J Korean Acad Prosthodont : Volume 38, Number 3, 2000

Radiation effect on peri-implant tissue after implantation

Hyeog-Sin Kweon, DDS, MS, PhD[a], **Kwang-Yeob Song, DDS, MSD, PhD**[b],
Department of Prosthetic Dentistry, College of Dentistry, Chosun University[a]
Department of Prosthetic Dentistry, College of Dentistry, Chonbuk National University[b]

Statement of problem. There were several studies on the effects of irradiation to periimplant bone tissue. However, no clear biological effect of irradiation on peri-implant bone tissue was reported yet.

Purpose. This study compared the effect of irradiation on the surrounding tissue of a HA-coated implant fixture with controls.

Material and methods. 6 Steri-Oss implants were implanted into the femur of 6 mongrels. The implanted dogs were divided into three groups and received irradiation. After 1 month, 2months and 4 months healing period, the histologic examination and mobility test and digital radiographic imaging analyses were performed to compare the control and experimental group respectively.

Results. The irradiated group showed slower healing than control group in light microscopic observations. The mobility test demonstrated significant less number (Periotest) in control group than that of irradiated groups. The digital radiographic imaging analysis showed that the bone density of irradiated group was higher than control group.

Conclusion. Generally, control group showed favorable bilogical response and less mobility than irradiated group. The conflict result of bone density value were measured by the digital radiographic imaging analysis. The digital radiographic imaging analysis needs more research in future.

Through forty-year researches and clinical experience of dental implant in modern dentistry, dental implantation was recognized to be a successful technique which could restore missed teeth and their surrounding tissue[1]. In particular, an osseointegrated implant introduced into dental science by Branemark et al[2] has been going to widen the treatment range of prosthodontics and maxillofacial prosthetics and to settle down its firm theoretical background by many animal experiments and clinical researches[3-5]. Thus, the discovery of osseointegrated implant was regarded as the momentum of great change in the long history of dental science.

Thereafter, many forms of implants were developed and implanted in jaw in various ways and were used to restore the missed function of stomatognatic system[6-9]. As the fixture of a dental implant, submucosal, subperiosteal, endosteal and transosteal fixtures were used according to the place of implantation[10], and as the material of the fixture, metal[11], ceramic[12], carbon[13,14] and synthetic resin et al[15], were used. In addition, many forms of implant fixtures such as spiral[16,17], bladvent[18], screw and cylinder etc, were prepared in consideration of the distribution of occlusal force and the quantity of residual alveolar bone, and the interface treatment methods of these implant fixtures were developed variously[19].

The material of an original osseointegrated implant fixture developed by Branemark was pure titanium, and its form was a smooth-faced cylinder with fine spiral threads[20]. In recent, however, implant fixtures which were coated with hydroxyapatite(HA) or sprayed with titanium plazma were developed and were used clinically[21].

Specially, HA had influence upon promoting the formation of new bone and increasing the contact between bone and implant, in initial stage of osseointegration and so many researches about HA coated implant have been going on. Jarcho et al[22-27] reported on porous HA particles in the alveolar bone of a dog and a human body, and Levin et al[28-33] stated about the formation of bone after implanting dense HA particles. Denissen and de Grook[34], and Quinn and Kent[35] grafted dense HA particles in a dog's extraction socket and, in result, presented the possibility that the HA particles could restrain the resorption of alveolar bone after the extraction of teeth. When Kraut[36] and Davis[37] transplanted an implant fixture of titanium to a human body, they implanted porus HA particles in the damaged area around bone. Ardoin et al[38], Block et al[39] and Ducheyene et al[40] reported on the histological respect of a HA-coated titanium implant fixture and the difference of mechanical combinational force between a HA-coated implant fixture and a pure titanium fixture.

Coating the interface of a pure titanium implant fixture with HA was aimed at attaining the solid osseointegration between a implant fixture and surrounding bone tissue, resisting masticatory force effectively while an implant prosthesis would function in the mouth, and ensuring the long-term success of a dental implant.

The long-term success of a dental implant depended upon various factors such as sufficient osseointegration between an implant fixture and its surrounding bone tissue, prosthetic design to distribute excessive masticatory force, a patient's ability of managing oral hygiene, the periodic examination of a patient and the change of a patient's health condition and circumstances after implantation[21].

With the frequent use of dental implant in dental clinics, quite a few patients among successful implantation patients were exposed to various environments and one of them was irradiation for the diagnosis and treatment of a general disease. The diagnosis and treatment using radiation had many merits, while they could accompany side effects like osteoradionecrosis, and they could cause the destruction of immature bone tissue and the delay of its maturity particularly. Thus there were several reports on a relation between an implant and radiation recently. Asikainen et al[41] studied the retarded reaction of bone tissue after irradiation, and Misch et al[42] reported that a pure titanium implant fixture and a HA-coated implant fixture were implanted in the irradiated jaw and osseointegration was attained. Also, Mian et al[43] reported the effect of irradiation upon the bone tissue and the effect of backscatter irrradiation between a implant fixture and its surrounding tissue. Besides, there were some reports on the influence of irradiation after implantation. Granstrom et al[44] reported on the clinical effect of irradiation after implantation, and Schon et al[45] studied the influence of irradiation upon peri-implant bone tissue after implantation. But no one clarified the biological effect of irradiation upon peri-implant bone tissue after implantation yet. In addition, there were few histological researches into the biological effect of irradiation after implantation.

Thus, this study was aimed at evaluating the biological effect of irradiation upon the surrounding tissue of a HA-coated implant fixture after implantation. After HA-coated implant fixtures were implanted in mature dog's femurs and were irradiated, the histological examinations, the mobility tests and the digital radiographic imaging analyses for the fixtures were performed.

MATERIAL AND METHODS

Material

1) Laboratory animals

A litter of 6 mongrels which were 8 months old and 13kg or thereabouts were selected as experimental animals for this study so that the most identical condition possible might be given. Also, they were raised for 1 month under the same condition, and then were used in the experiment. Total 6 dogs were divided into 3 groups, that is to say, 1 month group, 2 months group and 4 months group on the basis of duration from implantation to the manufacture of tissue specimens, and 2 dogs were assigned to each group. Also, each group was separated into an irradiated experimental group and a non-irradiated control group, respectively (Table 1). All laboratory dogs had been bred under the same condition until the experiment was ended. There was much apprehension for infection in case of implantation in the mature dog's jaws, and implant fixtures were implanted in the mature dog's left femurs.

