A STUDY ON THE CORRELATION BETWEEN IMPLANT STABILITY VALUES AND INITIAL INSERTION TORQUE

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Statement of problem. Osseointegration is important mechanism of dental implant but it is not easy to evaluate. Indirect measurement is non-invasive and clinically applicable but they need more study about correlation between indirect values and degree of osseointegration.

Purpose. The aims of this study were to evaluate the coefficient of correlation between indirect measurement and direct measurement under different healing time, and assessment of effect of initial insertion torque to the implant stability.

Material and Methods. 20 rabbits received 3 implants on each side of tibia. Three kinds of implants (machined surface implant, Sandblasted with Large grit and Acid etched implant, Resorbable Blast Media treated implant) were used. During the surgery implant insertion torque were measured with Osseocare™. After the 1, 4, 8, 12 weeks of healing time, animals were sacrificed and stability values (Implant Stability Quotient with Osstell™, removal torque with torque gauge) were measured.

Results. The Bone quality of rabbit tibia was classified into 2 groups according to the insertion torque. Resonance frequency analysis (ISQ) and removal torque showed positive correlation until 4th week ($r=0.555$, $p=0.040$). After 8th week ($r=-0.011$, $p=0.970$) the correlation became weak and it turned negative at 12th week ($r=-0.074$, $p=0.801$). Insertion torque and ISQ showed changing correlation upon the healing time (1st week: $r=0.301$, $p=0.033$, 4th week: $r=-0.429$, $p=0.018$, 8th week: $r=0.032$, $p=0.865$, 12th week: $r=-0.398$, $p=0.029$). Insertion torque and removal torque has positive correlation but it was not statistically significant (1st week: $r=0.410$, $p=0.129$, 4th week: $r=-0.156$, $p=0.578$, 8th week: $r=0.236$, $p=0.398$, 12th week: $r=-0.260$, $p=0.350$).

Conclusion. In this study, bone quality may affect the degree of osseointegration positively during healing time and correlation between ISQ and degree of osseointegration can be different according to the healing time and bone quality.

Key Words
Implant, Insertion torque, Implant Stability Quotient, Removal torque, Correlation

The restoration of edentulous area with dental implant, developed by Per-Ingvar Brånemark in 1965, has been used successfully and now considered as one of most predictable treatment in dental clinic.[1] For successful implant treatment, it is important that making a good osseointegration between bone and implant. So there has been studies about this phenomenon. Brå nemark announced that osseointegration is defined as a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant.[2] Others defined it as the clinical reality of a morbidity-free, stable, bone anchorage: A process whereby clinically asymptomatic rigid fixation of alloplastic materials is achieved and maintained in bone during functional loading.[3] Adell[4] mentioned that achieving osseointegration is slow and gradual process, and he suggested that bone quality and quantity, patient's general health, surgical technique, implant material, design, surface property, number of implant and loading conditions etc. should be considered. The quantitative evaluation of osseointegration is important to determine the success or failure of implant placement, the timing of functional loading and prediction of prognosis. The evaluation methods of osseointegration is not clearly defined, the direct observation of interface between bone and implant might be the most accurate way but it is not clinically available.[1] Radiographic observation would be an alternative but it is not of much help in this respect because it has limitation in resolution.[5] Removal torque evaluation what is different with reverse-torque test, is a direct methods could quantitatively evaluate the degree of osseointegration but also not practical.[10,11] Indirect assessment of osseointegration could be affected by many factors but they are non-invasive and clinically applicable. In there indirect methods there are tapping test,[5] mobility test,[5,6] reverse-torque test,[7] resonance frequency analysis[8,9] and so forth. Resonance frequency analyzer was developed by Meredith et al. and one of most reliable and clinically applicable methods to measure implant stability and assume the degree of osseointegration.[1,8,12,13]

