A STUDY ON THE CHANGE OF IMPLANT STABILITY USING RESONANCE FREQUENCY ANALYSIS

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Statement of problem : Resonance frequency analysis (RFA) has been increasingly served as a non-invasive and objective method for clinical monitoring of implant stability. Many clinical studies must be required for standardized baseline data using RFA.

Purpose : This study was performed to evaluate RFA value changes in two stage surgery group and one stage surgery group in patients.

Material and method : Forty-seven mandibles in consecutively implant installed patients were selected for this study and 141 fixtures were installed. Ninety-three fixtures were double threaded, machined surface design (Brånemark® MK III, Nobel Biocare AB, Göteborg, Sweden) and 48 fixtures were root form, threaded, HA-coated surface one (Replace™ , Steri-Oss/Nobel Biocare AB, USA). Among those, each 10 fixture was installed in one stage group patients. ISQ values were measured using Osstell™ (Integration Diagnostics Ltd. Sweden) during fixture installation, at healing abutment connection and in the loading period for two stage surgery group patients and during at each 4, 6, 8, 10, 12week and in the loading phase for one stage surgery group patients and evaluated the changes according to the time and fixture type.

Results : In two stage surgery group, mean and SD of ISQ values of machined surface implants were 76.85±3.74, 75.76±5.04, 75.73±4.41 and those of HA-coated surface implant were 75.05±6.23 , 77.58±5.23, 78.32±4.29 during fixtures installation, at healing abutment connection and in the loading period, respectively. In one-stage surgery group, the ISQ values of machined surface and HA-coated surface implants decreased until 4 or 6 week and maintained at plateau for 1-3 week and increased to the loading period.

Conclusions : Machined and HA-coated surface implants showed minimal ISQ changes with time if they were installed at the sites showing at least intact cortical plate and good bone qualities. And HA-coated implants had a tendency to show somewhat increased ISQ values with time.

Key Words

Implant stability, Resonance frequency analysis (RFA), Machined surface, HA-coated surface, Two stage surgery, One stage surgery

For successful implant therapy, it is essential to achieve well-maintaining osseointegration. Osseointegration is a continuing structural and functional coexistance, possibly in a symbiotic manner, between differenciated, adequately remodeling, biologic tissues and strictly defined and controlled synthetic components, providing long lasting, specific clinical functions without rejection mechanics. The factors controlling osseointegration have been established as material compatibility, surface macrostructure, surface microstructure, status of implant bed, surgical trauma of installation and prosthetic loading.[1] The above factors eventually affect implant stability from fixture installation to long-lasting maintenance of bioactive interface thereafter. Protocols incorporating considerations of these fundamentals were well established.[2]

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.[3] The concept of implant survival and success are quite different, survival is commonly relating to the retention of an implant within the jaws of the patient and success requires acceptable its criteria. Comments on bone quality, overall stability and load bearing capacity are often not discussed in clinical reports. Albrektsson et al.[4] have discussed the concepts of survival and success for oral implants in some detail. There is a clear need for quantitative techniques to enable the success criteria for endosseous implants to be more clearly defined.

Nowadays, resonance frequency analysis (RFA) technique has been increasingly served as a sensitive and objective tool for clinical monitoring of implant stability.[5,6] However, for the precise evaluation of individual implant stability or comparison with other implants in various clinical conditions, standardized baseline data using RFA are urgently required.[7] Therefore, more clinical studies are needed to elucidate resultant implant stabilities in such specific conditions as identification of implant status at risk for implant failure, individualization of healing periods after implant placement and so on. In present study, it was planned and performed that RFA value changes with time would be observed after implants placement in patients.

The aims of this study were to evaluate the RFA values of machined and HA-coated surface implants in patients immediately after implant placement, at healing abutment connection and in the loading phase of two stage surgery group and to evaluate the relationships between RFA values and other parameters such as bone quality, fixture length, marginal bone level, and cover screw exposure in two stage surgery group and to evaluate the RFA value changes during healing period in one stage surgery group.

MATERIALS AND METHODS

1. Patients selection (Table I)

During the spring and summer of 2001 in the Implant Clinic of Seoul National University Dental

Table I. Overview of patients distribution

Protocol / Edentulous state	Two stage surgery			One stage surgery		Total
	Single	Partially	Fully	Single	Partially	
Male	3	16	1	0	5	26
Female	4	14	1	2	1	21
Total		39		8		47

Hospital (Seoul, Korea), 47 mandibles in consecutively implant installed patients were selected for this study. They were 21 females and 26 males and their age range was 17-68 years (mean age 49.8 years). Twelve patients were smokers, who were only included in two stage surgery group that was consisted of 39 patients. In one stage surgery group, all 8 patients were nonsmokers. All patients were considered to be a good general condition. The cases required bone grafting material or showed no intact cortical bone plate such as wound healing site were ruled out. Edentulous states of patients were 9 single tooth loss, 36 partially edentulous and 2 fully edentulous states. Opposing teeth conditions were natural teeth or fixed bridges except 3 patients who were removable partial denture wearers.

2. Installed fixtures (Table II)

Total 141 fixtures were installed. Ninety-three fixtures were double threaded, machined surface implants (Brånemark® MK III, Nobel Biocare AB, Göteborg, Sweden) and 48 fixtures were root form, threaded, HA-coated surface implants (Replace™, Steri-Oss/Nobel Biocare AB, USA). The diameter of fixtures was 3.75 or 4.0 mm for Brånemark® and 4.3 mm for Replace™ fixtures. Each 10 fixture was installed in one stage surgery group and 121 fixtures were installed in two stage surgery group.