2) Implant fixtures

The implant fixtures of Stere-Oss implant system (Steri-Oss, Yorba Linda, CA, USA) which were widely used in dental clinics were selected as the implant fixtures for this study, and they were 8mm long and 3.8mm diametric ones with external hexa-structure. The interface of an implant fixture was coated with hydroxyapatite and total 6 implant fixtures were selected.

Methods

1) The surgery and the implantation of laboratory animals

Every laboratory dog of each group was put under general anesthesia by injecting 2cc Xylazine (Rompun, Bayer V et al., hem-Korea Co., Korea) and 2cc Ketamine (Ketara, Yuhan Co., Korea) into the muscle of its femur in order that an implant fixture might be grafted in its femur. Then small doses of anesthetic were added in the intervals of surgery. After the hair of left femur was shaved and disinfected, he was put under local anesthesia by 2% lidocaine so as not to bleed and not to feel pain. The knife was inserted deeply into skin till its contact with bone, and 12cm of skin was incised upward from knee joint. Then muscular layer and periosteum were opened and the femur was exposed. A hole for an implant fixture remained to be 3.8mm in diameter. The prepared implant fixtures were implanted in each hole and were covered with their cover screws. Each hole was sutured tightly with 4-0 suture silk in a layer-to-layer method. For the prevention of the inflammation of every dog's femur after the surgery, 2cc Lincomycine (Lincocin, Hanguk Upjon Co., Korea) was injected into each dog's muscle for 3 days and 1cc for 2 days.

2) Irradiation

Total 6 dogs were divided into 3 groups, that is to say, 1 month group, 2 month group and 4

Table 1. Classification of experimental animals.

Duration	1 month		2 months		4 months	
Animal Animal	Control group	Experimen -tal group	Control group	Experimen -tal group	Control group	Experimen -tal group

month group on the basis of duration from implantation to the manufacture of tissue specimens, and 2 dog's were assigned to each group. Then each group was separated into an irradiated experimental group and a non-irradiated control group, respectively. Irradiation was performed with 6 MV X-ray by a Linear Accelerator (Varian Co., USA) which was used in the treatment of a tumor (Fig. 1). Among the laboratory dog's of 1 month and 2 months groups, those of experimental groups were irradiated after 10th day from implantation so that the influence of early irradiation on osseointegration might be evaluated. The range of irradiation was decided to be 3 × 5cm. The amount of irradiation was 15Gy at a time. Among the laboratory dog's of 4 months group, those of experimental group were irradiated in the same method and in the same amount after 3rd month from implantation so that influence of irradiation on peri-implant bone tissue might be evaluated after their bone tissue was matured somewhat.

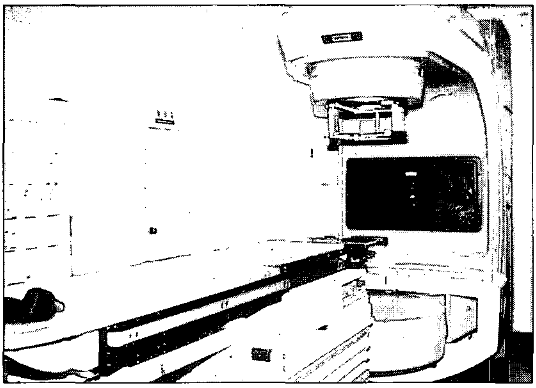
Fig. 1. Linear Accelerator.

3) The injection of fluorescent substance

Calcein (SIGMA) which infiltrated in only new bone tissue selectively and fluoesced in green was injected so that the time and direction of bone growth might be observed through a confocal laser scanning microscope. 20mg/kg Calcein was injected into each laboratory dog's muscle of control groups and experimental groups, and the dog was sacrificed for preparation of a tissue specimen in 10th day (Table 2).

4) The preparation and observation of tissue specimens

The experimental dog's of each group were sacrificed in the 4th, 8th and 16th week after implantation, respectively. For the preparation of tissue specimens, the dog's femurs were removed and were fixed with 70% alcohol, so that the deformation of tissue specimens might be minimized. After the long axes of the implant fixtures were detected by radiographing the removed femurs, the slices of the extracted femurs were made. The slices were fixed in 70% alcohol for 6 days and were washed in flowing water for 1 day. Then they were preserved in villanueva bone stain solution and were dyed. After they were dehydrated in 70%, 90%, 95%, 100% Ⅰ, 100% Ⅱ, 100%

Table 2. Time table for the application of Calcein

Duration	1 month		2 months		4 months	
Animal Animal	Control group	Experimen -tal group	Control group	Experimen -tal group	Control group	Experimen -tal group
Date of irradiation	10th day		10th day		90th day	
Date of the injection of Calcein	20th day		50th day		110th day	
Date of sacrifice	30th day		60th day		120th day	

Ⅲ and 100% Ⅳ alcohol for 12 hours, respectively, they were clarified and were infiltrated into by the mixture of acetone and spur resin. After they were embedded in spur resin, they were left as they were under vacuum and at room temperature for 2 days. Treated at the temperature of 70℃ for 1 day, they were hardened at room temperature. After hardening the slices were cut successively to the thickness of 80～100㎛ by means of low speed diamond wheel saw (South Bay Technology Inc. USA), they were ground to the thickness of 20㎛ through Omnilap 2000(South Bay Technology Inc. USA) grinder and were sealed up by cover glasses. The specimens were kept in a dark box for the protection of fluorescent substance and were observed by means of a light microscope and a confocal laser scanning mincroscope.

5) Mobility test

The mobility of each implant fixture was tested with Periotest (Siemens, Germany, Fig. 2), which was equipped with a micro-computer internally. The impact bar of Periotest run by electricity gives the impact of 4 times a second, and total 8gm impact of 16 times for 4 seconds on an implant fixture, its internal computer sensed the reactions of more than 4 times among them by an implant fixture's mobility and its buffer effect, and then expressed numerals from -8 to +50 on a screen and in a sound. In this study, the mobility of an implant fixture was tested as soon as a experimental animal was sacrificed. After a pick-up type of a square impression pin was connected with an implant fixture, it was hit with Periotest vertically. Then the mobility was measured 5 times an implant fixture and it was averaged.

