BONE RESPONSE OF THREE DIFFERENT SURFACE IMPLANTS : HISTOMORPHOMETRIC, PERIO TEST VALUE AND RESONANCE FREQUENCY ANALYSIS IN BEAGLE DOGS

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Statement of problem. The intial stability for osseointegration of implant has been an interesting factor. Especially, in the case of poor bone quality or immediately loaded implant, various strategies have been developed focusing on the surface of materials to improve implant fixation to bone. The microscopic properties of implant surfaces play a major role in the osseous healing of dental implants.

Purpose. The aims of this study are to perform a histologic and histomorphometric comparison of the healing characteristics of three different surfaces and the comparison of resonance frequency analysis (RFA) values measured by Osstell™ and perio-test values (PTV) measured by Periotest.

Material and methods. A total of 24 screw titanium implants (Dentium Co., Seoul, Korea) with 6mm in length and 3.4mm in diameter, were placed in the mandible of 4 beagle dogs. Implants were divided into three groups following the surface treatment methods: Group I is machined(control group). Group II is anodically oxidized. Group III is coated 500nm in thickness with hydroxyapatite(HA) by ion beam assisted deposition(IBAD) on the anodized oxidization. Bone blocks from 2 dogs were caught after 3 weeks of covered healing and another blocks from 2 dogs after 6 weeks. RFA values and PTV were measured right after insertion and at 3 and 6weeks. Histomorphometric analysis was made with Kappa Image Base System to calculate bone-to-implant contact (BIC) and bone area inside the threads. Pearson's correlation analyses were performed to evaluate the correlation between RFA and PTV, BIC and bone area ratio of three different surfaces at 3 and 6 weeks.

Results.

1) In all surface treatment methods, the RFA values decreased and the PTV values increased until 6 weeks in comparison to initial values.
2) At 3 weeks, no significant difference was found from bone-to-implant contact ratio and bone area ratio of three different surface treatment methods($P>0.05$). However, at 6 weeks, different surface treatment methods showed significantly different bone-to-implant contact ratio and bone area ratio($P<0.05$).

3) In the implants with the IBAD on the anodic oxidization, significant difference was found between the 3 weeks and the 6 weeks bone area ratio($P<0.05$).

4) Correlation was found between the RFA values and the bone area ratio at 3 and 6 weeks with significant difference($P<0.05$).

Conclusions.

These results indicate that the implants with the IBAD on the anodic oxidization may have a high influence on the initial stability of implant.

Key Words

IBAD (Ion-beam assisted deposition) method, Initial stability, Histo-morphometric analysis, RFA and PTV

The success of implant largely depends on the initial stability during implant surgery and the osseointegration during healing process. Since the initial stability is influenced by bone state, various implant materials and implant surgeries have been tried with regard to bone quality.

According to Jaffin and Berman[1], bone type I, II and III of Lekholm and Zarb[2]'s classification showed 3% failure rate while bone type IV had 35% failure rate. The difference of the failure rate was influenced by delay of the initial stability which resulted from the loss of tight contact because of adjacent large bone marrow. Albrektsson[3] found that implant material, design and surface treatment was important for successful osseointegration. Glauser et al[4] claimed that in case of relatively poor bone quality, the initial implant stability was affected by implant designs and surface treatments.

To solve the problems of initial stability, interest in surface treatment of implant has increased. Many researchers tried to overcome limits through implant designs or surface treatments, and therefore implant surface treatment methods have been continuously changing. Machined surface implant without any surface treatment is smooth on the outside but has minute roughness. After combined with oxygen, machined surface forms an oxide layer, which is considered to be stable. Anodic oxidization surface treatment intends to earn firm fixation through the growth of bone in the pore of the oxide layer, which is formed by anodic oxidization. Song et al[5] conducted resonance frequency analysis(RFA) and histomorphopmetric analysis to see the bone response of anodically roughened surfaces, HA coated surface, and RBM surface implant in beagle dogs. Song's study found that the bone-to-implant contact(BIC) ratio and the RFA values did not show any significant difference in each group. Werner Zechner et al[6] claimed that anodized oxidation and HA coated implants showed higher BIC ratio than machined surfaces in mini pigs. Lisa Knobloch et al[7] placed surface treated implants with machine and anodized oxidation into beagle dogs, and restored them with fixed prosthesis at 2, 4 and 6 weeks, and performed periotest analysis. Knobloch's study[8] showed that the anodized surface was stabler than the machined one.

