ISQ as a Diagnostic Tool in Implants Affected with Bone Loss: An In Vitro Experimental Study

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Purpose: To determine the relationship between bone loss that occurs during the peri-implantitis process and variations in implant stability using resonance frequency analysis (RFA) measurement methods. ***Materials and Methods:*** Forty self-tapping implants were placed in cow ribs, and study scenarios were established according to the affected implant side and bone loss depth (n = 10 implants per group): Case 1 = bone loss on one side (vestibular); Case 2 = bone loss on two opposite sides (buccal and lingual); Case 3 = bone loss on two adjacent sides (buccal and mesial); and Case 4 = four-sided bone loss (circumferential). For each group of 10 implants, first a bone loss of 0 mm was evaluated, then 4-mm defects (simulating 1/3 of bone loss) were created and evaluated, and finally 8-mm defects (simulating 2/3 of bone loss) were created and evaluated. Osteotomy measurements were made with a periodontal probe. For each implant, RFA was measured by the same operator using the Beacon system (Osstell). ***Results:*** The initial implant stability quotient (ISQ) values of the 40 implants exceeded 70, reflecting an average of 73 in the buccolingual (VL) and 74.8 in the mesiodistal (MD) directions. ISQ measurements in the 10 implants in which bone dehiscence was performed on the vestibular aspect reflected a decrease in ISQ values as bone loss increased. When generating bone loss in two opposite sides (buccal and lingual), a greater decrease in ISQ values was observed when 2/3 of the implant were affected. The average VL ISQ measurement was less than 70 when at sites with 2/3 of bone loss. ***Conclusions:*** When bone loss occurs on only one side of the implant, the ISQ values decrease, but the implant maintains good stability. The same occurs when two opposite sides of the implant are affected, as the unaffected side has the least decrease in ISQ value. *Int J Oral Maxillofac Implants 2024;39:468–472. doi: 10.11607/jomi.10510*

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In 2014, peri-implantitis was defined as a progressive and irreversible disease of implant-surrounding hard and soft tissues, accompanied by bone resorption, decreased osseointegration, increased pocket formation, and purulence.[1] In 2017, a group of world-class specialists convened and established the definitions of peri-implant health status, mucositis and peri-implantitis. *Peri-implantitis* was defined as "a plaque-associated pathologic condition occurring in tissues around dental implants, characterized by inflammation of the peri-implant mucosa and subsequent progressive loss of supporting bone."[2]

According to a meta-analysis, the weighted mean prevalence of peri-implantitis is 22% (CI: 14% to 30%).[3] A working group at the Sixth European Workshop on Periodontology reported that peri-implant mucositis occurs in up to 80% of subjects (50% of sites) restored with implants, with peri-implantitis in 28% to 56% of subjects (12% to 40% of sites).[4]

Given that peri-implantitis is associated with bone loss, diagnostic tools are very important for the study of peri-implantitis to establish the cause, degree, and type of bone loss.[5] There are varying outcomes in relation to the use of radiologic methods as effective and accurate diagnostic tools for bone loss associated with implants. González-Martín et al reported that periapical radiographs and even CBCT have low accuracy in the diagnosis of peri-implant bone, particularly if the buccal width is < 1 mm or if the bone is associated with marginal peri-implant defects.[6] On the other hand, Insua et al established that CBCT is a viable method and a valid tool to establish a diagnosis of and treatment plan for peri-implantitis.[7]

As a result, the use of resonance frequency analysis (RFA) has been proposed as a secondary diagnostic tool to monitor bone loss and peri-implant mobility.[8] In the mid-1990s, Meredith et al developed RFA as a method to measure the stability of dental implants.[9] Since then, using RFA devices to assess the primary stability of dental implants has gained widespread use, especially in recent years. Established in 2003, the unit of measurement used to assess implant stability is the implant

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Fig 1 Five implants were positioned in each cow rib, with 20 mm between each implant.