There are studies about the correlations between measurement methods of osseointegration.[6,8,14-16] Especially correlations between direct and indirect methods are very important. In many studies, there were close correlations between direct and indirect measurements but surgical methods, implant design, surface treatment and host factors affected the measurement values and host response resulted in different conclusions.[12,14,16] In these days more advanced surgical technique and new implants are developed so there are continual needs to research about the correlations between stability measuring methods. Implant stability is considered to play a major role in success of osseointegration. Primary stability at placement is a mechanical phenomenon but secondary stability is the increase in stability attributable to bone formation and remodeling in surrounding bone.[12]

Bone quality was considered as a critical parameter associated with implant success rate.[14] In case of poor bone quality higher failure rate were reported.[17-20] Although, with more improved implant surface and surgical technique there were more affirmative results are reported.[10,14,19-21] But diagnosis of bone quality is still important to proper selection of implant systems and to decide surgical modification. Bone quality and quantity may assessed by radiographic methods but true bone quality present in the jaw can be determined during explorative drilling in fixture site preparation.[22] The cutting resistance measurement is reliable and applicable in clinical routine work.[14] In clinical situations cutting resistance and implant insertion torque might be different, because for more stable placement there could be surgical modification such as bone condensation, it will affect insertion torque.

In this study, the bone quality assessed with insertion torque and the change of stability values of three different surfaced implants during healing period was recorded. The aims of this study were to obtain the value of implant insertion torque, implant stability values and removal torque to verify the correlation between each value.

MATERIAL AND METHODS

IMPLANT INSTALLATION

In this study 20 adult rabbit, weight about 3~4kg, were used. Three implants were placed in proximal metaphysis of each tibia. Total implant number was 120. Types of implant were machined implant (Ra=0.5㎛), SLA implant (Sandblasted with Large grit and Acid etched (double etched with HCl/H_2SO_4, Ra=1.2㎛) and RBM (Resorbable Blast Media (hydroxyapatitie with 40~80 mesh, Ra=2.0㎛). All implants were made with grade III commercially pure titanium and the dimension was 3.0mm in diameter and 5.0 in length (Neobiotech Co., Seoul, Korea).

At day of surgery, the animal received intramuscular injection of ketamin 0.15㎖ / ㎏ (Ketalar, Yuhan Co. Seoul, Korea) and xylazine 5㎎ / ㎏ (Rompun, Bayer Korea, Ansan, Korea) for general anesthesia. After local anesthesia, shaving and disinfection was done. Incision was made to expose the metaphysis of tibia. Implants were placed under recommended surgical procedure (Fig. 1). Site preparation was done with full depth drilling and final step drill was used regardless bone quality. OsseoCare™ (Nobel Biocare AB, Göteborg, Sweden) was used to place implant and measure the initial insertion torque (Fig. 2). All implants were self-tapped. After the placement muscle and periosteum were sutured with resorbable suture material (4-0 vicryl, Johnson & Johnson Int. USA) and skin was sutured with 3-0 silk suture material. Both side tibia was received same procedure. After the surgery to prevent possible infection 50㎎ / ㎏ of lincomycin HCl (Lincomycin, Huons, Hwaseong, Korea) was injected intramuscularly.

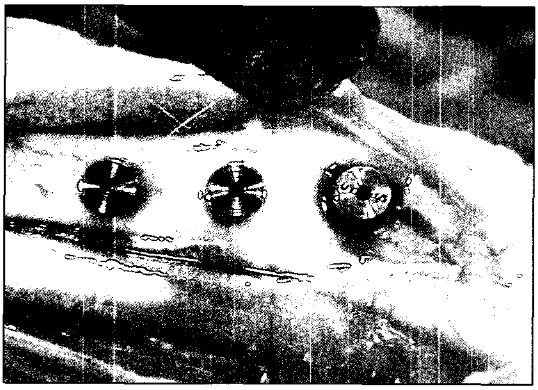

Fig. 1. Three different implants were placed in rabbit tibia.