HA coating, which is the attachment of hydroxyapatite(same inorganic material as bone) to machined surfaces, has drawbacks such as uneven surface or separation from implant surface. To complement such drawbacks, many ways of coating[8-10] have been developed, such as dip coating, hot isostatic pressing[11], flame spraying[12], plasma spraying[13,14], and pulsed laser deposition.[15] Concerning the plasma spraying, a few of problems were reported such as chemically uneven coating layer, dissolution in saliva and a low rate of bond strength.[16,17] In an effort to earn thin and even surfaces in HA coating, ion beam-assisted deposition(IBAD) was introduced.[18,19] Park et al[20] showed that the HA coating by the IBAD method demonstrated more favorable results than the aluminum oxide-blasted surface in removal torque, bone-to-implant contact (BIC) ratio and bone area ratio. According to Kim et al[21], the BIC ratio was the highest in the IBAD treated surface.

The clinical result of implant treatment was mainly evaluated by clinical and radiographical analyses. As a non-destructive method for assessing implant stability and osseointegration, an objective, quantitative and repeatable method was needed, thus the periotest value(PTV, Siemens AG, Benshelm, Germany) and the resonance frequency analysis(RFA, Osstell Integration Diagnostic Ltd., Savedalen, Sweden) were used to evaluate the stability of implant. Recently, the resonance frequency analysis has been approved as a more effective method for quantitative calculation of implant stability in vivo.[22-25] It was also reported that the perio-test value was influenced by the length of implant fixture and the length of abutment[26], implantation site[27], location and direction of force.[28] However, the perio-test value is effective in the aspect of cost and time, and is also reported to have clinical correlation with RFA value.[29] Most research on the surface treatment of implant[30-32] have focused on comparison analysis by histomorphometrical analysis or removal torque analysis. However, there has not been much research about correlation analysis among the RFA values, the PTVs, and histomorphometircal analysis of the bone-to-implant contact and bone area ratios according to the surface treatment methods in beagle dogs.

In this study, implants with 3 different surface treatment methods were placed in the mandible of 4 beagle dogs. In order to analyze the healing characteristics of the implants, histomorphometric analysis, RFA and PTV were performed and correlations among them were evaluated. This study intends to provide a theoretical base for clinical stability of a new surface treatment method through examining initial stability with RFA values and PTVs and through evaluating the degrees of bone-to-implant contact with histomorphometrical analysis.

MATERIAL AND METHODS

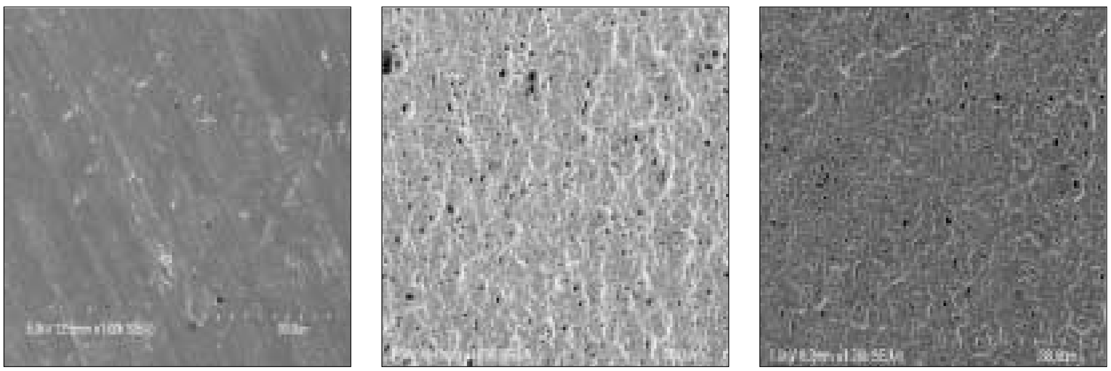
1. Animals and materials

Four adult beagle dogs, weighing approximately 10 kg and with permanent teeth fully erupted, were prepared in this study. Screw type implants(Dentium Co., Seoul, Korea) manufactured from pure titanum 3.4 mm in diameter and 6 mm in length were used in this study. The main thread had a pitch of 0.65 mm and the upper part was double threaded. A total of 24 implants were divided into 3 groups according to surface treatment methods. Following are 3 different surface treatment methods(Fig. 1):

1) Group 1(MAC) had machined surface.
2) Group 2(ANO) was anodically oxidized with pulse power(Autoelectric Co., Seoul, Korea).
3) Group 3(IBA) was HA(Ca / P=1 / 1.67) coated with 500 nm in thickness by IBAD on the anodically oxidized surface.

