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IN VITRO COMPARATIVE STUDY BETWEEN ISQ AND PERIOTEST® VALUES ON THE IMPLANT STABILITY MEASUREMENTS ACCORDING TO THE INCREASED EFFECTIVE IMPLANT LENGTH.

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Statement of Problem. Objective and quantitative measurement of implant stability is very important from implant installation to long-lasting maintenance period thereafter.
Purpose of study. This study was to evaluate and compare two ISQ and PTVs on the implant stability measurements according to the increased effective implant length.
Materials and methods. Twenty self-tapping fixtures were installed in the bovine scapula and in 10 of those for group I, ISQ and PTVs were obtained in the vertical / horizontal directions according to the increased effective implant length using Osstell™ and Periotest®. After stability measurement, removal torques were measured between the after installation and after thread exposure group.
Results. ISQ and PTVs showed decreased and increased values according to the increased abutment length. Apart from PTVs, ISQ values were shown higher in horizontal direction to the long axis of bone in both the after installation and the after thread exposure groups. Removal torque values were shown higher in after installation group.
Conclusion. From the results of this study, implant stability measurement using resonance frequency analysis was more sensitive and discriminative than PTVs measurement.

The factors controlling osseointegration and bone-to-implant interface have been explained as material compatibility, surface macrostructure, surface microstructure, status of the implant bed, surgical technique of installation, and prosthetic loading.[1] The above factors eventually affect implant stability from fixture installation to long-lasting maintenance of bioactive interface thereafter.

Implant stability may be considered as primary stability at the time of implant placement and secondary stability in function. Clinical follow-up studies have shown that the risk for implant failure is higher in soft bone qualities and when using short implants, which implies that the degree of stability is important.[2] Therefore, if it can be possible to measure quantitative stability precisely and monitor implant status from the time after installation, failure risks may be found in advance and reduced.

Traditionally, clinical non-invasive tests have been used to evaluate the implant stability such as percussion, radiogragh, Periotest®(Siemens AG,Germany), Dental fine tester®(Kyocera, Japan). These methods have some difficulties in standardizing the implant stability objectively, due to application technique variations and inter-observer variabilities.

Periotest® was designed to perform quantitative measurements of the damping characteristics of the periodontal ligament surrounding a tooth and thereby establish a value for its mobility.[3] The result is displayed digitally and audibly on a scale of 8(low mobility) to 50(high mobility). Some authors propose using Periotest® for testing implant stability. Periotest value(PTV) and the range for successful implants have been reported as -5~+5.[4,5] But, Kim[6] and Cho[7] investigated the relationship between the level of bone surrounding an implant derived from radiographs and Periotest® measurements. On a measurement of 94 implants it was found that there was no significant relationship between the PTV and the bone resorption ratio. Also, Derhami et al. showed PTV variations according to the measurement spot height, angulations between handpiece and implant, holding distance of the tapping head to abutment surface.[8]

In the late 1990s, the resonance phenomenon of electrically stimulated object was applied to evaluate the implant stability by Meredith.[9] Meredith, with explanations in his thesis, developed the prototype of the resonance frequency analyser. This method uses a small L-shaped transducer that is fastened by a screw to the implant or to the mucosa-penetrating abutment. Electrical stimuli evokes resonance of vertical beam and the first flexural resonance frequency is identified as a peak.[10] He performed in vitro and in vivo studies[11-13] and claimed that quantitative methods, including resonance frequency analysis(RFA), can yield valuable information on assessment of implant stability as a prognotic determinant.[14] Studies using RFA have shown that the technique is sensitive to the implant's stiffness in bone and increased effective implant length such as marginal bone resorption.

The aim of this experimental study in bovine bone was to compare the RFA values with the Periotest values according to the increased effective implant length. Removal torque measurements were also done.

MATERIALS AND METHODS

For implant installation, fresh bone was gained between the acromion process end and spine of bovine scapula. Bone specimen selections were done by sectioning and measuring a 1-2mm cortical layer(Fig. 1).