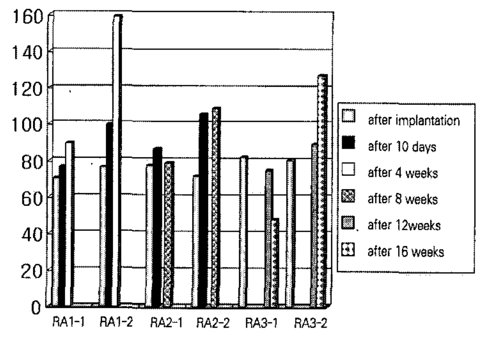

Fig. 2. Measurement of the radiographic density of peri-implant bone by digital imaging system.

6) Digital radiographic imaging analysis

For digital radiographic analysis, the control group and the experimental group were radiographed 3 times, that is, first shortly after an implant fixture was implanted, secondly when it was irradiated and thirdly as soon as the dog was sacrificed for the preparation of a tissue specimen. The radiographes were taken by means of cephalometric radiography and under the same condition of 100㎃, 6.3kvp and 0.14sec constantly. Digital radiographic imaging analysis was done by means of the taken radiographes and a personal Mackintosh computer. The taken radiographes were inputted through a scanner (Epson, Korea) connected to the computer. After the center of an implant fixture was located, its radiographic density was measured on both the left and the right side of each implant fixture and it was averaged. An inputted screen was digitalized to support the space resolution of 640 × 480 pixel and 256 gray scale, and NIH image program was used in the imaging analysis.

RESULTS

Histological analysis

(A light microscope and a confocal laser scanning microscope : Table 3)

An implanted fixture passed through a cortical bone at the top of a femur vertically and was set well in a medullary portion where bone marrow spaces existed. In a transcortical portion, an implant fixture was supported by compact bone. In a medullary portion, it was supported mainly by trabecullas directly below compact bone and

Table 3. Tissue reaction around an implant fixture from a histological view.

	1 month		2 months		4 months	
	Control group	Experimen -tal group	Control group	Experimen -tal group	Control group	Experimen -tal group
New bone formation	*		***		***	*
Osseointeg-ration	*		**		***	

* Indicates poor reaction
** Indicates average reaction
*** Indicates good reaction

by sporadic trabecullas in bone marrow spaces.

1) 1 month group after implantation

(1) Non-irradiated group

In a transcortical portion, an implant fixture came into contact with bone directly by means of compact bone which Haversian system was developed well. The Haversian system was that lamellar bone was formed to that degree that bone marrow spaces were hardly observed and osteocytes were arranged well concentrically. In a medullary portion directly below a cortical bone, the fixture was supported by mature trabecullas attached to its interface rectangularly. In bone marrow spaces, immature trabecullas and the formation of bone were not observed (Fig. 3-A). In observations through a laser confocal scanning microscope, a little green fluorescent substance which stood for the formation of new bone was observed mainly along the fixture and the interface of bone in parallel with the fixture, whereas the active bone formation or bone remodeling were not observed (Fig. 3-B).

(2) Irradiated group

As compared with a non-irradiated group, the contact area between an implant fixture and a cortical bone decreased on the whole. In the periosteal portion at the top of a cortical bone and the section of a cortical bone, an implant fixture was supported by irregular and immature trabecullas (Fig. 4-A). Also, in a medullary portion, the fixture was surrounded by a few irregular trabecullas which were not attached to its interface rectangularly (Fig. 4-B). In a view through a laser confocal scanning microscope, concentric green fluorescent substance was observed a little in bone marrow spaces between compact bone, while fluorescent substance to show the formation of new bone entirely was not observed in a portion to pierce compact bone and in a medullary portion (Fig. 4-C).

2) 2 months group after implantation

(1) Non-irradiated group

From a transcortical portion to a medullary portion, osteocytes were arranged well, lamellar bone was formed and an implant fixture was supported by mature bone including bone marrow spaces (Fig. 5-A). According to the observation by laser confocal scanning microscope, the form of mature bone which fluorescent substance was not observed in the interface of the fixture and in lamellar bone was observed (Fig. 6-B).

(2) Irradiated group

Except that the number of bone marrow spaces was increased and the thickness of the plate of a cortical bone was decreased a little in a transcortical portion at the top of an implant fixture as compared with a non-irradiated group, an implant fixture was supported by mature lamellar bone

Table 4. Measurement of mobility by periotest value.

	1 month		2 months		4 months	
	Control group	Experimen -tal group	Control group	Experimen -tal group	Control group	Experimen -tal group
Value	-5.7	-4.8	-6.4	-5.5	-7.6	-5.1

like a non-irradiated group. In a medullary portion at the bottom of an implant fixture, however, an implant fixture was maintained by irregular immature trabecullas arranged in parallel with the fixture, and a contact area between the fixture and immature trabecullas was increased in spite of the outstanding decrease of mature bone(Fig. 6-A, B). In a view through a laser confocal scanning microscope, a good amount of green fluorescent substance to show the formation of bone was observed in the interface of the fixture and in some bone.

3) 4 months group after implantation

(1) Non-irradiated group

From the transcortical portion of an implant fixture to its entire medullary portion, the fixture was supported by mature lamellar bone. In a medullary portion, some mature trabecullas which didn' t form lamellar bone were arranged rectangularly to the fixture. Entirely, mature bone expressed a well-developed Haversian system which oseocytes were arranged concentrically around Haversian canal(Fig. 7-A, B). In observations through a laser confocal scanning microscope, concentric green fluorescent substance was observed a little inside bone marrow spaces on the interface of the fixture.

(2) Irradiated group

As compared with a non-irradiated group, the quantity of lamellar bone in the region of a cortical bone was decreased remarkably, the thickness of a layer supported by mature trabecullas at the bottom of an implant fixture was decreased, and trabecullas were arranged very irregularly(Fig. 8-A, B). In a view by means of a laser confocal scanning microscope, very irregular green fluorescent substance was observed entirely(Fig. 8-C).

