Determination of the Optimum Torque to Tighten the Smartpegs of Magnetic Resonance Frequency Analyses Devices: An Ex Vivo Study

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The aim of this study was to find an optimal value for tightening the Smartpegs for magnetic radiofrequency analysis devices (RFAs) devices. Thirty implants were placed in 3 cow ribs. The RFA value of each implant was measured in buccal and mesial directions after tightening the Smartpegs with 1, 3, 4, 8, 9, 10, and 11 Ncm. Additionally, 4 different examiners measured the RFA after hand tightening the Smartpegs, and the results were compared. The buccal implant stability quotient (ISQ) values when the Smartpegs were tightened to 1Ncm were significantly lower than the ISQ values when the Smartpegs were tightened to 3, 4, 8, 9, 10, and 11 Ncm ($P < .05$). The mesial ISQ values when the Smartpegs were tightened to 1, 3, and 4 Ncm were significantly lower than the ISQ values when the Smartpegs were tightened with higher torque values ($P < .05$). The buccal measurements made by 1 examiner was significantly lower than 3 Ncm ($P < .05$), and the buccal measurements made by 1 examiner was significantly lower than 4 Ncm ($P < .05$). The mesial ISQ values measured by 2 examiners were significantly lower than 3 Ncm ($P < .05$), and the mesial ISQ values measured by the other 2 examiners were significantly lower than 8 Ncm ($P < .05$). The tightening of the Smartpegs should be standardized by the manufacturer to a range of 5-8 Ncm in order to gain reliable objective RFA values, instead of leaving it to subjective finger pressure.

Key Words: dental implants, radiofrequency analysis, osseointegration, primary stability

INTRODUCTION

It has been well documented that primary stability and the preservation of stability in the healing process are important factors for the success and survival of dental implants.[1–3] The stability measured right after implant insertion is called primary stability and has been regarded as a prerequisite for successful osseointegration.[2–5] Secondary stability is the stability during the healing process; it requires direct contact between implant and bone without the interposition of connective tissue.[4] Stability decreases due to the resorption of necrotic bone adjacent to the implant after surgery and its replacement by extracellular matrix, which results in reduced bone to implant contact in the first weeks. As bone remodeling terminates and osseointegration becomes solid, stability increases again.[4,5] Therefore, it is crucial to measure implant stability at surgery and during the healing process to determine the adequate bone-implant stiffness to warrant proceeding with restoration, and the method used for measuring implant stability should be accurate and reliable. Various stability measurement techniques have been used to measure dental implant stability.[6] Of these, resonance frequency analyses (RFA) is the widely accepted method that has been reported to be reliable, sensitive, and objective.[1–4,7]

The method used for measuring RFA was developed by Meredith in 1998,[2] by connecting an adapter to an implant in an animal study. The RFA system, commercially named Osstell, was electronic and had a cable connection between the L-shaped transducer and the resonance frequency analyzer.[2]RFA is the belief that a frequency of audibility range is repeatedly vibrated onto an implant and that in stronger bone implant surfaces, resonance occurs in a higher frequency.[8] In the beginning, radiofrequency values were accessible in Hertz, but the values were later transformed to implant stability quotient (ISQ) units ranging from 1 to 100, where 100 is the highest degree of stability.[8] Osstell was later followed by Osstell Mentor and Osstell ISQ, which used magnetic technology instead of the cable connection.[8–10] The magnetic devices are easier to handle, can be sterilized, and have been reported to present more reproducible and representative results compared with the cabled device.[10,11] However, the interobserver reliability of the magnetic devices

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Figure 1. Radiofrequency analysis measurements of the examiners.