Table I. Comparison of anodized oxidization and HA-IBAD

	Anodizing oxidization	HA-IBAD
Thickness	2~3 μm	500 nm
Crystal structure	Anatase	Amorphous HA
Porosity / Bond strength	Around 7%	More than 35 MPa
Surface element	Ca, P, Ti, O	Ca, P, Ti, O
Roughness(R_a)	Around 0.35 μm	Lower than 1μm



Machined Surface (MAC) Anodizing oxidization (ANO) Anodizing oxidization + IBAD (IBA)

Fig. 1. SEM ×1000 of Three different surfaces.

Surface roughness of implants was measured from the upper part of thread by the manufacturer with using Top Scan3D. Properties of group II and III are explained below(Table I):

2. Implant Surgery and Insertion

The dogs were anesthetized with an intramuscular injection of Hcl Ketamine(Ketamine, Yuhan Co., Seoul, Korea, 2mg / kg body weight), and local anesthesia was injected into each implantation site with 2% Lidocaine 1ml(Lidocaine 1:100,000, Yuhan Co., Seoul, Korea). To make the edentulous state, 4 mandibular premolars were extracted bilaterally from each dog and, after three months of healing, implants were inserted. A guide drill was first used for penetration into the compact bone and was followed by a drill with 2.0 mm in diameter, a pilot drill with 3.0 mm in diameter and a final drill. With regard to implantation site, the bone quality of anterior and posterior part of mandible was taken into account and three types of implants were inserted, while changing the order according to surface treatment methods(Fig. 2). After the insertion of the implants was stabilized, cover screw was connected. Implant sites were sutured with 3-0 resorbable silk. After surgery, the animals received antibiotics(Ganamaicin 50mg / kg, Dong-a, Seoul, Korea) intramuscularly for seven days. The suture materials were removed a week after implant surgery.

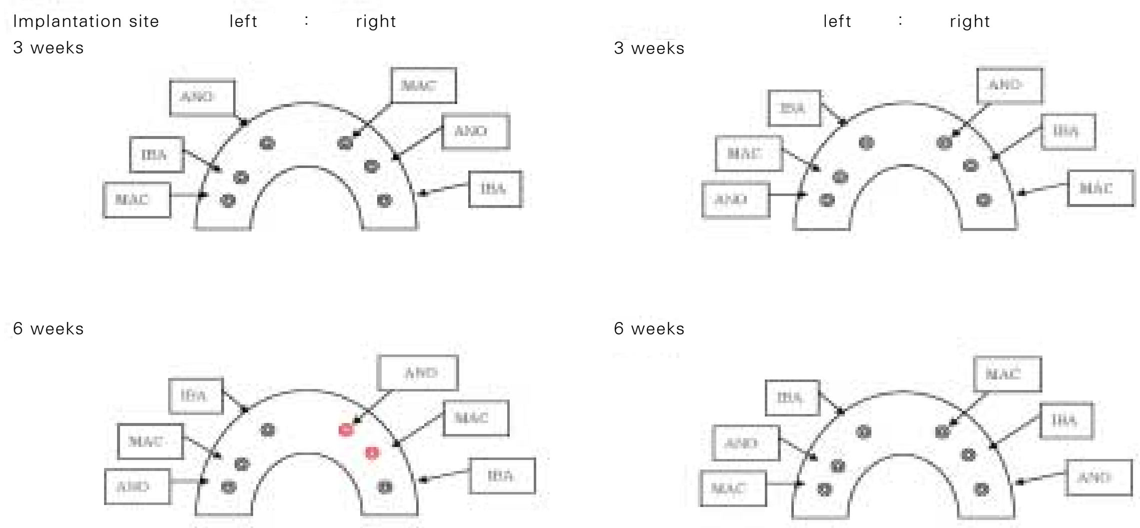


Fig. 2. Implantation site of three different surfaces.