3. Resonance frequency analyser

Osstell™ (Integration Diagnostics Ltd. Sweden, Fig. 1) was used for implant stability measurements in this study. It is composed of Osstell™ instrument (a LCD graphical display, Fig. 2), transducers (Fig. 3), data manager (Fig. 4, 5). The fixture level transducer (Type F1) was used for Brånemark® RP and Replace™ and abutment level transducers were used for Brånemark® Standard, EstheiCone, Multi-Unit abutments (Type A1, A2 and A3, respectively).

The transducers were orientated perpendicular to the alveolar ridge with lingual position of the upright part of the beam and were tightened by hand. Results were displayed graphically and represented as an ISQ (Implant Stability Quotient,1-100).[8] Initially, ISQs were obtained three times at each fixture and averaged. But because data reproducibility of Osstell™ instrument was very excellent, ISQs were gained once then.

4. Bone quality and quantity assessment during initial drilling

During the initial drilling with a guide drill (Nobel Biocare AB, Göteborg, Sweden), bone qualities were assessed. For the details of the assessment, the status of cortical bone was decided from its thickness and feelings classfied as very hard, hard, less hard, soft and very soft senses, and that of

Table Ⅱ. Overview of installed fixtures distribution

Protocol	Two stage surgery			One stage surgery		Total
Edentulous state	Single	Partially	Fully	Single	Partially	
Machined surface	2	67	14	2	8	93
HA-coated surface	6	32	0	3	7	48
Total	121			20		141

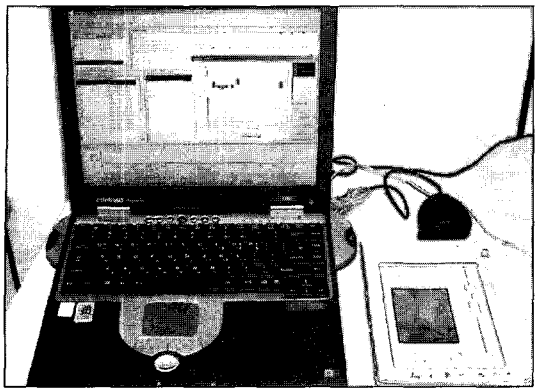

Fig. 1. Setup of Osstell™ instrument, data manager and supplied infrared link.

Fig. 3. A transducer(Type A1) connection with a standard abutment.

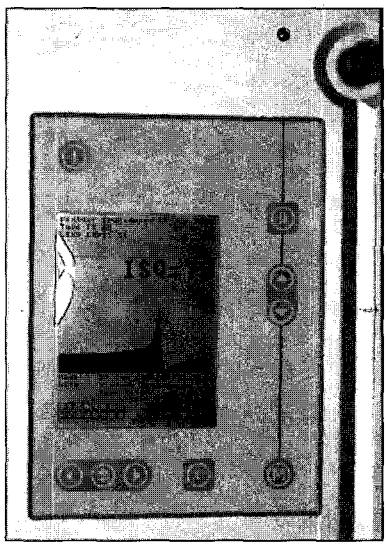

Fig. 2. A LCD graphical display of the Osstell™ instrument.

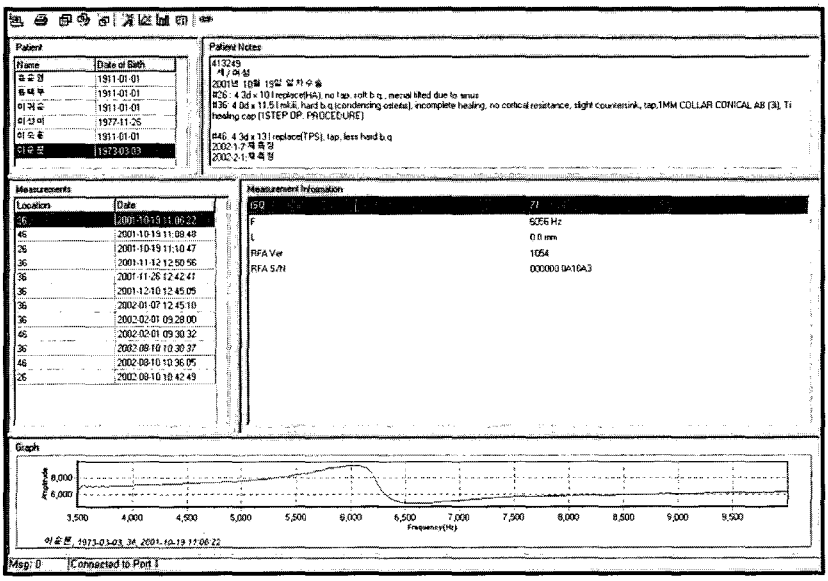

Fig. 4. A software-viewing example of one patient record form in Osstell™ data manager.