Those areas of bovine scapula have less thick cortical layers than those of ribs. Selected bone specimens were embedded in dental hard stone for stable base(150mm x 100mm x 40mm) to 2/3 level of full bone height. After the stone reached to initial setting stage, bone specimen with stone base was soaked in cold water to reduce the effect of heat. A total of 20 machined surface, self-tapping AVANA fixtures(Osstem Co., Korea, 4.0x 10mm) were used. 10 fixtures(group Ⅰ) of those were used for RFA, PTV measurements after installation and re-measurements after first thread exposure. The RFA, PTV were measured for each implant in the two directions, vertical and horizontal to the long axis of bone specimens. Removal torque measurements followed.

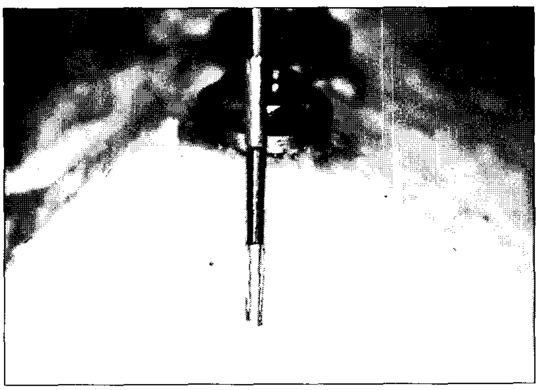

Fig. 1. 1-2mm cortical layer was shown.

Table I**.** Subgrouping of Group I data for statistics. ('a' is the immediate measurement after fixture installation, 'b' is the measurement after thread exposure. 'R', 'P', 'V', 'H' is the ISQ value, Periotest value, vertical and horizontal direction respectively.)

Measurement time(a,b)	Measurement value(R,P)	Measurement direction(V,H)	Subgroups of Group I
After installation (a)	ISQ(R)	Vertical(V)	aRV
		Horizontal(H)	aRH
	PTV(P)	Vertical(V)	aPV
		Horizontal(H)	aPH
After thread exposure (b)	ISQ(R)	Vertical(V)	bRV
		Horizontal(H)	bRH
	PTV(P)	Vertical(V)	bPV
		Horizontal(H)	bPH

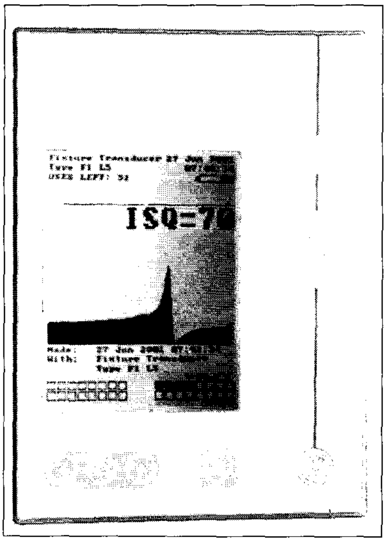

Fig. 2. Osstell™(Integration Diagnostics Ltd., Sweden). It presents the peak Hz of first flexural curve as a ISQ value.

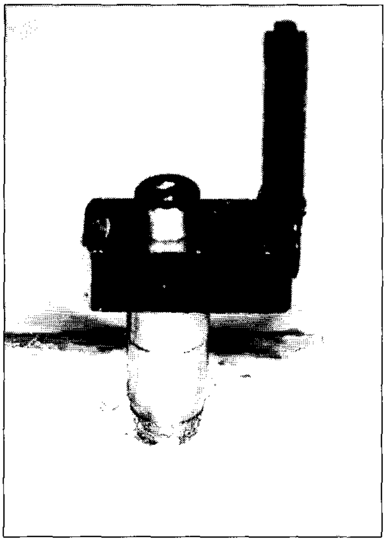

Fig. 3. Transducer connected to the abutment was shown.

Measurement data subgroups of Group I for statistics are shown in Table I.

The fixture installation procedure was done carefully. The final twist drill had a 3.3mm-diameter and tap was used because of dense bone quality. A countersink drill was used 1/2 depth of guide line for settling of flange supracrestally and then fixture was installed electronically. No ratchet wrench was used.

Resonance frequencies were measured using Osstell™(Integration Diagnostics Ltd., Sweden)(Fig. 2).