3. Research Protocol

RFA values were measured by Osstell(Integration Diagnostic Ltd., Savedalen, Sweden) right after implant surgery and at 3 and 6 weeks. Periotest values were measured with Periotest(Siemens AG, Benshelm, Germany) right after implant surgery and at 3 and 6 weeks. After 3 and 6 weeks, respective animals were euthanized. The specimens of the mandible were divided longitudinally with the implant at the center and then fixed in neutral buffered formalin for more than 48 hours. Fixed specimens were then ground to a final thickness of about 5 mm and further dehydrated in an ascending concentration of alcohol rinses from 50 to 100%. After finally being dehydrated with 100% dehydrated alcohol more than three times, the specimens were infiltrated with alcohol and a light-curing resin (Technovit 7200VLC Kulzer GmbH, Kulzerwehrheim, Germany) for three to five days and then polymerized under light for 16 hours. After polymerization, the specimens were cut with a micro-cutting machine(Exakt MG 300, Hamburg, Germany) using a diamond wheel saw and to a thickness of approximately 200㎛. After cutting, they were ground with a micro-grinding machine(Exakt MG4000) using 800, 1200 and 2000 sandpaper and the thickness was approximately 30㎛. Through cutting and grinding, calcified specimens were manufactured, stained with hematoxylineosin and observed with a microscope(Olympus BX51, Olympus Co., Tokyo, Japan). Histomorphometric analysis was performed with an Olympus BX microscope (Olympus BX51, Olympus Co., Tokyo, Japan) connected to a computer. The image analysis software used was Kappa Image Base Metro (Kappa Opto-electronics, Gleichen, Germany). The 6 best ratios of both bone-to-implant contact ratios and bone area ratios were selected and the mean value of the six values was used in this study.

4. Statistical Analysis

Resonance frequency analysis values and periotest values were calculated using ANOVA(using SPSS for Windows ver. 12.0, SPSS Inc., Chicago, U.S.A., $P<0.05$). For histomorphometric analysis on the bone-to-implant contact (BIC) ratio and bone area ratio, Kruskal-Wallis' analysis(using SPSS for Windows ver. 12.0, SPSS Inc., Chicago, U.S.A.) was conducted with a 5% significance level. RFA values and PTVs were compared with using t-test, and BIC ratio and bone area ratio were compared with using the Mann-Whitney U-test. To find out the relationship between RFA values and PTVs of 3 and 6 weeks and BIC ratio or bone area ratio, Pearson's correlation analysis was conducted.

RESULTS

1. Resonance Frequency Analysis and Periotest Value

As time passed from day 1 to 3 and 6 weeks, RFA decreased and PTV increased. In the case of 3 weeks, group III had the highest RFA level(72.50 ± 2.43) and the lowest PTV(1.17 ± 0.41). In the case of 6 weeks, RFA was the highest in group III(76.75 ± 5.89), and PTV was higher in group I(2.92 ± 2.07) than in group III(1.25 ± 2.34) with significant difference($p<0.05$, Table III, Fig. 3, 4).

2. Histologic and Histomorphometrical Analysis

(1) Histologic finding

With regard to tissue recovery and bone response, noticeable differences were not found in all the

Table II. Surface treatment methods

Code	Surface Treatment
MAC(Group I)	Machined surface
ANO(Group II)	Anodizing oxidization
IBA(Group III)	IBAD + Anodizing oxidization

Table III. Resonance frequency analysis(RFA) values and periotest values(PTVs)

Surface Treatment	RFA values		PTVs	
	Right after implant	3weeks	Right after implant	3weeks
MAC	75.56 (6.39)	68.67 (6.84)	1.44 (1.33)	4.22 (2.73)
ANO	74.22 (8.80)*	65.44 (5.96)	2.67 (0.87)	3.78 (1.48)
IBA	73.17 (3.37)	72.50 (2.43)	2.33 (0.52)	1.17 (0.41)
	RFA values		PTVs	
	Right after implant	6weeks	Right after implant	6weeks
MAC	71.25 (8.24)	73.08 (7.19)	2.50 (1.45)	2.92 (2.07)
ANO	76.08 (9.39)	66.75 (9.88)	0.50 (2.02)	3.00 (3.49)
IBA	85.25 (7.82)	76.75 (5.89)	-0.08 (1.56)	1.25 (2.34)

*: Standard deviation is written in parenthesis.

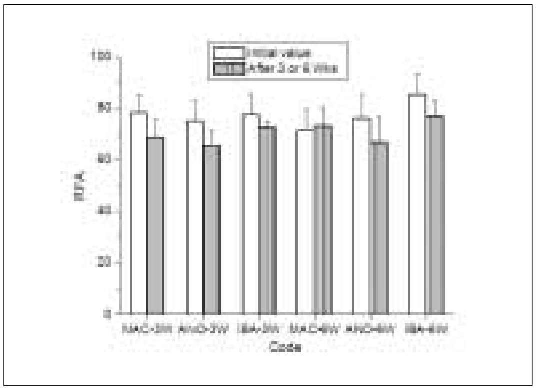


Fig. 3. Resonance frequency analysis values(ISQ).