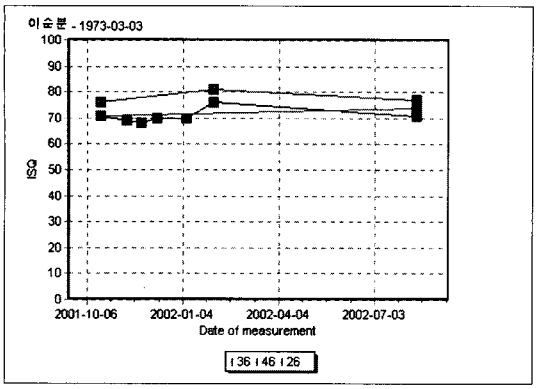

Fig. 5. An example of the ISQ changes of 3 implants in one patient according to the time lapse (1 implant for one stage surgery, 2 implants for two stage surgery).

cancellous bone was done from the feelings classified as compact, coarse, loose and very loose senses. With bearing the combinations of these feelings in mind, bone qualities were scored (Grade 1-4) by Lekholm and Zarb bone classification.[9] With periapical and panoramic radiographic images, bone quantities were also decided by that index and confirmed intraorally (Grade A-E).

5. Clinical primary stability acquisition during installation

For the installation of Brånemark® MK III fixtures, recommended drill series were used. In some cases, tapping and countersinking procedures were not or minimally done for obtaining adequate fixtures stability. For Replace™ system, corresponding final size drills to the fixture were used at the terminal stage of high speed drilling and tapping procedure was minimally used. But counterbore drill was not used due to its characteristics of final size drill shape and fixture design. Resultant clinical primary stabilities were fair or excellent, and confirmed with resonance frequency analysis using Osstell™ instrument. Most of all implants were inserted that their tops of fixture flanges were slightly located at the subcrestal bone level aimed at the level of the external hex of the fixtures with bony crest.

6. Stability measurement schedules and cover screw exposure evaluation and marginal bone level assessment

6.1. Two stage surgery group

ISQ values and periapical films were obtained right after implant insertion, at healing abutment connection, and in the loading phase of implants. The loading durations of prosthesis on each fixture in two stage surgery group were 5-10 months. All prostheses were fixed type restorations. Before second stage uncovering operation, the patterns of spontaneous early exposures of cover screw were assessed and classified. Tal H. classified the patterns of early exposures of cover screw.[10-12] Because there was no statistically significant difference between class 0 and class 1 in his classification, modification of classes was done and used in this study (Table III).

6.2. One stage surgery group

For this work, all Repalce™ fixtures were immediately connected with healing abutments at implant insertion stage after RFA measurements. 1mm height EsthetiCone® abutments (Noblel Biocare AB, Sweden) were connected to all Brånemark® fixtures in this group and healing caps were placed after RFA measurement. Transducer for EsthetiCone® abutment (type A2) was used for this measurement. Further ISQ values were measured at 4, 6, 8, 10, 12 weeks and in the loading phase, respectively. Patients were instructed to maintain good oral hygiene and to take soft diet. Periapical radiographs were taken at implant insertion, 12 weeks and in the loading phase. The loading durations of prosthesis on fixtures in one-stage surgery group were 6-9months.

Table III. Classification of early cover screw exposure before second stage surgery

Class	Clinically assessed points
0	No exposure or breach in the mucosa covering the implant is observed.
1	The mucosa above the cover screw is fenestrated. The cover screw is visible. The boders of the perforation's aperture do not reach or overlap the borders of the cover screw at any point.
2	Cover screw is visible. In some parts, the borders of the perforation aperture overlap the borders of the cover screw.
3	Cover screw is completely exposed.

Table IV. Assessed marginal bone level score of implant fixture in periapical radiograph. Matched scores and the lowest bone contact levels in each mesial and distal side of implant were as followings

Score	Radiographically assessed points
0	above the flange bottom of implant fixture
1	at or above the 1st thread end of implant fixture
2	at or above the 2nd thread end of implant fixture
3	at or above the 3rd thread end of implant fixture

7. Periapical radiograph taking and reading point

To evaluate the marginal bone level of implants, periapical radiographs were taken with long cone paralleling technique. Periapical radiographs taking was done such that the films were positioned with the axis of implant and the aperture of long cone as parallel as possible. Because RFA values were known to be sensitive to the marginal bone level surrounding the implants[13] and were known to vary 2-3 ISQ according to the 1mm bone level change[8], the marginal bone levels of implants were determined and scored through the findings as to the level of thread of installed implant with x 5.5 magnifying lens (Table IV). Scored levels were evaluated with ISQ values at each period.

8. Statistical analysis

SPSS ver.10.0 package for Windows was used. For evaluations of RFA changes with time factor and operation method, repeated measure ANOVA test and Scheffe's post-hoc test were used ($p<0.05$). The Pearson correlation test ($p<0.01$) was used for statistical analysis of the correlation between fixture length and RFA values at implant installation as well as for the correlation between marginal bone levels and RFA values from the installation to the loading period. The correlation between cover screw exposure and marginal bone level changes was also analyzed.

RESULTS

Among 141 fixtures, 2 fixtures failed and were confirmed with Osstell™. Their ISQ values were 78 and 81 at the installation, but showed 51 and 45 at the healing abutment connection and then decreased to 43 and 40, respectively, 2 weeks later. They were removed and ruled out from statistical analysis. One (78-51-43 ISQ value change) of the two fixtures was not showed clinical mobility at the healing abutment connection. Even though this was short-term observation, other implants had no problems in the loading period and showed good clinical performances and ISQ values. Therefore, overall survival rate was 98.6%. The highest ISQ value was 92, it was recorded on one fixture at the healing abutment connection and the lowest value was 62, it was recorded on two fixtures at the installation.