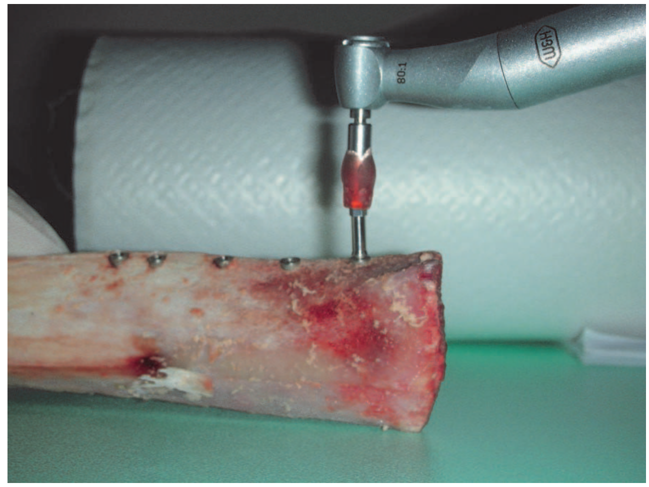

Figure 3. Image of the Smartpeg tightening by using the cordless prosthodontic screwdriver.

has been found to be poor, which is a disadvantage compared with the electronic Ostell.[10] The Smartpegs for the magnetic devices are hand tightened by using a plastic driver,[12] and the tightening forces may show alterations due to the different forces exerted by different examiners.[10] The Osstell Company proposes that the Smartpegs should be tightened to 4–5 N, which is described as "finger tight."[8] However, finger tightness is variable and is not an objective criterion.[10] Therefore, the present study was conducted to determine the optimal value for tightening the Smartpegs and resolve these misperceptions.

Materials and Methods

Ex vivo specimen preparation

For the experimental procedures, 3 fresh cow ribs belonging to the same animal were used to represent human edentulous jawbones due to the macroscopic composition of cortical and medullar bone.[10,13]

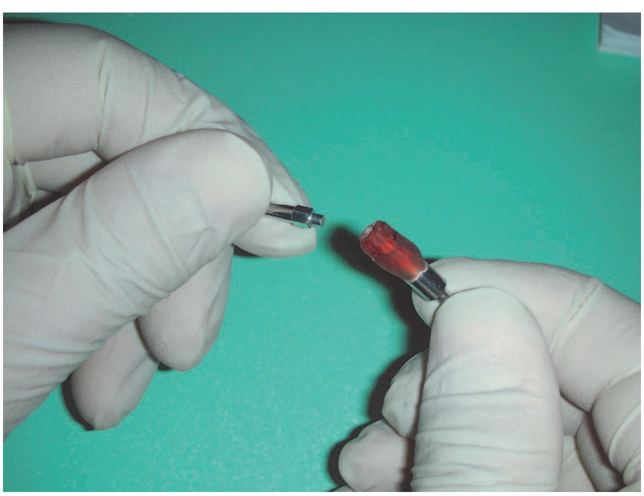

Figure 2. Image of the new appliance fabricated for measuring the tightening forces.

The implant beds were prepared following the standard protocol recommended by the manufacturer, and 30 implants were inserted into the ribs (10 each) with a safe distance in between. The implants were all 3.8-mm wide and 13-mm long and belonged to the same manufacturer (Trias implant system, Servo-Dental GmbH & Co. KG, Hagen, Germany).

Measurements

The RFA measurements were made by 4 examiners blinded to the study protocol using the Osstell Mentor (Osstell Mentor, Integration Diagnostics, Savedalen, Sweden). A magnetic peg calibrated for the Trias implant system was inserted by means of a plastic screwdriver (Smartpeg type 7, Integration Diagnostics, Savedalen, Sweden) and hand tightened by each examiner on each implant. The probe of the analyzer was seized 1 mm from the Smartpeg at a 90° angle, and the RFA value was registered as implant stability quotient (ISQ) on the digital screen of the instrument (Figure 1). The measurements were performed in the buccal and mesial directions for each implant. Additionally, instead of the original plastic screwdriver of the Smartpegs, a new appliance was fabricated for measuring the tightening forces as follows: The Smartpeg calibrated for the Trias implant system was inserted into the drill extension appliance of the Trias dental implant system and fixed with a pattern resin (GC Pattern Resin, GC America, Alsip, Ill; Figure 2). The Smartpegs were tightened to every implant with a multifunctional endodontic motor (VDW Gold, VDW, Munich, Germany) at 1, 3, and 4 N tightening forces and with a cordless prosthodontic screwdriver (W&H Dentalwerk, Bürmoos, Austria) at 8, 9,10, and 11 Ncm tightening forces (Figure 3) with the aid of this appliance.