Mobility test

As the result of mobility tests for 1 month groups, the mobility of an implant fixture was -5.7 in the non-irradiated group and -4.8 in the irradiated group. Thus the latter mobility was bigger than the former mobility. On the other hand, the mobility of an implant fixture was -6.4 in the non-irradiated group and -5.5 in the irradiated group in case of 2 months groups. The latter mobility was somewhat bigger than the former mobility, but the mobility of 2 months groups was decreased as compared with that of 1 month groups. In case of 4 months groups, the mobility of an implant fixture was -7.6 in the non-irradiated group and -5.1 in the irradiated group, and so a great difference between two groups was showed(Table 4).

Digital radiographic imaging analysis

As the result of digital imaging analysis for taken radiographes, radiographic density around an implant fixture was 70.2 shortly after the surgery, 76.7 after 10 days and 89.5 after 1 month in a non-irradiated 1 month group. In case of an irradiated 1 month group, it was 76.5 shortly after the surgery, 99.5 after 10 days and 158.7 after 1 month. Thus the radiographic density of the irradiated 1 month group was higher than that of the non-irradiated 1 month group.

In case of a non-irradiated 2 months group, radiographic density around an implant fixture was 77.4 shortly after the surgery, 86.5 after 10 days and 78.9 after 2 months. The radiographic density increased around an implant fixture in the begin-

Table 5. Measurement of the radiographic density of peri-implant bone by digital imaging system.

	1 month		2 months		4 months	
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group
After surgery	70.2	76.5	77.4	71.5	82.0	80.5
After 10 days	76.7	99.5	86.5	105.6		
After 1 month	89.5	158.7				
After 2 months			78.9	108.7		
After 3 months					74.5	88.9
After 4 months					47.8	126.8

ing and then decreased. In an irradiated 2 months group, it was 71.5 shortly after the surgery, 105.6 after 10 days and 108.7 after 2 months. In case of 4 months groups, radiographic density around a non-irradiated implant fixture was 82.0 shortly after the surgery, 74.5 after 3 months and 47.8 after 4 months, while radiographic density around an irradiated fixture was 80.5 shortly after the surgery, 88.9 after 3 months and 126.8 after 4 months(Table 5, Fig. 2).

DISCUSSION

With the frequent use of dental implant in clinical dentistry, the patients were exposed to various environments, that is to say, intraoral environments such as excessive masticatory force and oral hygiene etc., extraoral environments such as smoking and irradiation etc. and various general diseases. These factors had great influence on the long-term success of dental implant.

In particular, irradiation for the diagnosis and treatment of various general diseases could cause peri-implant bone tissue to change biologically. In recent, researches related to the irradiation and the dental implant have been under way, and Albrektsson[46] said that dental implant was used in an irradiated jawbone successfully. Granstrom et al[44] reported that implant fixtures were implanted in irradiated jawbones and 61.6% fixtures among them were successful. There were reports on the influence of irradiation on peri-implant bone tissue after implantation. Granstrom et al[44,47-50] stated that the failure rate of implant increased abruptly in case of irradiation on implant fixtures implanted in jawbones. Also, Schon et al[45] reported that new bone was formed a little and the bone was matured slowly around an irradiated implant fixture when an implant fixture was irradiated after implantation and the change of its surrounding bone tissue was observed with the lapse of time.

For the promotion of osseointegration between an implant fixture and its surrounding bone tissue, an implant fixture whose interface was treated in various ways was developed, and the effect of its interface treatment on osseointegration was studied. Kim et al[20] reported that the interface form of an implant fixture had great influence on osseointegration, when a HA-coated implant fixture, a titanium plazma sprayed implant fixture and a ceramic-coated implant fixture were used. According as Kim et al[21] studied concerning the relation between the interface form of an implant fixture and irradiation, new bone was formed a little and the bone was matured slowly in an irradiated experimental group, and particularly irradiation did much harm to peri-implant bone tissue at the stage of bone remodeling. In histological researches into the healing for bone tissue around a HA coated implant fixture in co-irradiated bone, Matsui[51] said, "Based on the present data, as well as data from the literature, it is suggested that the success rate of HA implants in irradiated bone increases with the interval after radiotherapy. It is also recommended that HA implants in irradiated bone be installed so that bearing by the cortical bone is increased." In this study, in case of a non-irradiated 1 month group, an implant fixture came into contact with bone directly by means of well-developed compact bone in a transcortical portion. In a medullary portion, an implant fixture was supported by mature trabecullas attached to its interface rectangularly. On the other hand, in an irradiated 1 month group, a contact area between an implant fixture and a cortical bone was decreased entirely. In a medullary portion, an implant fixture was surrounded by a few irregular trabecullas which were not attached to its interface rectangularly. These phenomena could appear because irradiation delayed the maturity of peri-implant bone tissue and destroyed healthy bone tissue.

In case of a non-irradiated 2 months group, from a transcortical portion to a medullary portion, osteocytes were arranged well, lamelar bone was formed and an implant fixture was supported by mature bone including bone marrow spaces. In case of an irradiated 2 months group, the thickness of the plate of a cortical bone was decreased a little in a transcortical portion as compared with a non-irradiated 2 months group, but entirely an irradiated 2 months group was similar to a non-irradiated 2 months group. Thus the formation of new bone was recovered more or less, which resulted from the recovery of bone healing ability after irradiation. As for bone healing ability to the lapse of time after irradiation, Arshad et al[52] said that it was improved in 12 months after irradiation, and Jacobsson[53] and Marx[54] reported that surgery could be performed between 1 month and 6 months after irradiation. This study expressed a similar view to their researches in that the formation of new bone was recovered somewhat in a irradiated 2 months group. In other words, it was thought that the formation of new bone was proceeded in a cortical bone with the lapse of considerable time after irradiation. However, it was thought that irradiation prevented bone from maturing because mature bone was decreased remarkably in a medullary portion at the bottom of an implant fixture.

In case of an irradiated 4 months group, an implant fixture was irradiated after 3 months from implantation. As compared with a non-irradiated 4 months group, the quantity of lamellar bone in the region of a cortical bone was decreased prominently, and the thickness of a layer supported by mature trabecullas at the bottom of an implant fixture was decreased. Judging from the above, irradiation did great harm to the maturity of bone and the remodeling of bone as well as the formation of new bone.