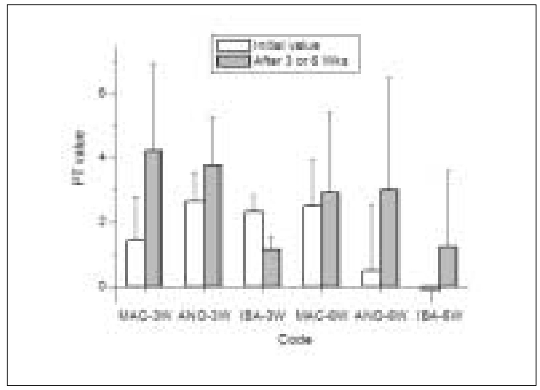


Fig. 4. Periotest values.

groups. At 3 weeks, bone remodelling began and several inflammatory and defect areas were observed. At 6 weeks, bone remodelling became very active with abundant Haversian canals and reversal lines being observed. As time passed from 3weeks to 6weeks, newly formed bone derived from old bone gradually changed into compact bone. Minor inflammation in the threads is thought to be caused by heat damage. Minor bone defects were also observed at the upper thread, which are thought to be caused by compression during insertion(Fig. 5, 8).

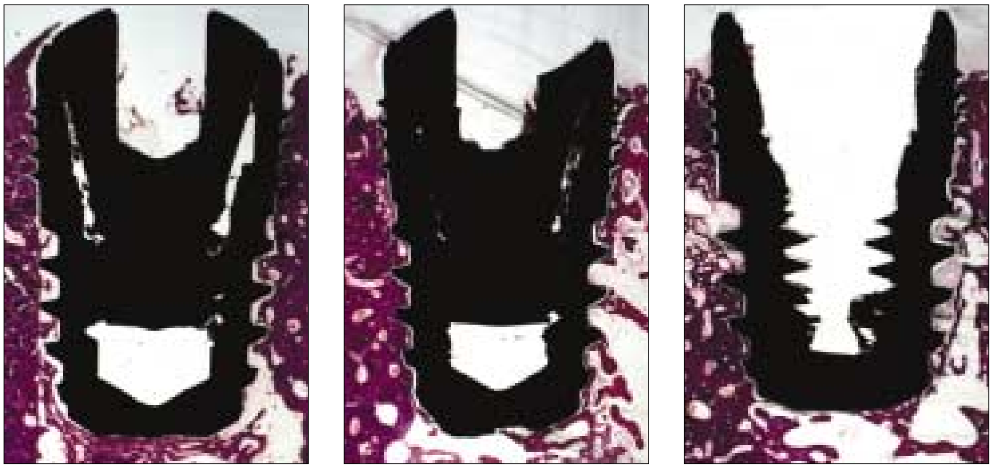
(2) Histomorphometrical Analysis

In general, Bone-to-implant contact (BIC) ratio and bone area ratio increased at 6 weeks compared to 3 weeks. At 3 weeks, no significant difference was found among the three groups. However, in the case of 6 weeks, group III showed the highest BIC ratio (0.38± 0.18)and bone area ratio (0.70± 0.15) with significant difference($p<0.05$, Table IV, Fig. 6, 7, 8).

3. Comparison and correlation analysis of RFA values and PTVs, and bone-to-implant contact (BIC) ratios and bone area ratios

Comparison of RFA values and PTVs with t-test revealed that RFA values and PTVs of 3 and 6 weeks did not have any significant difference($p>0.05$). Regarding the BIC ratios of three surface treatment, no significant differences were found between 3 and 6weeks respectively. No significant difference was found between 3 and 6 weeks bone area ratios of respective group I and II($p>0.05$). However, significant difference was found between 3 and 6 weeks bone area ratios of group III($p=0.038$). Correlation analysis of RFA values and PTVs, and BIC ratios and bone area ratios is followed :

A. Correlation was not found between RFA values and PTVs at 3 and 6 weeks respectively($p>0.05$).
B. Correlation was found between BIC ratio and bone area ratio at 3 weeks($p<0.05$). Correlation coefficient was 0.741. However, there was no correlation at 6 weeks($p>0.05$).
C. While no correlation was found between RFA values and BIC ratios of 3 and 6 weeks respectively, there was correlation between RFA values and bone area ratios of 3 and 6 weeks respectively($p<0.05$). Correlation coefficient was 0.762 and 0.935 respectively.
D. No correlation was found among periotest values, BIC ratios and bone area ratios of 3 and 6 weeks.



×40 6 weeks(Group I) ×40 6 weeks(Group II) ×40 6 weeks(Group III)

Fig. 5. Histologic finding of three groups at 6 weeks ×40.

