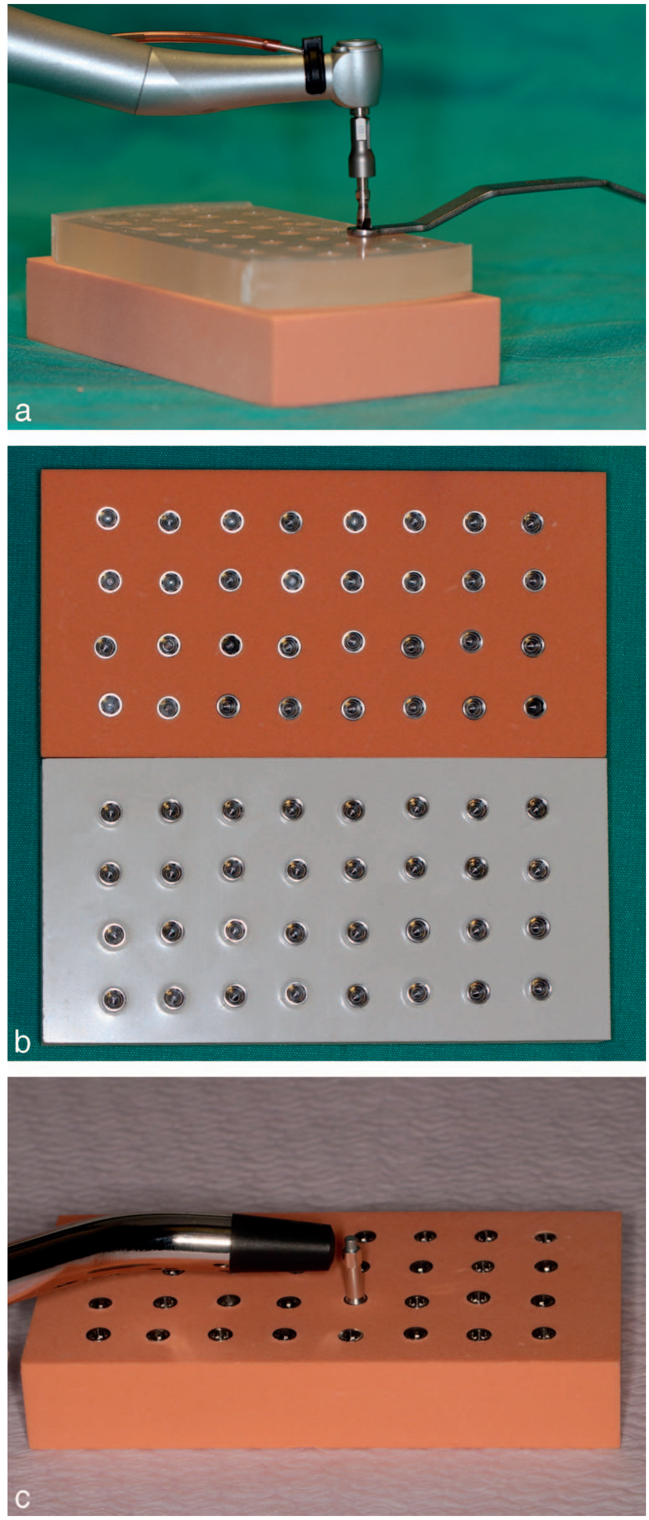

Figure 2. (a) Implant positions and angles were standardized with the surgical guide. Guided preparation of implant bed was based on the instructions given in a Neoss guided surgery manual. (b) Implants inserted in artificial bone blocks. (c) Measurement of ISQ values. A representative image with Osstell IDx. ISQ indicates implant stability quotient.

Implant stability measurements

Primary implant stability was measured using the Osstell IDx, Osstell Beacon, and Penguin RFA (Integration Diagnostics). The SmartPeg was screwed onto each implant using a plastic mount by hand tightening. The ISQ measurements were recorded 5 times in 2 directions from each implant (a total of 10 measurements for each device). The probe was placed approximately 2 mm away from the SmartPeg and with a 90° angle regarding the implant's major axis (Figure 2c). After unscrewing the SmartPeg, the MulTipeg was screwed onto each implant using a titanium mount, and ISQ values were measured by using the same method. The measurements were performed by 2 authors (BD and ND) separately to evaluate intraobserver and interobserver reliability. The interobserver reliability is related to the concordance of the ISQ values obtained by 2 observers for the same implant. The intraobserver reliability is related to the concordance of the ISQ values of repeated measurements performed by one observer for the same implant. The measurements of each observer were separately evaluated to assess the effect of the implant design, diameter, and bone type on primary stability.