Table 1 Cases Studied

	Affected side	No bone loss	1/3 bone loss	2/3 bone loss	ISQ	
					VL	MD
Case 1	Buccal	10	10	10	76.2	77.6
Case 2	Buccal + lingual	10	10	10	72.7	76.1
Case 3	Buccal + mesial	10	10	10	70	72.5
Case 4	Circumferential	10	10	10	73.1	73
Average	–	–	–	–	73	74.8

stability quotient (ISQ), represented as a value on a scale from 1 to 100. Clinical relevance is determined in the range between 50 and approximately 70, and thus 70 is considered to represent good clinical stability.

The ISQ is considered a reliable, easy-to-use, noninvasive method to both measure primary implant stability and monitor the osseointegration process.[10,11] The ISQ can also be used to assess the impact of bone loss caused by peri-implantitis.[12,13]

A quick, noninvasive, inexpensive peri-implantitis diagnostic tool can be extremely important for assessing the bone adjacent to the implant and monitoring the implant prior to peri-implantitis treatments, as it would provide very valuable data for the diagnosis, prognosis, and treatment of peri-implantitis.

This study aimed to determine the relationship between bone loss that occurs during the peri-implantitis process and variations in implant stability using RFA measurement methods.

MATERIALS AND METHODS

A total of 40 self-tapping implants were included in the study (I Clean Model, Dentis; 4.1-mm diameter, 12-mm length). The implants were placed in eight cow ribs following the drilling protocol for type I and II bones (due to the density of the ribs) recommended by the manufacturer of the implant system. The rib anatomy comprised 2- to 2.5-mm buccal and lingual plates and 4-mm trabeculae in between. Using magnifying glasses (×2.5), a total of 5 implants were positioned in each rib, maintaining a mesiodistal (MD) distance of 20 mm between each implant and in buccolingual (VL) relation to the anterior and posterior edges (Fig 1).

Four study scenarios were established according to the affected implant side and bone loss depth (Table 1): Case 1 = bone loss on one side (vestibular); Case 2 = bone loss on two opposite sides (buccal and lingual); Case 3 = bone loss on two adjacent sides (buccal and mesial); and Case 4 = four-sided bone loss (circumferential). Each case comprised 10 implants (one pair of two cow ribs).

For each case group, bone losses of 0 mm (initial state), 4 mm (simulating 1/3 of bone loss) and 8 mm (simulating 2/3 of bone loss) were established. Measurements were first made for the 0-mm loss, then the 4-mm defect was created and measured in the same implant sites, and finally the 8-mm loss was created and measured at the same locations.

Round and straight high-revolution turbine drills and abundant irrigation were used to carry out the osteotomies, and material remains were cleaning exhaustively. Osteotomy measurements were made with a periodontal probe (color-coded periodontal probe, Kerr) up to the corresponding level of bone loss (Fig 2).

For each implant, RFA was measured using the Beacon system (Ostell). Measurements were performed according to the system's specifications. The measurement abutment (SmartPeg) was screwed onto the implant using finger force (~4 to 6 Ncm), and the tip of the Osstell Beacon was held 3 to 5 mm from the magnetic SmartPeg tip, without actually touching it. Three measurements were made at one point for each direction (VL and MD), and the average of the three measurements was noted as the reference value (Fig 3). All measurements were recorded for later evaluation. All procedures were performed by the same operator (R.M.M.).

Statistical Analysis

Mean values and SDs were measured for all implants in each group. Rosenthal's test was performed to compare the differences between groups. $P < .005$ indicated a statistically significant difference.

RESULTS

A total of 40 implants were placed in eight fresh cow ribs. All implants were placed with an insertion torque > 35 Ncm, maintaining a minimum 2-mm distance to the buccal and lingual tables and a 2-cm space between implants.

Fig 2 Osteotomy measurements were made with a color-coded periodontal probe up to the corresponding level of bone loss.

Fig 3 ISQ measurements were made using a Smartpeg.

ISQ measurements were made in the VL and MD directions for each bone loss amount in each case type, obtaining a mean ISQ of 73 VL and 74.8 MD (see Table 1).