Table IV. Bone-to-implant contact ratio and bone area ratio

Surface Treatment	Bone-to-implant contact ratio		Bone area ratio	
	3 weeks	6 weeks	3 weeks	6 weeks
MAC(Group I)	0.29 (0.20)	0.21 (0.14)	0.56 (0.23)	0.68 (0.14)
ANO(Group II)	0.39 (0.23)*	0.36 (0.21)	0.48 (0.22)	0.52 (0.26)
IBA(Group III)	0.34 (0.24)	0.38 (0.18)	0.54 (0.27)	0.70 (0.15)

*: Standard deviation is written in parenthesis.

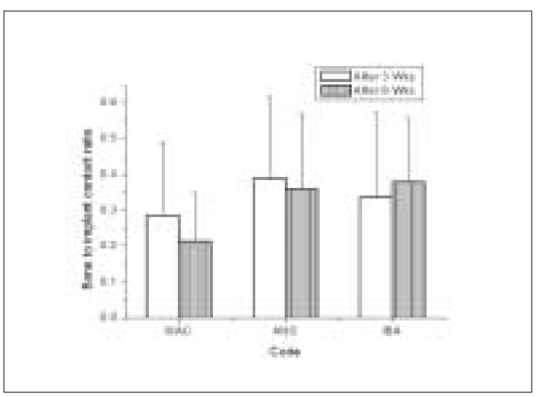


Fig. 6. Bone-to-implant contact ratio.

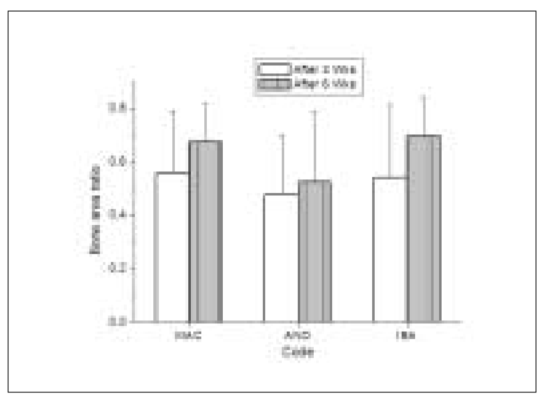
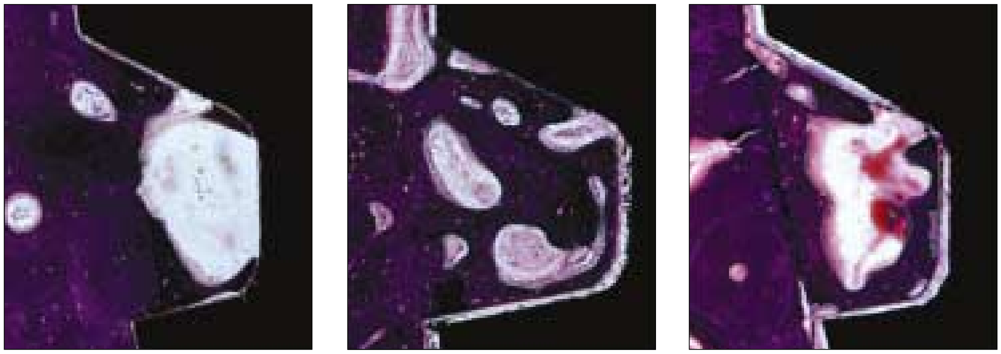
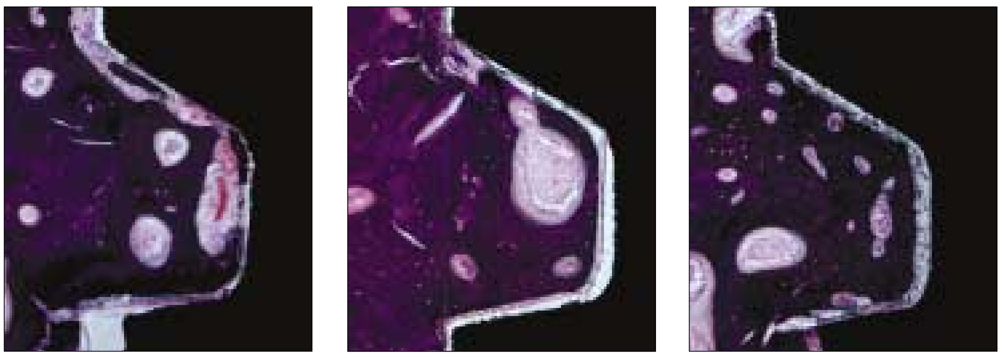


Fig. 7. Bone area ratio.