In observations through a laser confocal scanning microscope, new bone was formed along implant fixtures in non-irradiated groups, whereas it was formed widely in irradiated groups since irradiation caused bone maturity to retard not only in the interfaces of implant fixtures but also in the centers of bone far distant from their interfaces. That is to say, the direct contact between implant fixtures and bone was increased by mature lamellar bone and the quantity of newly formed immature bone was decreased according to the maturity of bone in non-irradiated groups with the lapse of time after implantation. On the other hand, the formation of new bone was very slow and its quantity was decreased conspicuously around implant fixtures in irradiated groups without regard to the time of irradiation, which was in accord with the reports of Granstrom et al[44,47-50] and Schon et al[45]. Also, this study using HA-coated implant fixtures was similar to the study of Kim et al[20] using pure titanium implant fixtures and titanium plasma sprayed implant fixtures.

There were several ways in evaluating the osseointegration between an implant fixture and bone tissue, and one of them was the mobility test for an implant fixture. It could be said that a mobility test was a precise quantitative analysis. In case of single-rooted teeth with healthy periodontal tissue, its mobility was between 1.5 and 7.0 or thereabouts[55,56]. Also, in case of implantation, there could be differences between the mobility of implant fixtures according to the elasticity of their surrounding bone. As the elasticity of compact bone was 13.700N/mm^2 and that of spongy bone was 1.370N/mm^2, the elasticity of an implant fixture could depend on the quantity of spongy bone around an implant fixture[3]. As for mobility, Schulte et al[57,58] insisted that implantation should be successful if the mobility of an implant fixture ranged from -6 to +8, but Olive[59] said that implantation should be unsuccessful if the mobility was more than +5. As the result of a mobility test for non-irradiated groups in this research, the mobility of an implant fixture was -5.7 in 1 month group, -6.4 in 2 months group and -7.6 in 4 months group. In case of irradiated groups, the mobility of an implant fixture was -4.8 in 1 month group, -5.5 in 2 months group and -5.1 in 4 months group. It was thought that peri-implant bone was matured enough since the mobility of each non-irradiated implant fixture was decreased suddenly with the lapse of time. In case of irradiated implant fixtures, it was thought that the mobility was the least in 2 months group, which resulted from the recovery of bone healing ability after irradiation.

There were many problems in digital radiographic imaging analysis till now. The evaluation of radiographic density around implant fixtures was difficult to be standardized, the direction of implantation was hard to be agreed to completely in setting implant fixtures in bone, and the radiographes were difficult to be taken under same conditions each time. Also, the radiographic density of bone itself could be differed according to the location of implantation, and the films of the radiographes should be developed under same conditions each time. In this study, digital radiographic imaging analysis was utilized experimentally so that the transformation of radiographic density around implant fixtures might be observed. In result, radiographic density around implant fixtures was decreased in non-irradiated groups with the lapse of time, though it was not decreased uniformly. Specially in a non-irradiated 4 months group, it was decreased with the lapse of time. On the other hand, radiographic density around implant fixtures was increased in irradiated groups with the lapse of time. Judging from the above, it was thought that the evaluation of radiographic density around implant fixtures through digital radiographic imaging analysis did not reach a trusty level yet since the radiographic density around implant fixtures did not express regular differences, and that digital radiographic imaging analysis ought to be researched continuously from now on.

CONCLUSIONS

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

1. In a view by means of a light microscope, peri-implant bone tissue was matured rapidly in non-irradiated groups with the lapse of time, while it was matured slowly in irradiated groups and was damaged particularly at the

stage of the remodeling of bone.

2. In observations through a confocal laser scanning microscope, peri-implant new bone was formed a little along implant fixtures in case of non-irradiated groups, whereas it was formed widely not only in the interfaces of implant fixtures but also in the centers of bone far distant from their interfaces in case of irradiated groups.
3. As a result of mobility tests in non-irradiated group, the mobility of an implant fixture was -5.7 in 1 month group, -6.4 in 2 months group and -7.6 in 4 months group. Thus it was reduced abruptly with the lapse of time. On the other hand, in irradiated groups, the mobility of an implant fixture was -4.8 in 1 month group, -5.5 in 2 months group and -5.1 in 4 months group. It was the least in 2 months group, but its difference between each group was hardly observed.
4. It was thought that the evaluation of radiographic density around an implant fixture by means of digital radiographic imaging analysis had several problems as well as many merits, and digital radiographic imaging analysis needed continuous researches in future.

REFERENCES

1. Han DW, Kim J. Histomorphometric analysis for vent area of titanium plasma sprayed IMZ implant in rabbits. J Korean Academy Prosthodontics 1994;32:171-178.
2. Banemak P-I, Hansson B.O., Adell R, Breine U, Lindstrom J, Hallen O, Ohman A. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg 1977;16:121-132.
3. Adell R, Lekholm U, Rockler B, and Branemak P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387-416.
4. Albrektsson T, Branemark P-I, Hansson H-A, and Lindstrom J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting direct bone-to-implant anchorage in man. Acta Orthop Scand 1981; 52:155-170.
5. Schroeder A, van der Zypen E, Stich H, and Sutter F. The reactions of bone, connective tissue, and epithelium to endosteal implants with titanium-sprayed interfaces. J Oral Maxillofac Surg 1981;9:15-25.
6. Linkow L, Mahler MS. Implants for fixed and removable prosthesis. Dent Clin North Am 1977;21:424-443.
7. Natiella JR, Armitage JE, Greene GW, Meenghan MA. Current evaluation of dental implants. J Am Dent Assoc 1972;84: 1358-1372.
8. Schroeder A, Schroeder A, Sutter F, Krekler G. Oral Implantology. New York Thieme Medical Publ Inc 1991:60-65.
9. Smith CH. Rational use of endosteal implants. J Prosthet Dent 1977;38:652-659.
10. Babbush CA. (ed) Implants Dent Clin North Am1980;24:399-594.
11. Leventhal G. Titanium a metal for surgery. J Bone Joint Surg 1951;33:473-474.
12. Hammer WB, Topazian RG, McKinne Jr, RV, Hulbert SF. Alveolar ridge augmentation with ceramics. J Dent Res 1973;52:356-361.
13. Kent JN, Bokros JC. Pyrolytic carbon and carbon-coated metallic dental implants. Dent Clin North Am 1980;24:465-485.
14. Schnitman PA, Schulman LB. Vitreous carbon implants. Dent Clin North Am 1980;24:441-463.
15. Hodosh M, Shklar G, Gettleman L, Povar M. Strength and biocompatibility of polymethacrylate-silica composite dental implant materials. J Prosthet Dent 1980;43:197-203.
16. Kaketa T, Suzuki. Histopathological findings on endo-osseous implants in dogs. Bull Tokyo Dent Coll 1969;10:61-70.
17. Lew I. The endosseous implants. Evaluation and modification. Dent Clin North Am 1970;14:201-213.
18. Linkow LI. Endosseous blade-vent implants. A two-year report. J. Prosthet Dent 1970;23:441-448.
19. Carlsson L, Rostlund T, Albrektsson B, Albrektsson T. Removal torques for polished and rough titanium implants. Int J Oral Maxillofac Surg 1988;3:21-34.
20. Kim SY, Kim YS. Experimental studies on the tissue response of HA coated, TPS and A1203 artificial root implant. J Korean Academy Prosthodontics 1991;29:267-284.
21. kim JS. The experimental study on the osseointegration to the irradiation. Chosun university school of graduate 1998.
22. Holmes RE. Bone regeneration within a coralline hydroxyapatite implant. Plast Reconstr Surg 1979;63:626-632.
23. IMZ Technique Manual.
24. Jarcho M. Tissue cellular and subcelluar events at a bone-ceramic hydroxyapatite interface. J Bioeng 1977;1:79-87.
25. Jarcho M. Calcium phosphate ceramics as hard tissue prosthesis. Clin Orthop Rel Res 1981;157:259-268.
26. Jarcho M. Biomaterial aspects of calcium phosphates Properties and applications. Dent Clin Nor Am 1986;30:25-32.