5.5mm height standard abutments were connected to the fixtures and standard abutment transducer was screwed on the top of abutment(Fig. 3) and the ISQ(Implant Stability Quotient) value was measured. ISQ is based on the resonance frequency of the transducer on a scale from 3500Hz(0 ISQ) to 8500Hz(100 ISQ).[15]

After measuring ISQ values, the transducer

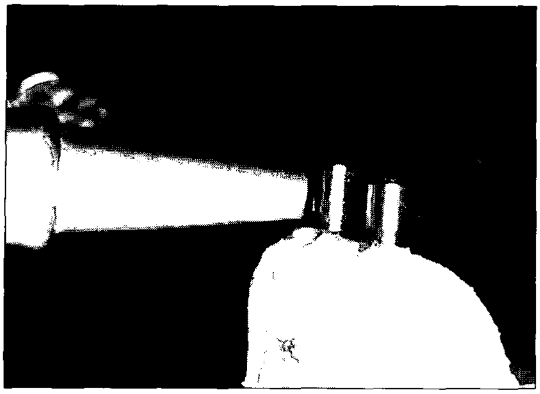

Fig. 4. The handpiece of Periotest® positioning was tried to be parallelling to the ground, focusing on the middle 1/3 of abutment and 1.5-2mm apart from abutment surface using grip of mechanical device.

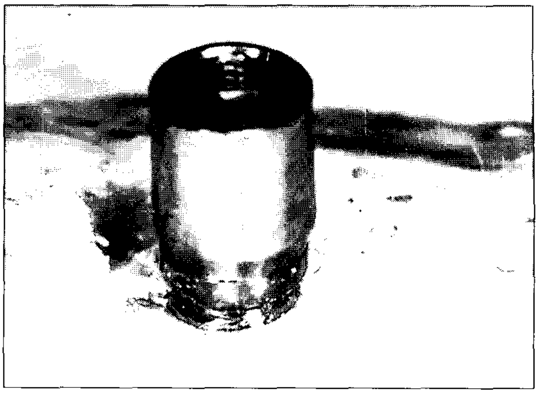

Fig. 5. First thread was exposed carefully to allow the increased effective implant length.

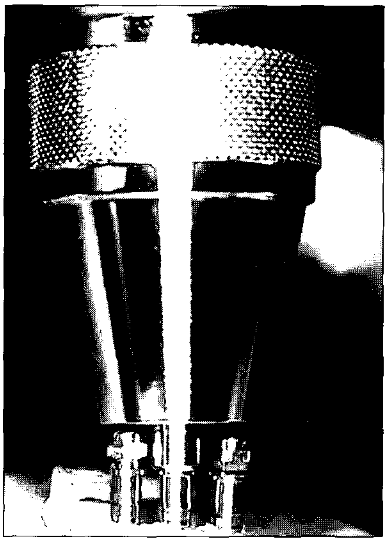

Fig. 6. The measurement of removal torque with a Torque gauge®.

was unscrewed and Periotest values were measured. The handpiece of Periotest® was fixed firmly by grip of mechanical device in position parallelling to the ground, the slug focusing on the middle 1/3 of abutment and 1.5~2mm aparting from abutment surface(Fig. 4). Measurements were done until same PTVs per each sample were shown three times and that valuewas taken.

After finishing ISQ value and PTV measurements, a small groove was prepared, using high speed fissure bur, around the flange of the fixture with care as to not contact with the implant.Bony remnants were removed by a sharp scapel to expose the first thread(Fig. 5).

After exposure, re-measurements of ISQ and PTVs were done and subsequently removal torques were measured by Torque gauge® (Tonichi, 15BTG/kgf · cm, Japan) (Fig. 6).

Remaining 10 fixtures(group Ⅱ) were installed as above installation protocols and removal torques were measured after 4 hours maintenance in humid condition. All removal torque values(Kgf · cm unit) were converted into Ncm unit.

In statistical analysis, a non-parametric paired t-test(Wilcoxon signed rank test; SPSS version 8.0 $p<0.05$) was used for ISQ and Periotest values and a non-parametric student t-test(Mann-Whitney U test; SPSS version 8.0 $p<0.05$) for removal torque values.