1. Bone quality and bone quantity (Table V)

In bone qualities, Grade 2 or 3 was mainly assessed in both groups. They were 87.6% in two stage surgery group and 95% in one stage surgery group. Grade B was mainly assessed in bone quantities of both groups. It was 77.7% in two stage surgery group and 100% in one stage surgery group.

2. Mean ISQ values of two stage surgery group at fixture installation, healing abutment connection and in the loading period

Mean and SD of ISQ values of machined surface implants were 76.85 ± 3.74, 75.76 ± 5.04, 75.73 ± 4.41 and those of HA-coated surface implant were 75.05 ± 6.23, 77.58 ± 5.23, 78.32 ± 4.29 at each period in two stage group (Table VI). It showed small mean ISQ value change after fixture installation, so implants of that group were seemed to be stable. Machined surface implants showed slightly lower ISQ values at healing abutment connection and maintained their values in the loading period. ISQ values of HA-coated surface implants showed higher value tendency than those of machined ones (Fig. 6).

3. ISQ changes of implants in two stage surgery group according to the bone qualities

Grade 4 group was ruled out in statistical analy-

Table V. Distribution of assessed bone qualities and quantities by Lekholm and Zarb Classification[9]

Group	Bone quality				Bone quantity		
	1	2	3	4	A	B	C
Two stage	12	56	50	3	19	94	8
One stage	1	10	9	0	0	20	0

Table VI. Mean and SD of ISQ in two stage surgery group

Implant	Fixture installation	Healing abutment connection	Loading period
Machined	76.85 ± 3.74	75.76 ± 5.04	75.73 ± 4.41
HA-coated	75.05 ± 6.23	77.58 ± 5.23	78.32 ± 4.29
Total (n=119)	76.24 ± 4.77	76.37 ± 5.16	76.47 ± 4.55

sis due to small sample size. Grade 3 group showed statistically significant value changes from those of other groups ($p<0.05$) in both fixture designs (Table VII, VIII). In machined surface implant, Grade 2 group showed the highest mean value in all periods (Table VII). In HA-coated surface implant, ISQ values were increased with time except Grade 1 group(Table VIII). In spite of small sample size, grade 4 group showed the lowest mean value at the fixture installation but caught up the values of other groups gradually (Fig. 8).

4. Correlation between fixture lengths and ISQ values at fixture installation

10mm or 13mm fixture length was mainly installed (31.9%, 45.4%, respectively). Pearson's correlation coefficient(r) between fixture lengths(Table IX) and corresponding ISQ values at fixture installation was 0.038($p<0.01$). Therefore, there was no correlation between two data (Fig. 9).

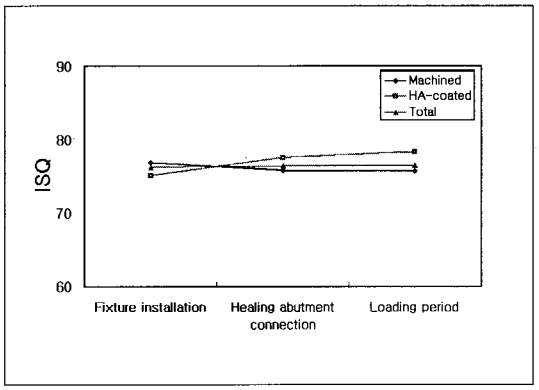

Fig. 6. The change of mean ISQ value in two stage surgery group.

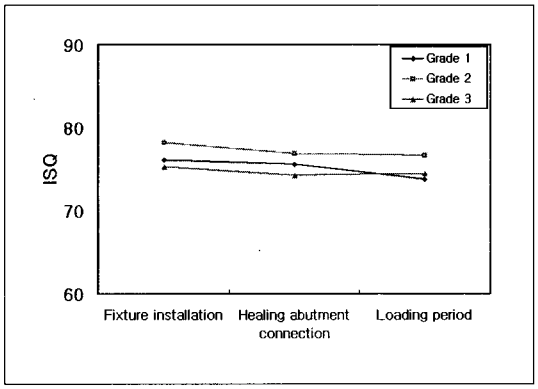

Fig. 7. Mean ISQ value changes of machined surface fixtures in two stage surgery group according to the bone qualities.

Table VII. Mean and SD of ISQ values of machined surface fixtures in two stage group according to classified bone qualities

Bone quality	Fixture installation	Healing abutment connection	Loading period	p-value*
Grade 1	76.11 ± 2.71	75.56 ± 3.97	73.78 ± 4.52	0.017
Grade 2	78.18 ± 3.44	76.90 ± 5.41	76.68 ± 4.32	
Grade 3**	75.30 ± 3.82	74.30 ± 4.56	74.53 ± 4.21	

* Repeated Measure ANOVA (between subject effects)

** denotes that differences of each mean were statistically significant ($p<0.05$) by Scheffe's post-hoc test.

Table VIII. Mean and SD of ISQ values of HA-coated surface fixtures in two stage group according to classified bone qualities

Bone quality	Fixture installation	Healing abutment connection	Loading period	p-value*
Grade 1	81.67 ± 10.21	82.33 ± 9.50	81.33 ± 5.51	0.021
Grade 2	78.29 ± 4.70	78.86 ± 4.85	79.86 ± 4.45	
Grade 3**	72.75 ± 5.10	75.95 ± 4.78	76.75 ± 3.89	
Grade 4	68.67 ± 3.06	73.67 ± 0.58	75.44 ± 1.15	none †

* Repeated Measure ANOVA (between subject effects)

** denotes that difference of each mean were statistically significant ($p<0.05$) by Scheffe's post-hoc test.

† denotes that statistical analysis was not performed due to small sample size.