×100 3 Weeks(Group I) ×100 3 Weeks(Group II) ×100 3 Weeks(Group III)



×100 6 Weeks(Group I) ×100 6 Weeks(Group II) ×100 6 Weeks(Group III)

Fig. 8. Histomorphometrical analysis of three groups at 3 and 6 weeks ×100.

DISCUSSION

Surface oxide properties are regarded to be of great importance in establishing successful osseoingration of titanium implants.[33] Much research has been made on initial stability in the case of poor bone quality. Especially, recent efforts have been made to earn the roughness, surface morphology and oxide layer most appropriate to the osseointegration. In Sennerby[34]'s ultrastructural studies of the implant interfacial zone, it was observed that the tissue elements directly bordered not the bulk titanium but rather the native oxide layer of the metal. This thin oxide layer was shown to be in contact with remodeled mineralized bone. The oxide layer(TiO_2) was amorphous, 17nm in thickness and 0.53~0.67μm (Ra) in roughness.[35] On the other hand, according to Tufekci E et al[36], implants with rough surfaces increase the bone-to-implant contact area and produce higher success rates even in implants with short length. Tufekci' s clinical treatment of poor bone quality showed the superiority of implants with rough surface treatment. Wennerberg et al[37] reported that titanium implants with 1.4μm in surface roughness(Sa) had higher bone-to-implant contact ratios than those with less roughness(Sa : 0.7-1.2μm). The implants used in this study were anodically oxidized (group II and III)at 270V and had a surface roughness of 0.35μm(Ra). With regards to the bone area ratio at 6 weeks, machined surface (group I) had higher figures than anodic oxidization and this result is thought to be caused by surface roughness. Machined surfaces actually show higher roughness and could be combined with oxygen, forming oxide layer, and inducing the osseointegration. However, there is room to discuss about the optimum roughness.

With regard to thickness of oxide layer, it was reported that when natural oxide layer was treated with thermal or eletrochemical oxidization[38], the thickness and the internal crystalization of oxide layer increased and the bone response improved, which is considered to be beneficial to stability.[39] Sul et al showed that implants with oxide thickness of approximately 600, 800, 1000nm demonstrated significantly stronger bone reponses in the evaluation of removal torque value than implants with approximately 200nm thickness of oxide layer.[38] Anodically oxidized (group II and III) implants used in this study had the oxide layer of 2~3㎛ thickness. There may be controversies but, in general, the optimum oxide thickness is known as around 1㎛.

In this study, ion beam-assisted deposistion (IBAD) was applied on the anodizing oxidization to make hydroxyapatite(HA) coating thin and even.

Recently published research revealed that the method of HA coating by IBAD on various surfaces showed more favorable result in bone-to-implant contact (BIC) ratio and removal torque than other surface treatment methods. In Kim et al's research[21], BIC ratio at 10 weeks was the highest in HA-IBAD coated surface(roughness 1.24㎛), followed by anodic oxidization(roughness 1.02㎛), Sol-gel(roughness 1.12㎛), SLA(roughness 1.76㎛) and machined surface(roughness 0.86㎛).

In this present study, BIC ratios and bone area ratios increased at 6 weeks compared to 3 weeks. At 3 weeks, no significant difference was found among the three groups. However, in the case of 6 weeks, group III showed the highest BIC ratio (0.38± 0.18) and bone area ratio (0.70± 0.15). High BIC ratio and bone area ratio of group III is thought to be attributed by the excellent bond strength and appropriate dissolution time of the HA, and replacement the HA with bone. Since HA coating is replaced with new bone and then induces osseointegration, the dissolution rate, which measures the dissolution of Ca/P film thickness, becomes important. The dissolution rate could be controlled by heating coating layers or by adjusting the Ca/P ratio. However, since the heating process could cause a crack in coating layers, using the Ca/P ratio is a more desirable way to decide the dissolution rate. Even though more research is required with regard to the Ca/P ratio and dissolution rate, this research used the HA with 1.67 Ca/P ratio.[18] In addition, regarding bone area ratio, group III showed significant difference between 3 and 6 weeks($p=0.038$). It was seen that IBAD + anodizing oxidization surface treatment contributed to better osseointegration than other surface treatment methods, and to a significantly faster bone formation and remodelling in the early phase. RFA values and PTVs at 6 weeks showed good influence of group III on initial stability. Group III had the highest RFA value (76.75± 5.89) at 6 weeks, comparison to group I(73.08± 7.19) and II(66.75± 9.88) with significant difference($p<0.05$). With regard to the PTVs, PTV of group III(1.25± 2.34) was significantly lower than that of group I(2.92± 2.07) at 6 weeks ($p<0.05$). This finding means that, compared to anodizing oxidization surface treatment, 500nm HA coating layer was appropriate to be resolved early and was successfully replaced with new bone. However, appropriate ratio and thickness of Ca/P, which directly affects bone replacement time, should be further studied.