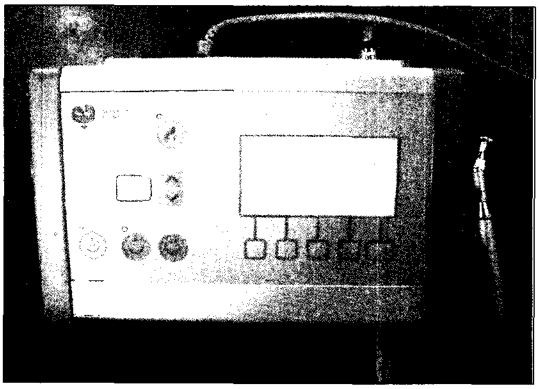

Fig. 2. Osseocare™ for implant placement and insertion torque measurement.

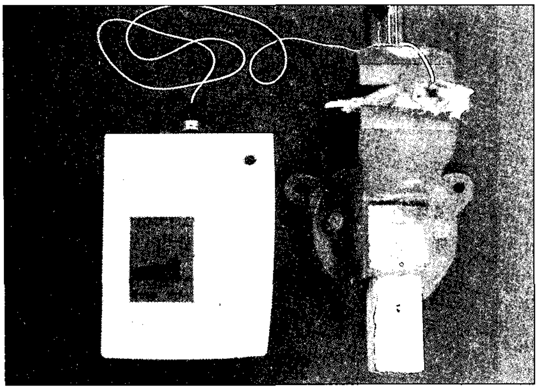

Fig. 3. Implant stability quotient were measured with resonance frequency analyzer.

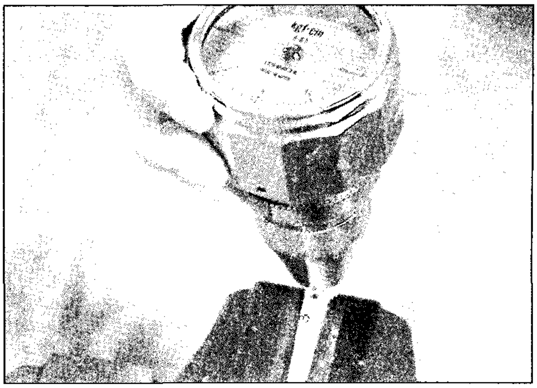

Fig. 4. Removal torque was measured with manual torque gauge.

SACRIFICE AND IMPLANT STABILITY MEASUREMENT

After the healing period of 1, 4, 8, 12 weeks, the animal was sacrificed with intravenous injection of overdosed thiopental sodium (Pentotal Na, Choongwae Pharma Co., Seoul, Korea). Implants with surrounding bone were removed. ISQ (Implant Stability Quotient) with Ostell™ (Integration Diagnotics AB, Såvedalen, Sweden) (Fig. 3) and removal torque with torque gauge (6 BTG Tohnichi Mfg. Co., Tokyo, Japan) was measured.(Fig. 4)

Statistical analysis was done with 95% confidence level using SPSS 12.0KO for Windows (SPSS Inc., USA). Correlation analysis was done with scatter plot graph, regression line adaptation, and evaluation of correlation coefficient.

RESULTS

1. Implant insertion torque

The mean and standard deviations of insertion torque are shown in table I. There are no significant differences between three implant types. Individual torque values are plotted in Fig. 5. It

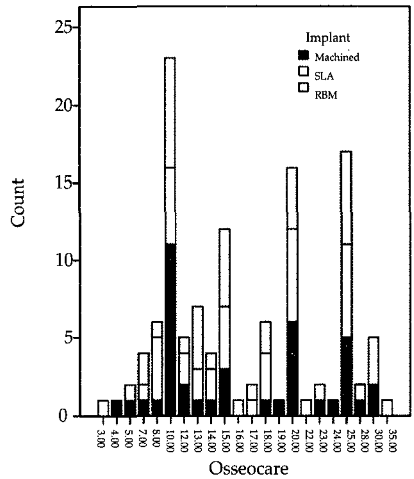

Fig. 5. Individual site values of cutting torque at implant insertion.

shows several peaks, it means there could be different groups. In this study bone densities are sorted out by insertion torque into 2 groups at 15Ncm. Because the rabbit was assigned randomly, at 8th week there was no high group.