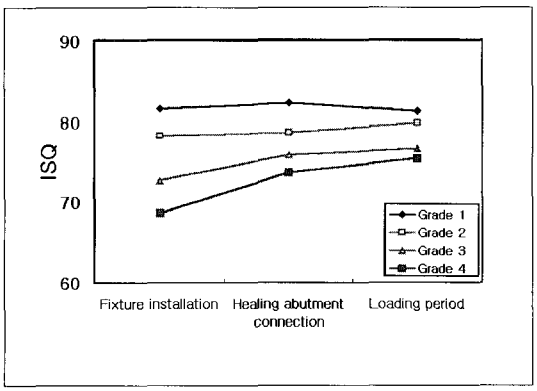

Fig. 8. Mean ISQ value changes of HA-coated surface fixtures in two stage surgery group according to the bone qualities.

5. Mean ISQ values of one stage surgery group

To the 4-6 weeks after fixtures installation, mean ISQ values decreased(Table X). Decreasing tendency was more frequent in machined surface implant but the values of those increased with time. Nevertheless, after some decreasing, HA-coated surface implants reached at plateau and showed increased values earlier than machined surface ones (Fig. 10).

6. Two stage surgery group vs one stage surgery group

The mean ISQ value changes according to time lapse between two stage and one stage surgery groups were likely minimal (Fig. 11). Mean ISQ values of one stage surgery group at 3 months after installation and in the loading period were larger. Smaller sample size than two stage surgery group and meticulous case selection and controlled special care during study in one stage surgery group might affect that results.

7. Correlation between ISQ value changes and marginal bone level score changes in two stage surgery group.

Marginal bone level scores were increased with time (Table XI). That means that there were marginal bone resorptions after fixture installation. High score change from fixture installation to healing abutment connection means that mild complication such as cover screw exposure was existed. On the contrary, low score change from healing abutment connection to the loading period means that marginal

Table IX. Installed fixture lengths

Fixture length (mm)	No. of fixtures
8.5	3
10	45
11.5	10
13	64
15	17
16	2

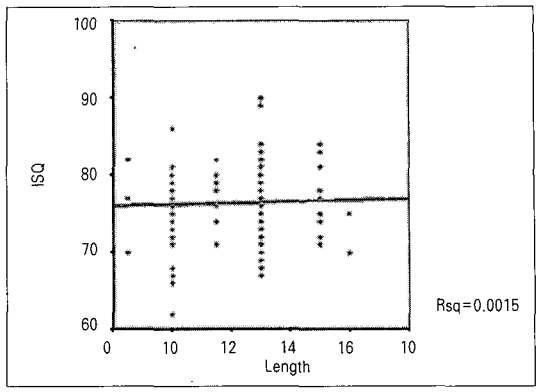

Fig. 9. Plot of ISQ values against fixture lengths for implants at fixture installation. r=0.038(p<0.01)

Table X. Mean and SD of ISQ values in one stage surgery group according to time lapse

Measurement time	Machined	HA-coated	Total (n=20)
0 week	76.60 ± 3.57	76.60 ± 3.84	76.60 ± 3.60
4 weeks	73.30 ± 4.72	74.60 ± 4.20	73.95 ± 4.39
6 weeks	72.40 ± 4.74	74.40 ± 4.01	73.40 ± 4.39
8 weeks	72.90 ± 4.65	75.90 ± 4.12	74.40 ± 4.55
10 weeks	73.70 ± 4.14	76.90 ± 3.67	75.30 ± 4.14
12 weeks	75.10 ± 4.25	78.00 ± 3.20	76.55 ± 3.95
Loading period	76.50 ± 2.92	79.30 ± 2.87	77.90 ± 3.16

bone resorption process was decreased and marginal bone level had a tendency to be stable. Pearson's correlation coefficient(r) between ISQ value changes and marginal bone level score changes from fixture installation to healing abutment connection period was -0.520 (p<0.01). That indicates a moderate to good negative relationship between two groups (Fig. 12). That r-value from healing abutment connection period to the loading period was -0.505 and indicates the same previous interpretation (Fig. 13).

8. Cover screw exposure observation before uncovering flap operation in two stage surgery group

In Table XII and Fig. 14, Class 0 (no exposure) was mainly observed before open flap surgery (75.6%). Class 1 was the most frequent perforation (9.2%), followed by Class 2 and 3 (7.6%). Cover screw exposure means mucosal perforation which can cause inflammatory reaction. The ISQ values of fixtures involved in classes showed perforation were all likely to be decreased at healing abutment connection. That means that mucosal perforation caused marginal bone resorption, which showed decreased ISQ values.