The ISQ measurements were carried out by an oral and maxillofacial surgeon blinded to the study protocol using the Osstell Mentor in the buccal and mesial positions for every implant at each tightening force. The ISQ values recorded at each tightening force and the ISQ values recorded by the examiners were compared afterward.

Table 1

Appropriateness of the parameters to normal distribution according to the Kolmogorov-Smirnov test

Measurement Type	Statistic	Degree of Freedom	*P*
1 N, buccal	0.170	30	.269
1 N, mesial	0.167	30	.326
3 N, buccal	0.336	30	.388
3 N, mesial	0.252	30	.397
4 N, buccal	0.270	30	.594
4 N, mesial	0.293	30	.472
8 N, buccal	0.320	30	.693
8 N, mesial	0.231	30	.286
9 N, buccal	0.324	30	.438
9 N, mesial	0.232	30	.245
10 N, buccal	0.279	30	.266
10 N, mesial	0.270	30	.618
11 N, buccal	0.310	30	.558
11 N, mesial	0.279	30	.221
Examiner 1, buccal	0.219	30	.797
Examiner 1, mesial	0.182	30	.857
Examiner 2, buccal	0.119	30	.235
Examiner 2, mesial	0.216	30	.217
Examiner 3, buccal	0.122	30	.254
Examiner 3, mesial	0.135	30	.377
Examiner 4, buccal	0.221	30	.633
Examiner 4, mesial	0.181	30	.366

Table 3

P values* of torque value comparisons according to the Bonferroni test

Torque Values	Buccal ISQ† *P*	Mesial ISQ *P*
1 N/3 N	.046*	.004**
1 N/4 N	.045*	.005**
1 N/8 N	.015*	.001**
1 N/9 N	.006**	.001**
1 N/10 N	.006**	.001**
1 N/11 N	.007**	.001**
3 N/4 N	1.000	1.000
3 N/8 N	.707	.002**
3 N/9 N	.838	.004**
3 N/10 N	.564	.049*
3 N/11 N	1.000	.176
4 N/8 N	1.000	.011*
4 N/9 N	1.000	.014*
4 N/10 N	1.000	.227
4 N/11 N	1.000	.572
8 N/9 N	1.000	1.000
8 N/10 N	1.000	1.000
8 N/11 N	1.000	1.000
9 N/10 N	1.000	1.000
9 N/11 N	1.000	.842
10 N/11 N	1.000	1.000

*$P < .05$; **$P < .01$.

†ISQ indicates implant stability quotient.

Statistical analyses

For statistical analysis of the results, the Statistical Package for Social Sciences (SPSS) for Windows 15.0 was used. A Kolmogorov-Smirnov test was conducted to establish whether the data were normally distributed. Since the parameters showed normal distribution, repeated measures analysis of variance and Bonferroni test for post hoc testing was performed to detect the significance between the measurements. The results were assessed at a significance level of .05.

Results

The appropriateness of the parameters to normal distribution are shown in Table 1. The parameters showed normal distribution. The mean ISQ values when the Smartpegs were tightened to 1, 3, 4, 8, 9, 10, and 11 Ncm are presented in Table 2. The buccal ISQ values when the Smartpegs were tightened to 1 Ncm were significantly lower than the ISQ values when the Smartpegs were tightened to 3, 4, 8, 9, 10, and 11 Ncm ($P < .05$; Table 3). The buccal ISQ values did not differ significantly at the other tightening forces ($P > .05$). The mesial ISQ value when the Smartpegs were tightened to 1 N were significantly lower than the ISQ values when the Smartpegs were tightened to 3, 4, 8, 9, 10, and 11 Ncm. ($P < .01$; Table 3). The mesial ISQ value when the Smartpegs were tightened to 3 Ncm were lower than the ISQ values when the Smartpegs were tightened to 8, 9, 10, and 11 Ncm ($P > .05$; Table 3). The mesial ISQ values when the Smartpegs were tightened to 4 Ncm were lower than the ISQ values when the Smartpegs were tightened to 8 and 9 Ncm ($P > .05$; Table 3). The mesial ISQ values did not differ significantly at the other tightening forces ($P > .05$; Table 3).