2. Implant stability test

1) Resonance frequency analysis(ISQ)

The results of ISQ measurement are shown in table II. It shows changes of ISQ depend on the healing time. The Mean values of implants' ISQ were increased until 4th week. Although at 8th week the ISQ was slightly decreased but the inclination was turned positive at 12th week. (Fig. 6)

2) Removal torque (RT)

The removal torque was increased depends on healing time. After 4th week, the mean of each implant was not showed statistically significant differences.(Fig. 7)

Table I. TImplant insertion torque measured with OsseoCare™ (N total=120)

Implant		N	Minimum	Maximum	Mean	Std. Deviation
Machined	Osseocare (Ncm)	40	4.00	30.00	16.18	7.19
SLA	Osseocare (Ncm)	40	3.00	35.00	16.40	6.94
RBM	Osseocare (Ncm)	40	5.00	30.00	16.55	6.88

Table II. Implant stability values(ISQ value & Removal torque value) of each weeks

Implant		N	1 week	4 week	8 week	12 week
Machined	ISQ	10	56.10±6.77	65.00±2.94	63.70±7.41	69.00±7.83
	RT (Ncm)	5	7.06±1.28	21.56±5.92	27.05±4.31	23.13±4.47
SLA	ISQ	10	61.20±6.73	70.40±4.12	70.00±6.11	71.30±4.85
	RT(Ncm)	5	7.45±0.54	37.83±2.46	34.10±2.54	34.30±6.31
RBM	ISQ	10	65.80±3.49	74.40±2.72	70.30±5.38	71.80±3.65
	RT(Ncm)	5	16.07±7.95	30.38±3.98	31.75±8.70	38.61±2.46

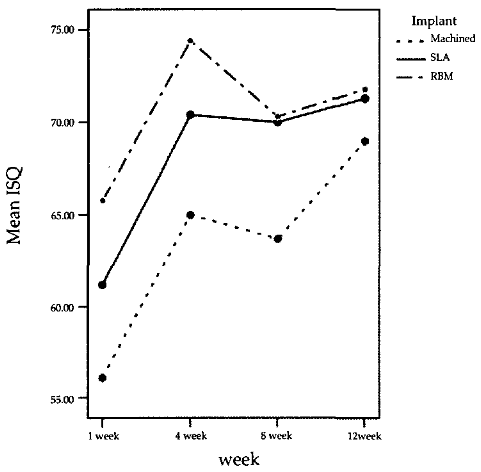

Fig. 6. Graph of ISQ of each implant.

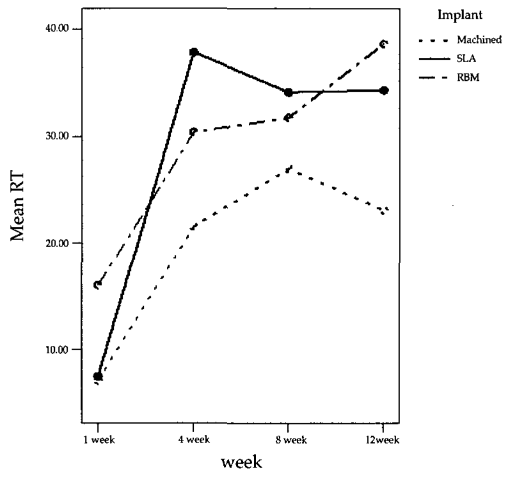

Fig. 7. Graph of removal torque of each implant.

3. Correlation

The correlation between ISQ and RT value was evaluated.(Fig. 8) The ISQ and RT value showed positive correlation until 4th week (r=0.555, p=0.040) but after 8th week (r=-0.011, p=0.970) the correlation became weak and it turned negative at 12th week.(r=-0.074, p=0.801) Because the qualities of bone affect both variations, partial correlation was used and coefficient was adjusted by insertion torque.