9. Correlation between cover screw exposure and marginal bone level score change from fixture installation to healing abutment connection

Pearson's correlation coefficient(r) between cover screw exposure and marginal bone level score was

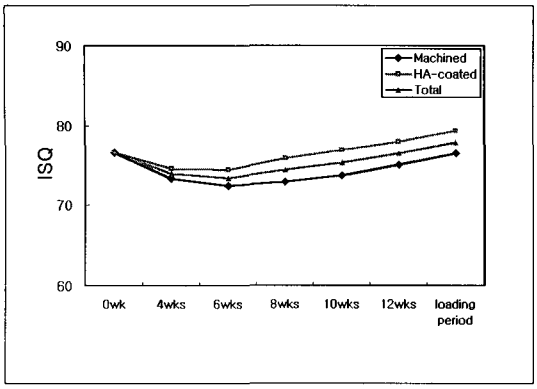

Fig. 10. Mean ISQ changes in one stage surgery group.

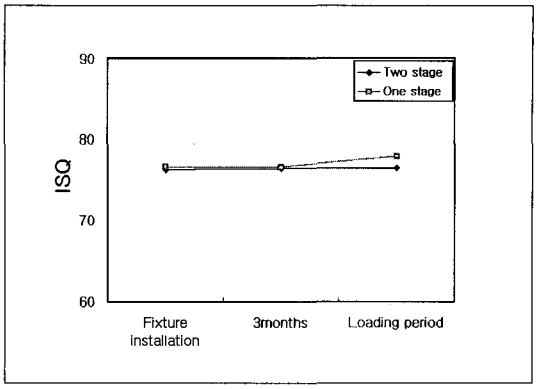

Fig. 11. Mean ISQ value changes of two and one stage surgery groups.

Table XI. Mean and SD of marginal bone level scores at each period and scores change in two stage surgery group

Assessed time and scores change	Mean ± SD
Fixture installation(1)	0.00
Healing abutment connection(2)	0.79 ± 0.84
Loading period(3)	1.08 ± 0.72
Scores change (2-1)	0.79 ± 0.84
Scores change (3-2)	0.29 ± 0.52

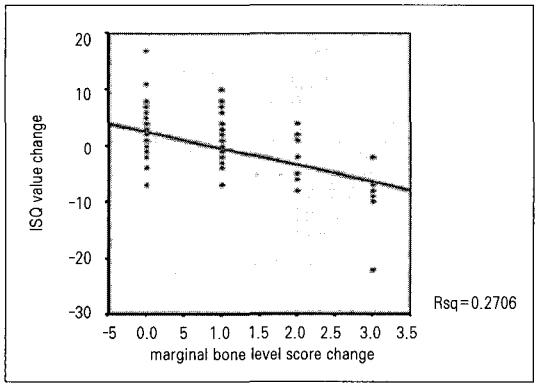

Fig. 12. Plot of ISQ value changes against marginal bone level score changes from fixture installation to healing abutment connection period. r= -0.520 ($p<0.01$).

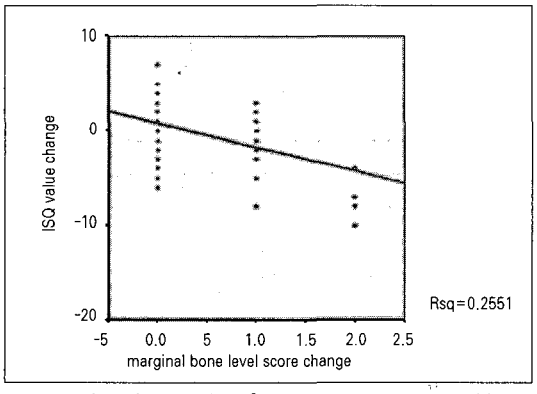

Fig. 13. Plot of ISQ value changes against marginal bone level score changes from healing abutment connection to loading period. r= -0.505 ($p<0.01$).

Table XII. Classified cover screw exposures and corresponding number of each fixture

Class	Brånemark® fixture (no./percentage) N=79		Replace™ fixture (no./percentage) N=40		Total(no./percentage) N=119	
0	61	77.2%	29	72.5%	90	75.6%
1	6	7.6%	5	12.5%	11	9.2%
2	5	6.3%	4	10%	9	7.6%
3	7	8.8%	2	5%	9	7.6%

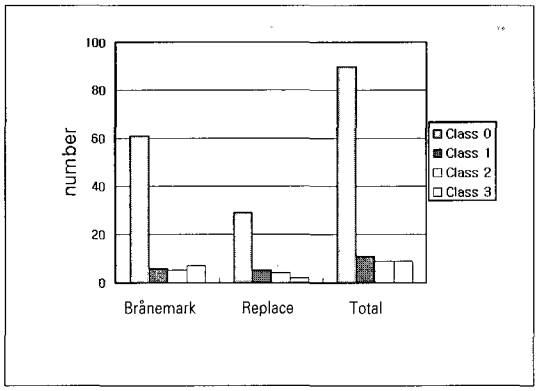

Fig. 14. Graph of the number of each fixture according to the classification of cover screws exposure.

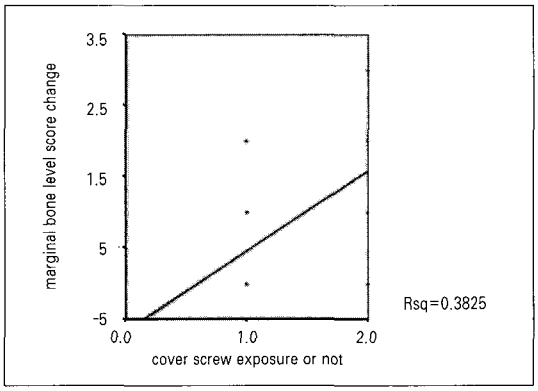

Fig. 15. Plot of marginal bone level score changes against cover screws exposure or not (1.0:no exposure, 2.0: exposure). r= 0.618 ($p<0.01$).