Mean values and differences were determined among cases according to the bony defect created. The results of Case 1 measurements (vestibular bone loss) reflected the following average values: initial: VL = 76.2, MD = 77.6; loss of 1/3: VL = 74.5, MD = 76; loss of 2/3: VL = 73.2, MD = 75.1 (Table 2).VL

The ISQ data from Case 2 (VL bone loss) had the following average values: initial = 72.7 to 76.1; loss of 1/3 = 70.9 to 74.8; loss 2/3 = 64.7 to 72.1. Detailed results are shown in Table 3.The average ISQ measurements in Case 3 (bone loss in contiguous mesial and lingual surfaces) were: initial = BL: 70, MD: 72.5; loss of 1/3 = BL: 65.3, MD: 69.9; and loss of 2/3 = BL: 62.5, MD: 65.1 (Table 4).

Table 5 shows the ISQ data from Case 4 (circumferential bone deficiency) sites. The average values were: initial = 73.1 to 73; 1/3 bone loss = 53.2 to 54.3; 2/3 bone loss = 17.9 to 21.9.

Table 2 ISQ Values in Case 1 Sites

Implant no.	No bone loss		1/3 bone loss (4 mm)		2/3 bone loss (8 mm)	
	VL	MD	VL	MD	VL	MD
1	72	72	75	76	75	75
2	80	75	78	76	75	76
3	75	79	78	78	76	78
4	75	80	72	78	76	76
5	77	80	75	76	73	73
6	73	78	73	77	73	76
7	78	78	75	77	71	75
8	75	80	71	78	68	72
9	80	77	75	76	74	75
10	77	77	73	75	71	75
Average	76.2	77.6	74.5	76	73.2	75.1

These implants were placed in sites with bone loss on one side (vestibular).

Table 3 ISQ Values in Case 2 Sites

Implant no.	No bone loss		1/3 bone loss (4 mm)		2/3 bone loss (8 mm)	
	VL	MD	VL	MD	VL	MD
1	76	77	74	75	70	72
2	75	77	70	75	70	75
3	72	76	70	76	64	71
4	75	79	69	76	36	75
5	64	74	70	72	66	71
6	78	77	73	77	72	75
7	72	76	72	77	70	75
8	70	70	72	76	65	70
9	75	78	69	75	65	70
10	70	77	70	69	69	67
Average	72.7	76.1	70.9	74.8	64.7	72.1

These implants were placed in sites with bone loss on two opposite sides (buccal and lingual).

The comparison of ISQ values at the beginning, with 1/3 bony defect and 2/3 bony defect in each side of the implants. Complete results are shown in Table 6. The biggest variation in ISQ was observed when a 2/3 bony defect was present in Cases 2 and 4, and the differences were statistically significant between the starting and final values.

DISCUSSION

ISQ values have become an important factor in assessing implant success. These values are studied in relation to other implant-related variables, such as implant-bed

Table 4 ISQ Values in Case 3 Sites

Implant no.	No bone loss		1/3 bone loss (4 mm)		2/3 bone loss (8 mm)	
	VL	MD	VL	MD	VL	MD
1	72	75	65	69	64	67
2	70	75	66	70	66	62
3	73	68	69	71	60	60
4	74	74	66	67	67	70
5	75	77	67	70	48	56
6	73	77	57	66	64	70
7	71	75	65	69	62	70
8	64	75	65	74	70	67
9	64	75	70	73	68	73
10	64	54	63	70	56	56
Average	70	72.5	65.3	69.9	62.5	65.1

These implants were placed in sites with bone loss on two adjacent sides (buccal and mesial).

Table 5 ISQ Values in Case 4 Sites

Implant no.	No bone loss		1/3 bone loss (4 mm)		2/3 bone loss (8 mm)	
	VL	MD	VL	MD	VL	MD
1	72	75	51	46	17	14
2	71	71	62	59	28	35
3	75	75	61	63	20	22
4	75	75	52	55	20	17
5	75	76	58	64	43	48
6	72	75	43	39	6	11
7	72	58	41	43	3	10
8	73	75	57	60	7	22
9	73	75	52	56	28	30
10	73	75	55	58	7	10
Average	73.1	73	53.2	54.3	17.9	21.9

These implants were placed in sites with four-sided bone loss (circumferential).