The correlations between insertion torque and ISQ (Fig 9), and between insertion and removal torque (Fig. 10) was evaluated. This was performed to inspect the effect of bone quality to the osseointegration and implant stability with time factor. Statistical analyses utilizing Pearson' s correlation test, were conducted to correlate ISQ with the corresponding Osseocare™ values. When plotting removal torque against ISQ, changes in inclination were obtained.(1st week: r=0.301, p=0.033, 4th week: r=-0.429, p=0.018, 8th week: r=0.032, p=0.865, 12th week: r=-0.398, p=0.029) Statistical analyses utilizing Spearman' s rho correlation test, were conducted to correlate values of RT with the corresponding Osseocare™ values. Generally insertion torque and removal torque has positive correlation but it was not statistically significant.(1st week: r=0.410, p=0.129, 4th week: r=-0.156, p=0.578, 8th week: r=0.236, p=0.398, 12th week: r=-0.260, p=0.350) This correlation was affected by type of implant but there was not sufficient sample number so further evaluation was not available.(Fig. 11)

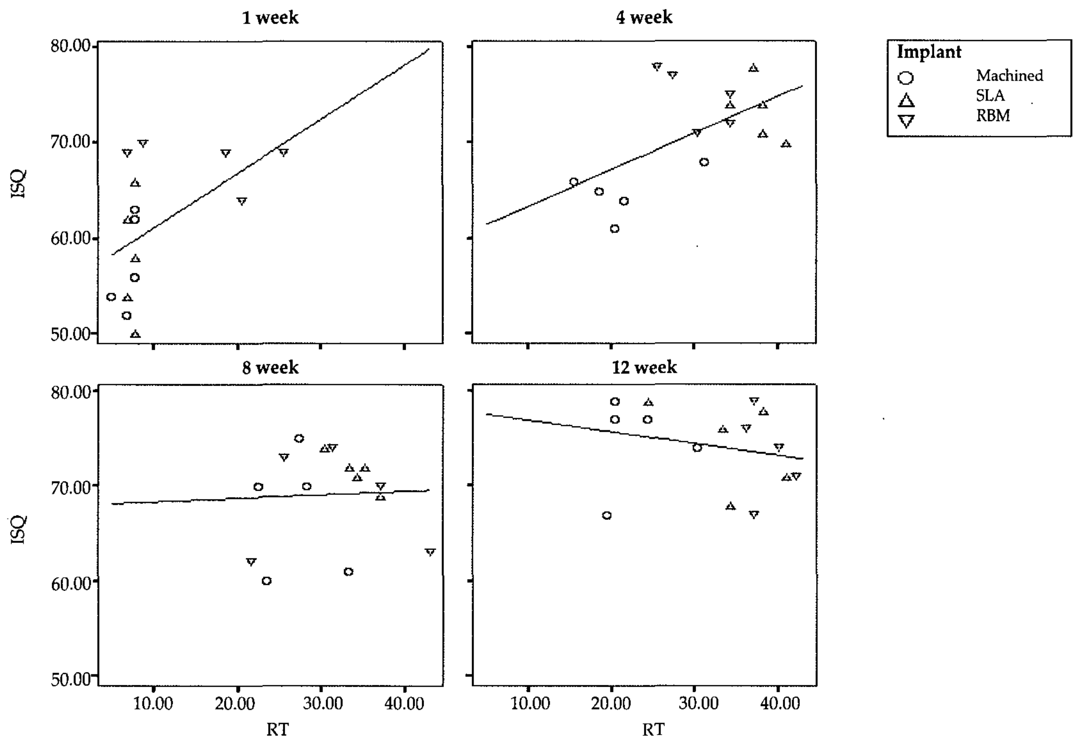

Fig. 8. Individual implant values of removal torque at each week plotted against corresponding individual implant mean ISQ.