Statistical analysis

The methodology and statistical applications were reviewed and approved by an independent statistician. Homogeneity and normality of distributions were assessed by Shapiro-Wilk tests. The 1-way analysis of variance (ANOVA) with post-hoc Tukey test was performed to compare the ISQ values of Osstell IDx, Osstell Beacon, and Penguin RFA. The 3-way ANOVA test was used to evaluate the effect of variances (implant design, implant diameter, and bone density) on ISQ values. The intraobserver and interobserver reliability were evaluated by the intraclass correlation coefficient (ICC). ICC values less than 0.5 indicate poor agreement, values between 0.5 and 0.75 indicate moderate agreement, values between 0.75 and 0.90 indicate good agreement, and values greater than 0.90 indicate excellent agreement.[13] All statistical analysis was performed by using SPSS software (PASW Statistics 22.0, SPSS Inc, Chicago, USA). The statistical significance level was set at 0.05. Results were reviewed by an independent statistician. A priori power analysis revealed that 2 samples in each group provide 95% power for the present study (effect size: 2.07, α: 0.05). It was decided to include 8 samples in each group to increase power of the study.

Results

The mean ISQ values obtained with Osstell IDx, Osstell Beacon, and Penguin RFA were listed in Table 1. There was no statistical difference between mean ISQ values of 3 RFA devices for observer 1 ($P = .932$) and observer 2 ($P = .699$).

Effect of implant diameter

The ISQ values of 3.5-mm diameter implants were significantly lower than 4.0-mm diameter implants when measured by 2 observers with each RFA device. The mean ISQ values measured with 3 devices for both implant diameters are presented in Table 1, and *P* values are presented in Table 2.

Table 1

Mean ISQ values obtained with Osstell IDx, Osstell Beacon, and Penguin

	RFA Device			
	Osstell IDx	Osstell Beacon	Penguin	*P* Value
Observer 1				
Implant Design				
Tapered	75.95	76.03	75.60	
Straight	75.71	75.98	76.04	
Implant Diameter				
3.5 mm	75.06	75.26	75.26	
4.0 mm	76.61	76.75	76.38	
Bone Density				
Type 2	78.20	78.40	78.18	
Type 3	73.46	73.61	73.46	
Mean	75.83	76.01	75.82	.932
Observer 2				
Implant Design				
Tapered	76.60	76.79	75.83	
Straight	76.12	76.19	76.33	
Implant Diameter				
3.5 mm	75.56	75.77	75.48	
4.0 mm	77.17	77.21	76.68	
Bone Density				
Type 2	78.32	78.39	78.37	
Type 3	74.40	74.59	73.79	
Mean	76.36	76.49	76.08	.699

Effect of implant design

There was no statistically significant difference between the ISQ values of tapered and straight implants when measured with all 3 RFA devices. The mean ISQ values measured with 3 devices for both implant designs are presented in Table 1, and *P* values are presented in Table 2.

Effect of bone density

The ISQ values of implants placed in the type 2 bone were significantly higher than those of implants placed in the type 3 bone, similarly for each RFA device. The mean ISQ values measured with 3 devices for both bone densities are presented in Table 1, and *P* values are presented in Table 2.

Intraobserver reliability of RFA devices

The ICCs of repeated measurements for 3 RFA devices were evaluated. For the Osstell IDX device, the ICC was 0.86 ($P = 0$) for the measurements recorded by the first observer and 0.91 ($P = 0$) for those of the second observer. For Osstell Beacon, the ICC was 0.96 ($P = 0$) for the ISQ values recorded by the first and the second observer. For Penguin RFA device, the ICC was 0.98 ($P = 0$) for the measurements recorded by the first observer and 0.96 ($P = 0$) for those of the second observer. As a result, there was a correlation between the repeated measurements made with 3 RFA devices for all implantation situations (Table 3).