As a nondestructive methods to assess the degree of osseointegration, in implant stability, this research used RFA and PTV. According to Isidor(1998) and Schulte(1993), it was reported that periotest values reflected bone resorption and BIC ratio.[41,42] Also, it was founded that RFA values were influenced by the effective implant length, bone morphology and bone density.[43,44] In this study, there was correlation between RFA values and bone area ratio of 3 weeks and those of 6 weeks respectively ($p<0.05$). As shown in the correlation result, RFA values better reflect the degree of bone formation than the PTVs. The RFA values of this study is thought to be attributed by the direct reflection of bone quality and density on RFA values. In Yi et al's clinical study[29] examining 333 implants, the correlation between RFA values and PTV was found. However, it was also reported that PTV analysis by itself was not enough to evaluate stability.

In this present study, the decrease of RFA values and the increase of the PTVs at 3 and 6 weeks is thought to result from poor bone quality of beagle dogs 3 months after teeth extraction, mechanical bone relaxation by bone compression during implant insertion, biological changes during early bone healing period, beginning of marginal bone loss. Regarding the changes of stability with time, it was found in Glauser et al[4]'s clinical research that, as a result of six month resonance frequency analysis, stability decreased until the first 3 weeks and then gradually increased.

Even though the biomechanism cycle of beagle dogs is known to be 1.5 times faster than that of human, the healing time of this present study(3 and 6 weeks) was relatively short to predict perfect bone reformation. Since implants were inserted into immature bones(3 months after extraction), BIC ratio and bone area ratio were relatively low. Despite of low ratios, this research has a significance as a study on early stability in imperfect bone state. However, considering the limitations of this study such as small number of research animals and relatively short observation time, continuous study is required for gaining clinical support for this research.

CONCLUSION

The total 24 implants were divided into three groups according to surface treatment methods. Following is the three groups of implants with different surface treatment:

1) Group I(MAC) had machined surface.
2) Group II(ANO) was anodically oxidized with pulse power(Autoelectric Co., Korea).
3) Group III(IBA) was HA(Ca / P=1 / 1.67) coated with 500 nm in thickness by IBAD on the anodically oxidized surface.

Within the limitations of this study, the following conclusions were drawn:

1. In all three groups, the RFA values decreased and the PTVs increased as time passed from the first day to 3 and 6 weeks.
2. At 6 weeks, IBAD+anodic oxidization implant showed significantly higher RFA values(76.75 ± 5.89) than anodic oxidization implant(66.75 ± 9.88) and machined implant(73.08 ± 7.19)($p<0.05$). On the other hand , at 6 weeks, machined implant showed significantly higher PTVs(2.92 ± 2.07) than IBAD+anodic oxidization implant(1.25 ± 2.34)($p<0.05$).
3. At 3 weeks, no significant difference was found from the bone-to-implant contact ratio and the bone area ratio of three different surface treatment methods.
4. At 6 weeks, different surface treatment methods showed different bone-to-implant contact ratio(sig 0.006); IBAD+anodic oxidization implant(0.38 ± 0.18), anodic oxidization implant(0.36 ± 0.21), machined implant(0.21 ± 0.14).
5. At 6 weeks, different surface treatment methods showed different bone area ratio(sig 0.006); IBAD+anodic oxidization implant(0.70 ± 0.15), machined implant(0.68 ± 0.14), anodic oxidization implant(0.52 ± 0.26).

6. In case of IBAD + anodic oxidization group, significant difference was found between the bone area ratios at 3 and 6 weeks($P<0.05$).
7. Correlation was found between the RFA values and the bone area ratios of 3 and 6 weeks($P<0.05$).

As drawn above, IBAD + anodic oxidization implants showed significantly different RFA values and PTVs in comparison with two other surface treatment implants. Also histomorphometrical analysis revealed that the IBAD + anodic oxidization implants showed significantly different bone-to-implant contact ratio and bone area ratio in comparison with two other surface treatment implants. This result is thought to provide a significant foundation to for further research in improving the initial stability of implants especially in case of poor bone quality or early loading implant. However, with regard to the correlation of analysis results, clinical research is needed.

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