RESULTS

Table Ⅱ. shows the mean values and standard deviations of ISQ values and Periotest values for each condition of Group Ⅰ. Generally, small standard deviations in ISQ values are shown when compared with mean values. According to the increased effective implant length, the mean values show decreased ISQ and increased PTV values. Relative higher values were shown in the vertical direction measurements. ISQ values were shown from 73 to 86 and PTVs from 2.0 to 5.0. In the measurement values, ISQ values showed statistically significant differences in both measurement time($p<0.05$) and measurement directions($p<0.05$). But Periotest values showed similar statistical result($p<0.05$) only when measured according to the measurement time. When measured in different directions, those values showed no statistically significant differences($p>0.05$) in spite of better values in horizontal direction(Table Ⅲ, Fig. 7, 8). Table Ⅳ. and Fig. 9. show removal torque values of two groups. There was statistically significant difference between the two groups($p<0.05$).

Table Ⅱ. The mean values and standard deviations of ISQ values and Periotest values.

Subgroups of Group I (n=10)		Mean±SD
aRV	ISQs	81.50±2.22
aRH	ISQs	77.40±2.87
aPV	ISQs	83.30±2.40
aPH	ISQs	78.70±2.84
bRV	PTVs	-2.40±0.97
bRH	PTVs	-0.30±1.25
bPV	PTVs	-3.00±1.49
bPH	PTVs	-0.60±1.70

Table Ⅲ. Wilcoxon signed ranks test in Group I(95% confidence level). Besides paired PTV values according to the direction, significant differences were shown.

Paired groups	p-value
aRV-bRV	0.005*
aPV-bPV	0.007*
aRH-bRH	0.005*
aPH-bPH	0.007*
aRV-aRH	0.011*
aPV-aPH	0.058
bPV-bRH	0.006*
bPV-bPH	0.083

* denotes that there is significant difference between two groups

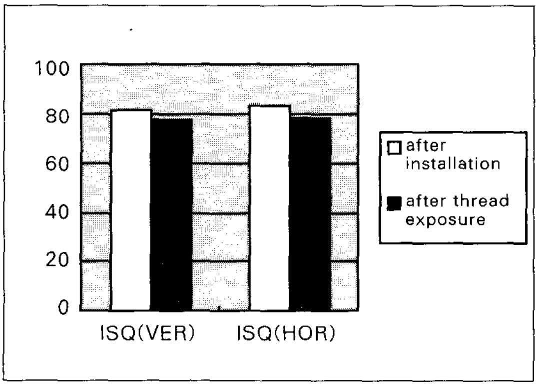

Fig. 7. Histogram of mean ISQ values according to the increased effective implant length and measurement directions.

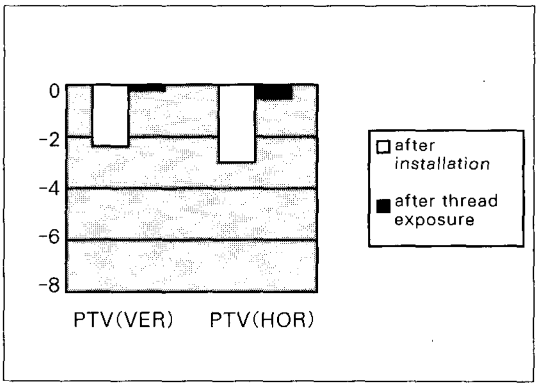

Fig. 8. Histogram of mean PTVs according to the increased effective implant length and measurement directions.

Table Ⅳ. The mean and standard deviation values of removal torque(unit:Ncm).

Groups	Mean±SD	Mann-Whitney U test
Group I(after thread exposure)	35.28±2.91	p=0.000*
Group II(after installation)	43.19±1.89	

*denotes that there is significant difference between two groups

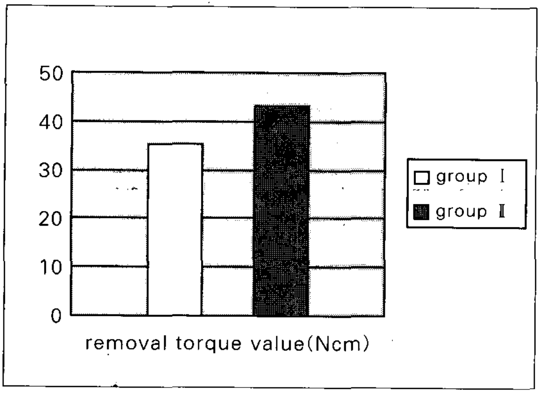

Fig. 9. Histogram of removal torque values of two groups.