Table 2

Mean implant stability quotient (ISQ) values

Torque Value	Buccal ISQ Mean ± SD	Mesial ISQ Mean ± SD
1 N	75.90 ± 8.32	78.37 ± 7.54
3 N	80.30 ± 6.96	83.23 ± 4.53
4 N	80.50 ± 6.55	83.50 ± 4.67
8 N	81.17 ± 7.20	85.00 ± 4.06
9 N	81.43 ± 6.34	85.03 ± 3.85
10 N	81.43 ± 6.37	84.70 ± 3.72
11 N	81.30 ± 5.88	84.60 ± 3.47

No significant differences were found between the buccal ISQ values measured by examiner 1 and the measurements made when the Smartpegs were tightened to 1, 3, 4, 8, 9, 10, and 11 Ncm ($P > .05$; Table 4). No significant differences were found between the mesial ISQ values measured by examiner 1 and the measurements made when the Smartpegs were tightened to 1, 3, and 4 Ncm ($P > .05$; Table 4). The mesial measurements of examiner 1 were significantly lower than the ISQ values when the Smartpegs were tightened to 8, 9, 10, and 11 Ncm ($P < .05$; $P < .01$; Table 4).

The buccal and mesial ISQ values measured by examiner 2 were significantly lower than the measurements made when the Smartpegs were tightened to 3, 4, 8, 9, 10, and 11 Ncm ($P < .05$; $P < .01$; Table 4). No significant differences were found between the buccal and mesial ISQ values measured by examiner 2 and the measurements made when the Smartpegs were tightened to 1 Ncm ($P > .05$; Table 4).

Table 4

P values" of comparisons of different torque levels and examiner measurements according to the Bonferroni test

	Buccal ISQ† *P*	Mesial ISQ *P*
Examiner 1/1 N	1.000	.130
Examiner 1/3 N	1.000	1.000
Examiner 1/4 N	1.000	.856
Examiner 1/8 N	.871	.006**
Examiner 1/9 N	.501	.005**
Examiner 1/10 N	.366	.044*
Examiner 1/11 N	.662	.045*
Examiner 2/1 N	1.000	1.000
Examiner 2/3 N	.032*	.001**
Examiner 2/4 N	.015*	.001**
Examiner 2/8 N	.007**	.001**
Examiner 2/9 N	.002**	.001**
Examiner 2/10 N	.001**	.001**
Examiner 2/11 N	.002**	.001**
Examiner 3/1 N	1.000	1.000
Examiner 3/3 N	.102	.030*
Examiner 3/4 N	.022*	.011*
Examiner 3/8 N	.019*	.001**
Examiner 3/9 N	.003**	.001**
Examiner 3/10 N	.001**	.001**
Examiner 3/11 N	.004**	.001**
Examiner 4/1 N	.461	.060
Examiner 4/3 N	1.000	.212
Examiner 4/4 N	1.000	.068
Examiner 4/8 N	.641	.002**
Examiner 4/9 N	.296	.003**
Examiner 4/10 N	.176	.024*
Examiner 4/11 N	.561	.034*

$^*P < .05$; $^{**}P < .01$.
†ISQ indicates implant stability quotient.

The buccal ISQ values measured by examiner 3 were significantly lower than the measurements made when the Smartpegs were tightened to 4, 8, 9, 10, and 11 Ncm ($P < .05$; $P < .01$; Table 4). No significant differences were found between the buccal ISQ values measured by examiner 3 and the measurements made when the Smartpegs were tightened to 1 and 3 Ncm ($P > .05$; Table 4). The mesial ISQ values measured by examiner 3 were significantly lower than the measurements made when the Smartpegs were tightened to 3, 4, 8, 9, 10, and 11 Ncm ($P < .05$; $P < .01$; Table 4). No significant differences were found between the mesial ISQ values measured by examiner 3 and the measurements made when the Smartpegs were tightened to 1 N ($P > .05$; Table 4).