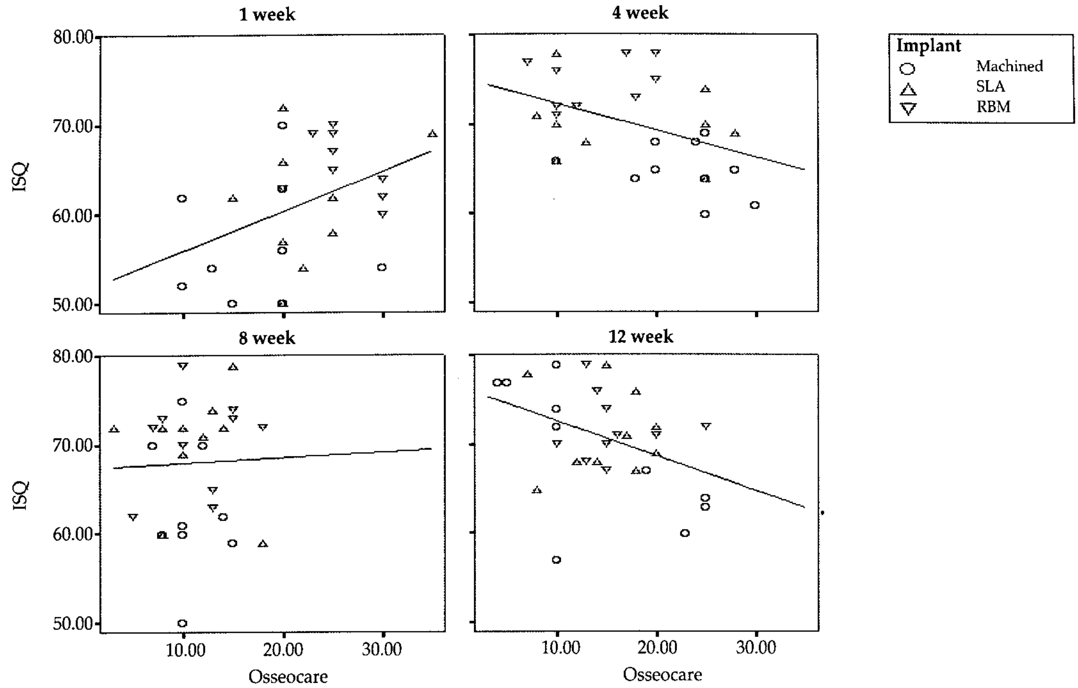

Fig. 9. Individual implant values of insertion torque plotted against corresponding individual implant mean ISQ of each week.