27. Kenny EB. The use of a porous hydroxyapatite implant in periodontal defects. J Periodontol 1988;59:67-78.
28. Barney VC, Levin MP, and Adams DF. Bioceramic implants in surgical periodontal defects : A comparison study. J Periodontol 1986;57:764-771.
29. Ellinger RF, Nery EB, and Lynch KL. Histological assessment of periodontal osseous defects following implantation of hydroxyapatite and biphasic calcium phosphate ceramics : A case report. Int J Periodont Rest Dent 1986;31:23-32.
30. Ganeles J, Listgarten MA, and Evian CI. Ultrastructure of Durapatite-periodontal tissue interface in human infrabony defects. J Periodontol 1986;57:133-143.
31. Levin MP, Getter L, Cutright DE. A comparison of iliac marrow and biodegradable ceramic in periodontal defects. J Biomed Mater Res 1975;9:183-192.
32. Rivero DP. Calcium phosphated-coated porous titanium implants for enhanced skeleal fixation. J Biomed Mater Res 1988;22:191-199.
33. Shepard WK. Human clinical and histologic responses to a Calcitite implant in intraosseous lesions. Int J Periodont Rest Dent 1986;6:46-54.
34. Denissen HW, de Groot K. Immediate dental root implants from synthetic dense calcium hydroxyapatite. J Prosthet Dent 1979;42:551-560.
35. Quinn JH, Kent JN. Alveolar ridge maintenance with solid nonporous hydroxyapatite root implants. Oral Surg 1984;58:511-520.
36. Kraut RA. Indications for use of porous hydroxyapatite at time of endosteal implant placement. Compend Contin Educ Dent 1989; 10:322-328.
37. Davis WH. Reconstruction of the severely resorbed mandible. J Prosthet Dent 1990;4: 583-592.
38. Ardoin RC, Block MS, Kent JN. SEM of hydroxyapatite coated and non-coated titanium dental implants in canines. J Dent Res 1986;65:222-233.
39. Block MS, Ken JN, Kay JF. Evaluation of hydroxyapatite-coated titanium dental implants in dogs. J Oral Maxillofac Surg 1987;45:601-612.
40. Ducheyne P. Effect of hydroxyapatite impregnation on skeletal bonding of porous coated implants. J Biomed Mater Res 1980;14:225-234.
41. Asikainen P, Kotilainen R, Vuillemin T, Sutter F, Voipio H-M, Kullaa A. Osseo-integration of dental implants in radiated mandibles An experimental study with beagle dogs. J Oral Implantol 1991;17:48-54.
42. Matsui Y, Ohno K, Michi K-I, Tachikawa T. Histomorphometric examination of healing around hydroxyapatite implant in Co60-irradiated bone. J Oral Maxillofac Surg 1994;52:167-172.
43. Mian TA, Putten van MC Jr, Kramer DC, Jacob RF, Boyer AL. Backscatter radiation at bone-titanium interface from high energy X-and gamma rays. Int J Radiat Oncol Biol phys 1987;13:1943-1967.
44. Granstrom G, Bergstrom K, Tjellstrom A, Branemark PI. A detailed study of titanium fixture implants lost in irradiated tissues. Int J Oral Maxillofac Implant 1994;9:653-662.
45. Schon R, Ohno K, Kudo M, Misch K. Peri-implant Tissue Reaction in bone Irradiated the Fifth Day After Implantation in Rabbits. Histologic and histomorphometric Measurements. Int J Oral Maxillofac Implant 1997;11:228-238.
46. Albrektsson T. A multicenter report on osseointegrated oral implants. J Prosthet Dent 1988;60:75-84.
47. Granstrom G. The use of hyperbaric oxygen to prevent implant fixture loss in the irradiated patient. Chicago Quintessence 1992;336-345.
48. Granstrom G. Rehabilitation of irradiated cancer patients with tissue integrated prostheses. Adjunctie use of HBO to improve osseointegration. J Fac Somato Prosth 1996;2:1-11.
49. Granstrom G, Tjellstrom A, Albrektsson T. Post-implantation irradiation on titanium implants for head and neck cancer treatment. Int J Oral Maxillofac Implant 1993;8:495-501.
50. Granstrom G, Tjellstrom A, Branemark P-I, Fornander J Bone-anchored reconstruction of the irradiate. Head Neck Surg 1993;108:334-343.
51. Matsui Y. Histomorphometric Examination of Healing Around Hydroxylapatite Implants in Co-Irradiated Bone. J Oral Maxillofac Surg 1994;52:167-176.
52. Ali A, David W, Ahmed M, Joanne D. Implant Rehabilitation of Irradiated Jaws A Preliminary Report. Int J Oral Maxillofac Implant 1997;4:523-526.
53. Jacobsson M. On bone behaviour after irradiation [thesis]. Sweden University of Gothenburg 1985.
54. Marx RE, Johnson RP. Studies in the radiobiology of osteoradionecrosis and their clinical significance. Oral Surg Oral Med Oral Pathol 1987;64:379-390.
55. Schlte W, Lukas D. The PERIOTEST method. Int Dent J 1992;42:433-441.
56. Jang KS, Kim YH, Kim YS. Mobility of natural teeth and osseointegrated implant. J Korean Academy Prosthodontics. 1995; 33:144-155.
57. Schulte W, d' hoedt B. PERIOTEST for measuring periodontal characteristics-Correlation with periodontal bone loss. J Periodont Res 1992;27;184-192.
58. Schulte W, Lukas D. PERIOTEST to monitor osseointegration and to check the occlusion in oral implantology. J Oral Implatol. 1993;19:23-35.
59. Olive J, Aparicio C. The PERIOTEST method as a measure of osseointegrated oral implant stability. Int J Oral Maxillofac Implant 1990;5:390-401.