DISCUSSION

Using bovine bone as an experimental material for resonance frequency analysis has a limitation due to its higher stiffness as a result of high bone density. Specimen selection was performed from the acromion process end to spine of bovine scapula. That area(3~5cm) has relatively thin cortical layer in bone, so it has more advantageous than the rib. But as bovine cancellous bone has highly compact trabecular pattern, even in preliminary tests, resonance frequency values were measured highly as it used to be. So installation protocols were changed such as followings ; use of tap in spite of self-tapping fixture, use of 3.3mm diameter twist drill as a final drill, minimized use of countersink drill, no use of ratchet wrench.

For the same condition to measure ISQ and PTV, abutment and abutment level transducer was used. Effective implant length (EIL) is the sum of abutment length and exposed fixture height above marginal bone around implant. Increased effective implant length show lower ISQ (or Hz) value and higher PTV. But Osstell™ presents calibrated ISQ value for abutment length. Therefore, ISQ values are affected by stiffness of implant in bone and marginal bone level around implant, regardless of connection with abutment. The sensitivity of this technique is 10Hz.[10] Studies using RFA have shown that the degree of stability is determined by the density of the bone, the surgical technique used and the design of the implant.[9,16] For instance, implant stability is lower in soft bone qualities when compared with denser bone, but increases with time.[17,18]

In the measurement direction(Table Ⅲ), regardless of thread exposure or not, PTVs showed no significant differences between vertical and horizontal direction in contrast with the ISQ values. ISQ values were shown significantly higher in horizontal direction. It can be expected like the following; if the vertical beam of transducer is connected to the implant in a horizontal direction, buttressing effect of long axis of bone and slightly higher marginal bone level mesiodistally contribute to its results. In contrast, PTVs were not sensitive to present these results. In most clinical situations, the transducer should be connected in a vertical direction, it can be said that the lowest ISQ value of that situation is shown and its meanings are valuable.

Osstell™(Integration Diagnostics Ltd., Sweden) used in this experiment is a complete system designed for the clinical measurement of implant stability and osseointegration. It can be used as a portable, handheld or free-standing instrument and patient data can be downloaded to a PC.

The system comprises three main components : the instrument, the transducer and the PC software. Results are displayed graphically and as an ISQ(0-100) value which can be related directly to stability and stiffness. The instrument will store up to 32 measurements before downloading via an infra red link or a serial cable to a PC.

In this experiment, Periotest® was fixed by mechanical device to prevent varying data from variations such as angulation, distance and height of handpiece. That is, fixation is most important to gain repeated PTVs but in clinical situations, it is not easily obtainable. Transducer connection of the resonance frequency analyser is clinically easy and firmly fixed by a screw. According to the increased effective implant length, the mean values show significantly decreased ISQ and increased PTV values($p<0.05$). That is to say, both RFA and Periotest® can detect a certain degree of implant status but RFA is more sensitive and precise than Periotest® in the same increased implant length condition.

Removal torque measurements were done to compare group I with group Ⅱ. Clearly, removal torque value of after installation group (group Ⅱ) was significantly higher ($p<0.05$, Table Ⅳ) than after thread exposure group (group Ⅱ). Removal torque has been a widely-used research method for assessing implant stability and osseointegration.[19,20] The technique involves measuring the peak torque necessary to shear the interface between the implant surface and the surrounding bone. This is clearly a destructive test technique in which the application of shear stresses at the use of removal torque in the clinical assessment of osseointegration appears not to be feasible. As removal torque is a measurement of the interfacial strength in shear, it is dependent on both the quality of the bond between the implant and the surrounding tissues, as well as on the geometry of the implant.

CONCLUSIONS

After implantation in the bovine scapula, the following conclusions were drawn within the limits of this study.

1. ISQ and PTVs showed significant decreased and increased values according to the increased abutment length($p<0.05$).
2. ISQ values were shown significantly higher in horizontal direction to the long axis of bone in both after installation and after thread exposure groups($p<0.05$).
3. PTVs showed no significant differences in the measurement directions both after installation and after thread exposure groups($p>0.05$).
4. Removal torque values were shown significantly higher in the after installation group($p<0.05$).

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