0.618 ($p<0.01$). That indicates a moderate to good positive relationship between two groups (Fig. 15). Therefore, from the above result, cover screw exposure may cause to decrease ISQ value and result in lowering the implant stability.

DISCUSSION

In patients selection, patients with intact cortical bone plate were selected as possible as can. Among 73 patients who were consecutively received 232 fixtures, only 47 patients were selected. One-stage surgery group patients were very meticulously selected and controlled, so they showed excellent initial fixture fixation, sufficient interocclusal distance, good oral hygiene, no smoking and cooperative passion. The diameters of selected fixtures were 3.75, 4.0 and 4.3mm. That size difference was not worth while to consider because matched transducer was previously calibrated by manufacturer.[8]

The resonance frequency value obtained from the Osstell™ transducer is automatically translated into an index called the Implant Stablilty Quotient (ISQ), which runs from 1 to 100. Extensive clinical testing has made it possible to establish this scale for evaluating the clinical stability of implants. The relationship between the ISQ value and the resonance frequency value is close to linear, and factors such as individual differences between transducers are also taken into account. In this study, 4 types of transducers were used. As each transducer has its own calibration values, it is possible directly to compare ISQ values that originate from different

transducers. A direct translation to ISQ from frequencies presented for early transducers is difficult, but when articles[14-16] presenting RF, the ISQ value can roughly be derived from : 1 ISQ per 50Hz.

On the failed 2 implants in this study, one showed largely decreased ISQ value change (-27 ISQ) without clinical mobility during second stage surgery. It presented an example of the effectiveness of RFA technique.

Table VI showed mean ISQ value changes with time in two stage surgery group. Overall mean values of machined surface implants were maintained with small changes. Sennerby et al.[17] reported similar results that 6 months after loading and about 10-11 months after implant placement did not show any changes compared with stability after placement and abutment connection in mandible. Al-Nawas et al.[18] also reported the experimental study results in dog. They evaluated RFA during implant insertion, at abutment connection and in the loading phase of dental implants and concluded that resonance freqeuncy at insertion was declining during the healing period regardless of the surface or screw design and during the loading phase no significant change was seen. From the result of stability measurement on the machined surface implants of mandibular molar area in functioning successfully during at least 12 months, mean ISQ values were maintained at the 71-73 level.[19] However, HA-coated surface implants showed somewhat increased ISQ values tendency with time in spite of high value after placement. It was seemed to be affected by rapid bone healing capacity of HA-coating.

In bone quality and bone quantity assessments, Lekholm and Zarb classification[9] was used in this study. Because primary stabilities were almostly very good or excellent, relatively high ISQ values were recorded at fixtures installation. Also, macrostructures of implants such as double threaded or threaded root form and surgical techniques such as no or minimal usage of tap and countersink drill contributed to that results even in Grade 3 bone quality. In Table VII, the ISQ values of machined surface implants had a tendency to decrease with time in Grade 1 and 2 bone qualities, however, they maintained their values with time in Grade 3 bone quality. This pattern was not similar with those of HA-coated surface implants. In Table VIII, the ISQ values of HA-coated surface ones showed maintained or increased pattern with time according to bone qualities. That difference of value change pattern between fixture surface types seems to be caused by interfacial bone response of HA-coating. Although bone quality was scored with care on the initial drilling, there was a limitation of objectiveness. One of the objective methods assessing bone quality is cutting resistance measurement.[20-23] Torque was determined by the current drawn by an electric motor while cutting a thread. Friberg et al.[24] noted that there was a correlation between resonance frequency measurements at implant placement and thread cutting forces for the most coronal third of the implant site. This finding is significant as it is likely that it is the most coronal part of the implant bed which plays the most significant role in implant stability and the support of the implant under load. Also, they showed that the stability of implants placed in softer bone seemed to catch up over time with more dense bone sites. Table VIII and Fig. 8 showed similar patterns of increasing value like above with time in the poor bone quality in spite of small sample size.

Table IX showed a correlation between fixture lengths and ISQ values at fixture installation. There was no correlation between both data, which coincided with other reports.[14,15,19] That means that the RFA value of each implant represents its stability status regardless of its length, so it is possible to compare each other and assess the relative stability.

The original idea of using a two stage surgery procedure was to avoid preloading of the implant and to allow for bone formation and integration of the implant to occur.[9] Thus, it was anticipated that, with a healing period, an increased implant sta-

bility would be achieved as compared to the day of implant placement. Successful use of one stage, nonsubmerged ITI implants inserted in mandibles has, however, been reported by Buser et al.[25,26] Deviations from the original protocol, i.e. to perform one instead of two surgical procedures, have been executed for both partially dentate[7] and edentulous patients using the Brånemark system.[20,28,29] The authors concluded that no clinical differences were seen between the two groups and the radiographic bone level was similar with or without a transmucosal junction. The one stage implant result also compared well with those reported for the traditional two stage technique. Friberg et al.[30] showed that the RFA values slightly decreased for the majority of the implants during the study period (15 weeks) independent of design. Consequently, the implants were as stable at time of placement as when measured 3-4 months post-surgery, i.e when the prostheses were attached.