No significant differences were found between the buccal ISQ values measured by examiner 4 and the measurements made when the Smartpegs were tightened to 1, 3, 4, 8, 9, 10, and 11 Ncm ($P > .05$; Table 4). No significant differences were found between the mesial ISQ values measured by examiner 4 and the measurements made when the Smartpegs were tightened to 1, 3, and 4Ncm ($P > .05$; Table 4). However the mesial measurements of examiner 4 were significantly lower than the ISQ values when the Smartpegs were tightened to 8, 9, 10, and 11 Ncm ($P < .05$; $P < .01$; Table 4).

Discussion

With the introduction of noninvasive RFA devices to dental practice for detecting the stability of implants, clinicians can decide the loading time of implants and monitor healing to take precautions to improve the bone to implant contact in order to prevent possible implant failures.[4] With the evolution of technology, the RFA devices are now magnetic and much easier to use during surgery and during the healing phases. Variations of RFA values under different torque forces applied to the transducer fixation screw have been presented for the original electronic RFA device.[7] Additionally, it has been shown that the RFA measurements made by the magnetic devices may also show variable results due to different forces applied during Smartpeg tightening by different clinicians.[10] Since it is not possible to standardize the finger pressure of every clinician in the range of 4–5 Ncm, which is suggested by the Osstell Company and known as "finger tight," and the poor intraclass correlation coefficient values obtained for the interobserver reliability of RFA measurements in a former study by the same team,[10] the present study was conducted to find an optimum tightening force to be applied to the Smartpegs when using the Osstell mentor.

The buccal RFA measurements made by 2 examiners did not show any differences when the Smartpegs were tightened by different standardized forces (examiners 1 and 4), whereas the buccal measurements made by 1 examiner were lower than 3 Ncm (examiner 2), and the buccal measurements made by 1 examiner were lower than 4 Ncm. The mesial ISQ values measured by 2 examiners were lower than 3 Ncm (examiners 2 and 3), and the mesial ISQ values measured by the other 2 examiners were significantly lower than 8 Ncm (examiners 1 and 4). It is obvious that the 2 examiners (examiners 1 and 4) applied stronger forces when tightening the Smartpegs than the other examiners.

For standardizing the tightening forces of the Smartpegs in the present study, a multifunctional endodontic motor was used for 1, 3, and 4 Ncm tightening forces and a cordless prosthodontic screwdriver was used for 8,9,10, and 11 Ncm. It was not possible to tighten the Smartpegs with 2 Ncm using the endodontic motor because of the factory settings of the device. Additionally the Smartpegs could not be tightened with 5, 6, and 7 Ncm forces, which may be regarded as a limitation of the present study. Our results show that when measuring the implant stability from the buccal side, the Smartpegs should be tightened with at least 3 Ncm. On the other hand, when measuring the mesial ISQs, the Smartpegs should be tightened with at least a force between 5 and 8 Ncm to overcome possible confusion.

It should be noted that in clinical circumstances, such as a wet environment due to saliva or blood or limited access due to a possible microstomia or a surgical flap, might cause more incongruences[10] when measuring the RFA with the Osstell Mentor, and the range of measurements may show greater interexaminer variability. Our results showed that the tightening of the Smartpegs should be standardized to a range of 5–8 Ncm in order to gain universally accepted, reliable, and objective RFA values, instead of leaving it to subjective finger pressure. This standardization should be made by the manufacturer because it is not possible for clinicians to make this standardization at the exact desired forces. Otherwise, it may not be possible to avoid discrepancies when monitoring the implant stability with the magnetic RFA devices especially when the measurements are made by different clinicians.

Abbreviations

ISQ: implant stability quotient

RFA: resonance frequency analysis

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