Reprint request to:
DR. HYEOG-SIN KWEON
DEPARTMENT OF PROSTHODONTICS, SCHOOL OF DENTISTRY,
CHOSUN UNIVERSITY.
588, SEOSEOK-DONG, DONG-KU, KWANGJU, 501-140, KOREA
TEL:82-62-220-3602 FAX:82-62-228-9789

FIGURE OF LEGENDS

Fig. 3. Non-irradiated group. Tissue reaction around an implant fixture in the 4th week.
  A: HA-coated fixture attached to bone and soft tissue through a light microscope(× 100).
  B: HA-coated fixture attached to bone and soft tissue through a confocal laser scanning microscope(× 80).

Fig. 4. Irradiated group. Tissue reaction around an implant fixture in the 4th week.
  A: HA-coated fixture attached to bone and soft tissue through a light microscope(× 30).
  B: Magnification of left side(× 100).
  C: HA-coated fixture attached to bone and soft tissue through a confocal laser scanning microscope(× 80).

Fig. 5. Non-irradiated group. Tissue reaction around an implant fixture in the 8th week.
  A: HA-coated fixture attached to bone and soft tissue through a light microscope(× 100).
  B: HA-coated fixture attached to bone and soft tissue through a confocal laser scanning microscope(× 80).

Fig. 6. Irradiated group. Tissue reaction around an implant fixture in the 8th week.
  A: HA-coated fixture attached to bone and soft tissue through a light microscope(× 30).
  B: Magnification of left side(× 100).
  C: HA-coated fixture attached to bone and soft tissue through a confocal laser scanning microscope(× 80).

Fig. 7. Non-irradiated group. Tissue reaction around an implant fixture in the 16th week.
  A: HA-coated fixture attached to bone and soft tissue through a light microscope(× 30).
  B: Magnification of left side(× 100).
  C: HA-coated fixture attached to bone and soft tissue through a confocal laser scanning microscope(× 80).

Fig. 8. Irradiated group. Tissue reaction around an implant fixture in the 16th week.
  A: HA-coated fixture attached to bone and soft tissue through a light microscope(× 30).
  B: Magnification of left side(× 100).
  C: HA-coated fixture attached to bone and soft tissue through a confocal laser scanning microscope(× 80).