In relation with above study, similar decreased ISQ values of machined surface implants were shown until 6 weeks period in this study. But its values reached plateau at 6-8 weeks or 10 weeks, and increased to the loading period. This result is different from that of Friberg et al.[30] It seems to be a possibility that no use of relined denture in this study affected that difference. In Table X, HA-coated implant showed more increased values to the loading period from after 6 weeks than installation, which is in contrast to the finding of machined surface implant. The ISQ values of machined surface implants showed recovery patterns of its own values shown at the installation. All patients healed without any severe problems and all implants were found to be stable at the end of the study period. The one-stage surgery protocol did not present any major adverse tissue reactions or implant complications postoperatively.

Effective implant length (EIL) means the sum of marginal bone height and the length of the abutment. There is a strong negative correlation between the EIL and resonance frequency.[14,15,31] Therefore, increased marginal bone resorption allow ISQ value to decrease. In present study, marginal bone resorptions were scored. That assessment method was somewhat rough, however, that was meaningful. The result showed that there was good negative correlation between marginal bone resorption and ISQ value changes, so resonance frequency measurements were related to the effective length of an implant above the level of the bone.

It is believed that during the osseointegration phase of submerged dental implants, complete mucosal coverage and isolation of the implant from the oral cavity avoids trauma and infection and establishes favorble conditions for osseointegration. Spontaneous early exposure is one of the complications that could adversely affect osseointegration of implants. Adell et al.[2] in a 15-year study of osseointegrated implants in the jaws, observed early perforations in the mucosa in 4.6% of their treated patients in spite of careful surgical protocol and postsurgical care. They believed that sealing the communication between the implant and the oral cavity was crutial to the success of osseointegraton. Early perforation and partial exposure of the implant's covering device are a focus for plaque accumulation which, if left untreated, may result in inflammation, damage to the peri-implant mucosa, and possible peri-implant loss.[10,32]

In present study, it was found that cover screw exposure before second stage surgery forced marginal bone level to decrease, consequently, which lowered ISQ values. That results were supported by the fact that correlation between cover screws exposures and marginal bone level score was strong. In comparison with other studies,[2,10] relativley high percentage of cover screw exposures was found and that might be caused 2 fully edentulous patients wearing relined denture during healing time. They showed mainly Class 3 mucosal perforations. Without them, the percentages of Classes except class 0 would be a quite decreased. Tal et al.[11,12] suggest-

ed that different factors might result in the formation of spontaneous early perforation, most of which were associated with mechanical trauma to the mucosa or tension in the tissue flaps covering the implants. And they noted that bone debris produced during the osteotomy could act as an additional predisposing factor; these are sequestrated and accompanied by chronic inflammatory cell infiltration as well as epithelial-covering reaction. In cases of cover screw exposure, more marginal bone resorption may be produced in HA-coated surface implant than machined surface implant due to its roughness character, which may play a role in accelerating the propagation of inflammatory reaction. Toljanic et al.[32] observed with HA- coated surface, press fit implants and reported that patients with exposed sites demonstrated a likelihood of bone loss 3.9 times greater than patients with nonexposed sites. Although the present study included HA-coated surface ones, it was rarely found to show rapid and destructive marginal bone resorption.

From the above results in this study, using resonance frequency analysis in two stage surgery group, implants stabilities in mandible with at least intact cortical bone plate and Grade 3 bone quality showed minimal ISQ changes with time if there was no complication such as mucosal perforation resulted in marginal bone resorption. One stage surgery group revealed different stability changes modes between machined and HA-coated surface implants with time. But because it has been believed that bone remodelling is continuous process at least until 18 months,[9] more observations will be needed in further studies in related with RFA technique.

CONCLUSIONS

Using the resonance frequency analysis, stabilities of mandibular implants in patients were measured from installation to the loading in two stage and one stage surgery groups and additional observations were performed during healing period. The followings were concluded that :

1. In two stage surgery group, mean and SD of ISQ values of machined surface implants were 76.85 ± 3.74, 75.76 ± 5.04, 75.73 ± 4.41 and those of HA-coated surface implant were 75.05 ± 6.23 , 77.58 ± 5.23, 78.32 ± 4.29 immediately after fixtures installation, at healing abutment connection and in the loading period, respectively.
2. In two stage surgery group, machined surface and HA-coated surface implants showed minimal ISQ changes with time if they were installed at the sites with intact cortical bone plate and good bone qualities.
3. In two stage surgery group, HA-coated implants had a tendency to show increased ISQ values with time.
4. In one stage surgery group, the ISQ values of machined surface and HA-coated surface implants decreased until 4 or 6 weeks and maintained at plateau for 1-3 weeks and increased to the loading period.
5. In one stage surgery group, the ISQ values of HA-coated surface implants were likely to show shorter decreased and plateau period than machined surface ones.
6. There was no correlation between installed fixture length and ISQ value at fixture installation (r=0.038).
7. There was a moderate to good negative correlation between ISQ changes and marginal bone level score changes in two stage group (r=-0.520, -0.505).
8. There was a moderate to good negative correlation between marginal bone level scores and cover screw exposure in two stage group (r=0.618).

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