Table 6 ISQ VL Values and Comparisons Between Groups

Case no.	Bone loss	Median ± SD	Rosenthal's r	*P*
Case 1	No bone loss	76.20 ± 2.70	1.27	.12
	1/3 bone loss (4 mm)	74.50 ± 2.32		
	2/3 bone loss (8 mm)	73.20 ± 2.57		
Case 2	No bone loss	72.70 ± 4.02	1.42	.002*
	1/3 bone loss (4 mm)	70.90 ± 1.72		
	2/3 bone loss (8 mm)	64.70 ± 10.44		
Case 3	No bone loss	70.00 ± 4.37	1.25	.04
	1/3 bone loss (4 mm)	65.30 ± 3.56		
	2/3 bone loss (8 mm)	62.50 ± 6.51		
Case 4	No bone loss	73.10 ± 1.44	0.22	.001*
	1/3 bone loss (4 mm)	53.20 ± 6.98		
	2/3 bone loss (8 mm)	17.90 ± 12.67		

*Statistically significant ($P < .005$).

preparation techniques and bone grafts,[14] short and extra-short implants,[15,16] and immediate implants.[17] In a review, Huang et al[18] identified 13 basic factors that can influence ISQ measurements in implants.

In clinical practice, ISQ measurements are used both for implant loading and as an indicator of possible osseointegration failure.

The initial ISQ value of the 40 implants placed exceeded 70, reflecting an average of 73 in the VL direction and 74.8 in the MD direction. These results coincide with those from Monje et al,[12] where the MD measurements are greater than the VL measurements. In studies carried out on cadaver mandibles, Chan et al obtained values of 73.0 and 73.8 in the VL and MD directions, respectively,[19] which are very similar to those obtained in the present study with implants placed in cow ribs.

ISQ measurements in the 10 implants in which bone dehiscence was performed on the vestibular aspect reflected a decrease in ISQ values as bone loss deepens. This finding coincides with studies published by Shin et al[20] and Yim et al.[21]

When generating bone loss in two opposite sides (buccal and lingual; VL assessment), a greater decrease in ISQ values was observed when 2/3 of the implant was affected. The average value of VL measurements was less than 70 when the loss is 2/3 (64.7), representing a decrease of 8 points from the initial average value (72.7).

The values obtained from the 10 implants in which osteotomies were performed on the vestibular and mesial surfaces reflect greater decrease than in previous cases. The average ISQ values are below 70 in all cases with 4 mm and 8 mm loss. ISQ measurements in the MD direction are lower than in cases where only one-way bone loss (VL) occurs.

The decrease in mean ISQ values is significant at sites with 1/3 bone loss, with decreases of 38.9% and 39.6% in VL and MD measurements, respectively. When 2/3 of the implant is affected by bone loss, the average ISQ values drop to 17.9 (VL) and 21.9 (MD). These results are similar to those reported by Shin et al,[20] who obtained very similar values in circumferential 5-mm corticotomies performed on implants (ISQ values of 57.43 ± 6.87). In another study on narrow circumferential defects (0.9 mm), Yao et al collected similar data on the decrease in ISQ as bone loss deepens, with a very significant decrease when circumferential loss was 2 mm.[22] In the same study, no differences were observed in the ISQ values when they were measured in the VL and MD directions, similar to the present study.

CONCLUSIONS

When bone loss occurs on only one side of the implant, the ISQ values decrease, but the implant maintains good stability (> 70). The same occurs when two opposite sides of the implant are affected, as the unaffected side has the least decrease in ISQ. If two contiguous sides are affected by bone loss, the ISQ values are < 70 when the bone loss reaches the first third of the implant in both the VL and MD directions. Circumferential bone loss had the greatest impact on implant stability, which was reduced along with the ISQ values. More long-term and in vivo studies are needed to set limits for bone loss and ISQ values beyond which implant survival is irreversibly compromised.

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