TABLE 2

P values of 3-way ANOVA test evaluating the effect of bone density, implant diameter, and implant design on ISQ values measured with each RFA device*

RFA Device	Bone Density	Implant Diameter	Implant Design
Observer 1			
Osstell IDX	.000**	.002**	.610
Osstell Beacon	.000**	.003**	.910
Penguin	.000**	.036**	.412
Observer 2			
Osstell IDX	.000**	.000**	.256
Osstell Beacon	.000**	.001**	.164
Penguin	.000**	.020**	.321

*ANOVA indicates analysis of variance; ISQ, implant stability quotient; RFA, resonance frequency analysis.

**Statistically significant difference according to 3-way ANOVA test.

TABLE 3

ICCs for intraobserver and interobserver reliability of 3 RFA devices*

	Intraobserver Reliability	Interobserver Reliability
Osstell IDX		
Observer 1	0.86	0.94
Observer 2	0.91	
Osstell Beacon		
Observer 1	0.96	0.93
Observer 2	0.96	
Penguin		
Observer 1	0.98	0.98
Observer 2	0.96	

*ICC indicates intraclass correlation coefficient; RFA, resonance frequency analysis.

Interobserver reliability of RFA devices

The ICC between ISQ values measured by the 2 observers were evaluated regardless of the bone density, implant design, and implant diameter. The ICCs were 0.91, 0.89, and 0.98 for Osstell IDx, Osstell Beacon, and Penguin RFA, respectively. There was a correlation between the observers for each RFA device ($P < .05$) (Table 3).

DISCUSSION

RFA devices produced by Osstell and Penguin companies are currently available in the market. The reliability of RFA devices to measure primary stability has well been proven over the years by its routine use in today's clinical practice. There have been numerous studies to investigate the reliability of Osstell Mentor and Osstell ISQ, which have been used for a longer time,[14–17] and Osstell IDx and Penguin RFA, which have been in clinical use for a shorter period of time.[18–23] To the best of our knowledge, there is no study in the literature about the reliability of Osstell Beacon presented as the latest version of Osstell company RFA device. The intraobserver and interobserver reliability of Osstell IDx, Osstell Beacon, and Penguin RFA devices were evaluated in the present study.

A previous study[24] showed that ISQ values obtained by Osstell ISQ were significantly higher than ISQ values obtained by Penguin RFA. It was stated that the intraobserver reliability of Penguin RFA was excellent as the ICC was over 0.90. In another previous study,[22] ICCs for ISQ values obtained from implants placed in bone type 2 and type 3 were 0.90 for Penguin RFA and 0.92 for Osstell ISQ. Norton et al[18] evaluated the correlation of ISQ among Osstell ISQ, Osstell IDx, and Penguin RFA. According to the results of the study, the highest reliability was between Osstell ISQ and Osstell IDx, while the lowest reliability was between Osstell ISQ and Penguin RFA. They reported the small differences (less than 4 units) in ISQ values, which is statistically significant while also clinically nonsignificant. In addition, they argued that the difference in design and calibration technique between MulTipeg and SmartPeg contributed to the difference between ISQ values obtained with Osstell and Penguin devices. In contrast to our statistical methods, ICC of the three instruments was undertaken in the study of Norton et al[18] for investigation of ICC between devices where repeated measures of the same implant were evaluated to get an ICC for each device in the present study. Becker et al[21] reported that the ISQ values recorded by Penguin RFA were marginally higher than Osstell, but the generation of Osstell device was not specified. Contrary to these results, there was no statistically significant difference between mean ISQ values obtained with Osstell IDx, Osstell Beacon, and Penguin RFA for each experimental group in the present study. Osstell Beacon and Penguin RFA had excellent intraobserver reliability for both observers. However, the intraobserver reliability of Osstell IDx was good with an ICC of 0.86 for the first observer and excellent with an ICC of 0.91 for the second observer. Osstell IDx, Osstell Beacon, and Penguin RFA showed excellent interobserver reliability with ICCs of over 0.90.