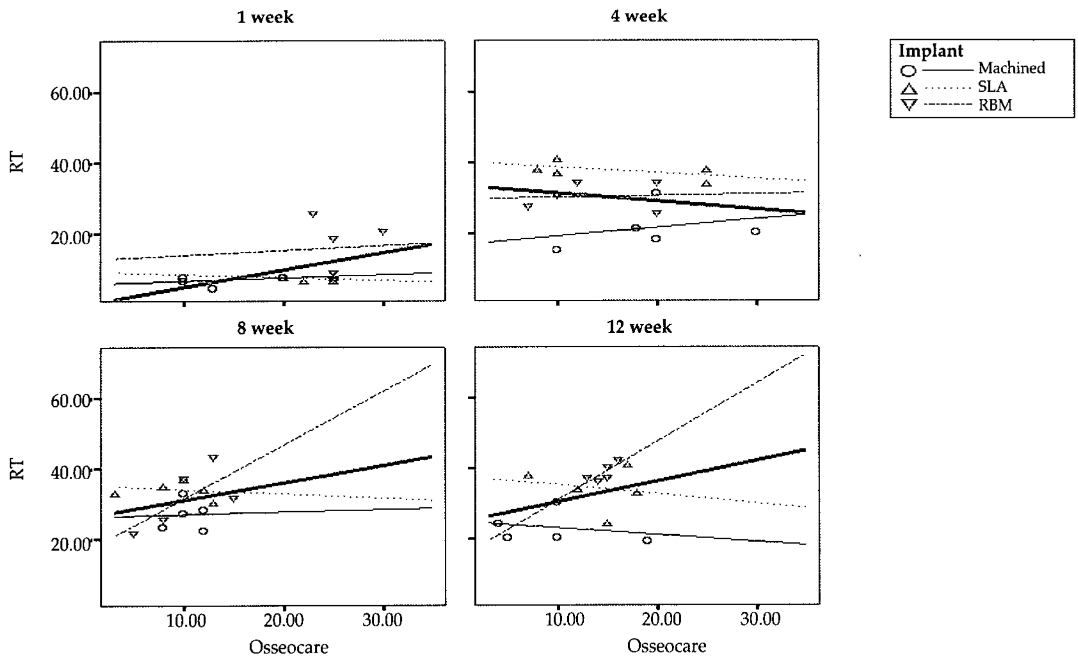

Fig. 10. Individual implant values of insertion torque plotted against corresponding individual implant RT value of each week.

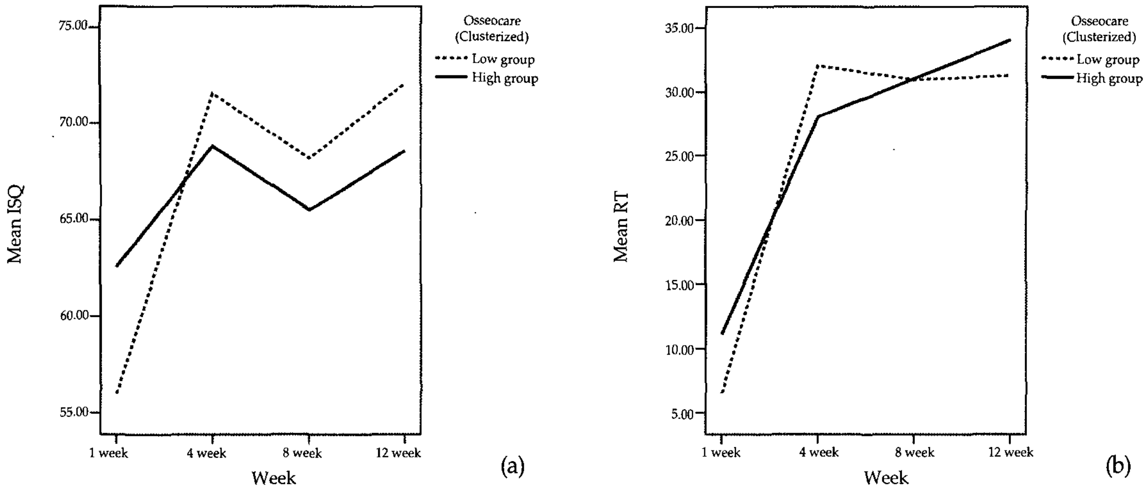

Fig. 11 The changes of mean ISQ (a) and RT (b) from 1st week to 12th week, depends on bone quality. Bone quality was assessed insertion torque and divided into 2 groups at 15Ncm. In graph (b) the value of at 8th week of high group was no-data.

DISCUSSION

Even though we uses osseointegrated implant but the term, osseointegration, is not yet fully defined.[1,3,5] Albrektsson and Wennerberg threw some questions.[1] Histologically, at what level of resolution was the direct contact? What percent of bone-to-implant contact around implant means osseointegration? What was the anchorage mechanism for osseointegration? How would it be possible to decide whether a clinical implant was osseointegrated?

For the degree of contact, lots of studies using histologic and histomorphometric analysis tried to answer. With controlled sectioning technique and computerized microscope measuring system made it possible that to demonstrate the experimental bone implants of commercially pure titanium will show an average of 90% or more direct bone contact at the cortical portion if the implantation time is at least 1 year.[5,10] Albrektsson and Sennerby[5] considered that any separations between bone and implant thicker than 10 ㎛ is an indicative of a soft tissue interface.