Barikani et al[17] showed that ISQ values for implants placed in type 1 bone were significantly higher than those for implants placed in type 3 bone using Osstell Mentor. In another previous study using Osstell Mentor for ISQ recording, the RFA results of implants placed in type 2, type 3, and type 4 bone were evaluated and the ISQ value increased with increasing bone density.[25] Diaz-Castro et al[24] analyzed the ISQ values of implants placed in bovine femoral epiphysis and ribs, which represents type 2 and type 3 bone, respectively. The analysis showed that the ISQ for type 2 bone was higher than type 3 bone. Consistent with the results of the previous studies, the ISQ values obtained by Osstell IDx, Osstell Beacon, and Penguin RFA were higher in type 2 bone than in type 3 bone in the present study.[23,25] The ISQ value reflects the micromobility in the bone-implant interface, which is closely related to the mechanical properties of the surrounding bone tissue.

Barikani et al[17] showed that 3.4-mm diameter implants presented significantly lower ISQ values than 4.3-mm diameter implant. Tözüm et al[26] also supported this result by showing that higher ISQ values were obtained with wider implants compared to narrow implants. The 4.0-mm diameter implants had higher ISQ values than the 3.5-mm diameter implants in the present study similar to the aforementioned studies. As another finding of the present study, the ISQ values for tapered and straight implants were not significantly different. In the study of Torroella-Saura et al,[27] a statistically significant difference in ISQ values (72.93 and 72.35) was not found when comparing the straight and tapered implants. Sakoh et al[28] stated that tapered implants showed significantly higher insertion torque than straight implants, but ISQ values did not show statistically significant difference. The authors concluded that the RFA did not clearly demonstrate the difference in primary stability between 2 implant macro designs. It has been stated that primary stability is affected by implant thread pattern, distance, geometry, and cutting design.[29,30] Therefore, comparing studies that used implants with different macro designs makes it difficult to draw accurate conclusions regarding the results. The study using the implant brand used in the present study and comparing the ISQ values of the tapered and straight implants also did not show a statistically significant difference between the ISQ values of 2 implant designs.[31] The reason for the lack of a statistical difference between the ISQ values of implant macro designs may be implant company-specific design. The implant manufacturer claims that apical part of straight implants has a slight conical implant design in combination with a secondary cutting face and so, accomplishes maximum stability in all types of bones. The manufacturer stated that both implant designs have a unique thread cutting and forming design. These differences in implant macro design and partially tapered design of the straight implant may be the reason for the results of the present study.

There are several limitations in the present study. Although the artificial bones with standardized density were used, the mechanical properties of living bone and clinical conditions could not be completely simulated. On the other hand, ISQ values were recorded in 2 directions from each implant by providing a standard angle and distance between RFA devices and the pegs. Thus, the standard deviation values were within a certain range. In the clinical conditions, the mesiodistal and buccolingual direction measurements may be difficult due to near position of adjacent tooth or difficulty handling the probe especially for the posterior teeth. ISQ measurements were performed using 2 different macro designs of the same implant brand. Primary stability of an implant may be affected with implant thread pattern, distance, geometry, and cutting design in addition to implant macro design, diameter, and bone density, so further studies might focus on the impact of these parameters on the primary stability and reliability of RFA devices using different implant brands. The ISQ values measured in the present study were above the threshold of 70 for immediate loading. These values may be related to the use of standard length implants in type 2 and type 3 bone densities. Investigation of ISQ values of short implants placed in lower bone densities is recommended for further studies.

Conclusion

According to the results of the present study, Osstell IDx, Osstell Beacon, and Penguin RFA presented excellent interobserver reliability. Thus, similar results were achieved even if different observers measured implant stability. The intraobserver reliability of Osstell Beacon and Penguin RFA were excellent, but that of Osstell IDx was good. Higher bone density and implant diameter provided greater primary stability. The implant design had no significant effect on implant stability. The ISQ values obtained from the implants did not differ between RFA devices for each implant diameters, implant design, and bone density. The measurements obtained by the 3 devices used were comparable.

Abbreviations

ICC: intraclass correlation coefficient
ISQ: implant stability quotient
RFA: resonance frequency analysis

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Note

The authors report no conflict of interest.

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