There have been two type of definition of osseointegration.[5] One is structurally oriented approach and the other based on biomechanical theory. Structurally oriented approach is direct contact between bone and implant, which is evaluated under microscopic systems.[5] Biomechanically oriented definition is defined as an interfacial attachment that is stronger than the surrounding bone[5,23,24] Albrektsson et al.[5,23] cited the study of Steinemann et al to describe this definition. In there the measuring of removal force is mentioned. Under microscopic examination it is just measuring a degree of bone apposition not force of bonding. The removal torque (RT) means overall shear strength of interface. Companied with histomorphometric measurement, it would be the most accurate measurement tool about osseointegration. The torque gauge manometer enabled direct readings of the torque (in Newton centimeter) necessary for loosening of the implant.[10]

In clinical case such a histological inspection and a removal test can not be applicable. As mentioned above, indirect assessment with reliable result should be utilized. The resonance frequency is determined by the stiffness of the implant/tissue interface and the distance from the transducer to the first bone contact.[8,9,14,15] This method is possible to monitor the change in tissue stiffness during the initial healing period and the subsequent follow-up period,[12,13] and about repeatability Meredith et al.[8] found the error to be less than 1%.

Interfacial stiffness could be altered by surgical technique modification such as utilizing smaller diameter final drill, use of self tapping design implant and bone compaction technique, so high initial (ISQ) can not guarantee implant success. In present study correlation between ISQ and RT value was showed. Initially they showed positive correlation but gradually decreased. This may result form remodeling of surrounding bone to resolve the stress caused by surgical procedure(decreasing of ISQ)[14] and gradual development of osseointegration (increase of removal torque).[10] Limited in this study more than certain level of removal torque (20Ncm) there seems statistically no correlation between RT and ISQ. There need more studies to explain.

Johansson and Strid[25] introduced a technique for determining bone density during the operation, especially at the recognition of bone regions with low density and at obtaining an objective measure of bone hardness during low-speed threading of implant sites. Friberg et al. found this technique reliable and applicable in clinical use.[14] In this study Osseocare™ was used to measure implant insertion torque. There are differences in insertion torque and cutting resistance, especially in clinical case there are significant change could be made from modification of surgical technique and selection of implant design.[14,17] But in this study there was no effort to change the initial stability of implant and modification of surgical technique, and self tapping implant served as final bone cutting tool. So we consider this insertion torque as final cutting resistance. Friberg et al. found a relationship between cutting torque and resonance frequency at implant placement.[14] In that study statistically significant correlation was seen between resonance frequency and patient mean cutting torque values at the upper/crestal third of the site. This finding emphasizes the importance of marginal bone density on implant stability as measurement with RFA. A statistically significant negative correlation was found between patient mean cutting torque values at the crestal bone and change in resonance frequency from implant placement to abutment connection. This means that the lower the cutting torque and resonance frequency values were at first stage surgery, the greater was the increase of resonance frequency as measured at second stage surgery, which suggests that the tissue response was more influential on implant stability in bone of low density. Similar result was obtained from present study. In result of assessment of bone quality by insertion torque, there seems two groups in rabbit bone quality. In case of rabbit tibia there is weak trabecular bone in medullar space, not like in human classification,[22] the thickness of cortical bone rules overall bone quality. Result of assessment of correlation between ISQ and insertion torque value and between RT and insertion torque showed different correlation patterns in ISQ and RT. Limited in this study ISQ reflect remodeling of surrounding bone more sensitively and RT are affected by bone quality positively. Since an excessive insertion torque showed hindrance to form osseointegration[4] and bone remodels to resolve stress from surgery,[26] ISQ value combined with insertion torque could be a good indicator to identify this situation and could be utilized to decide implant prognosis.

SUMMARY

This study aimed to evaluate the effect of bone quality to the degree of osseointegration. The degree of osseointegration was assessed by removal torque and the correlation with ISQ was evaluated. Limited in this study bone quality could affect osseointegration positively but correlation between ISQ and osseointegration could be different depends on healing time and bone quality.

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