FIGURE ①

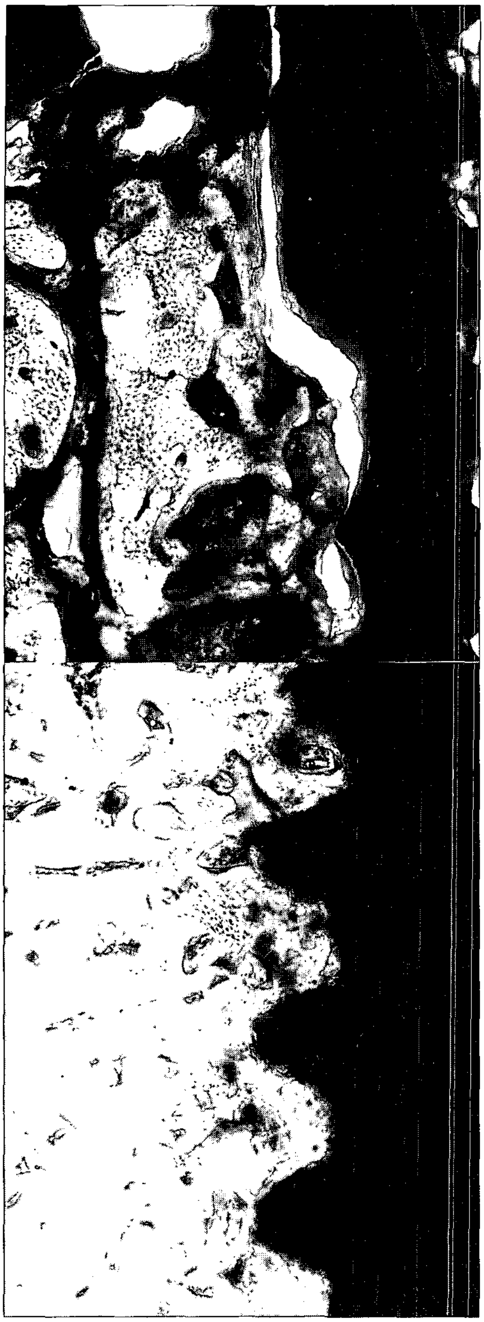

Fig. 3-A

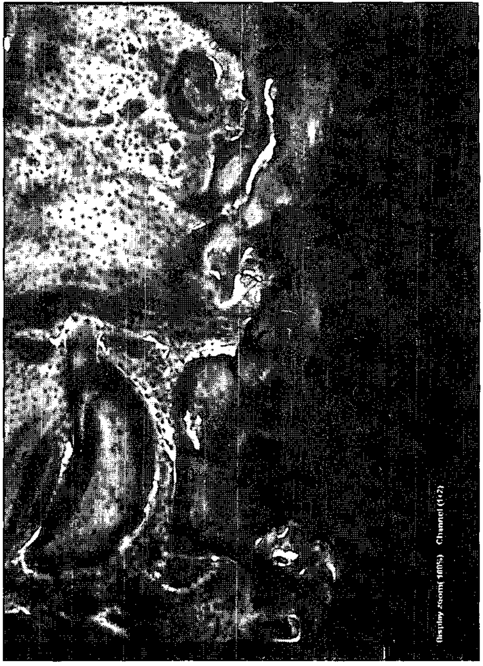

Fig. 3-B

FIGURE ②

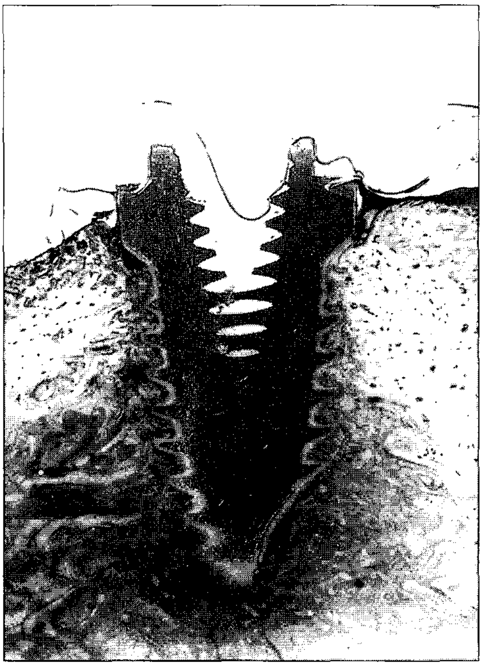

Fig. 4-A

Fig. 4-C

Fig. 4-B

FIGURE ③

Fig. 5-A

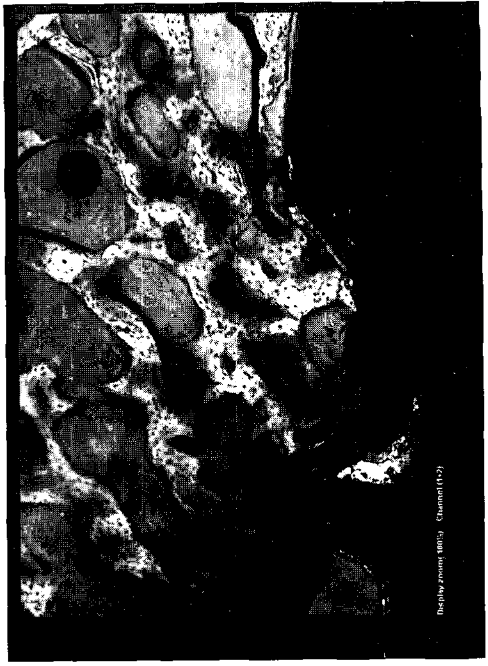

Fig. 5-B

FIGURE ④

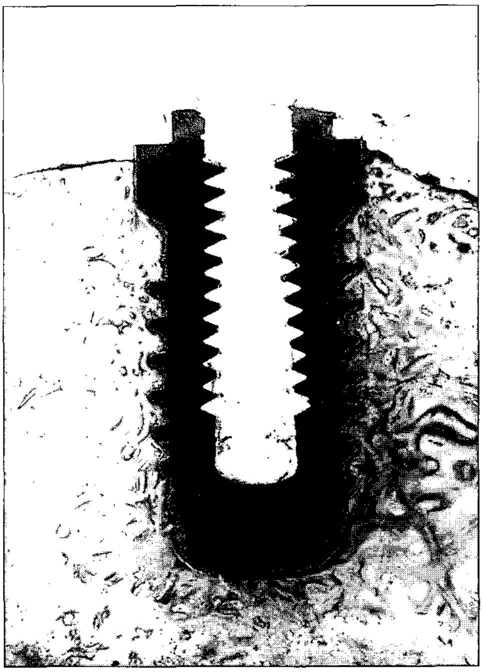

Fig. 6-A

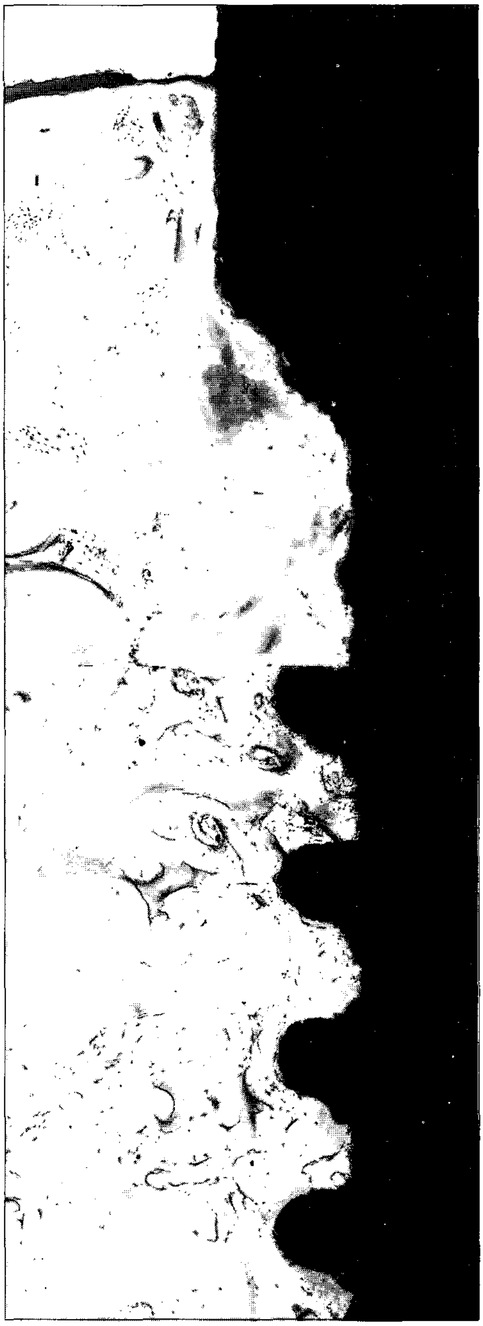

Fig. 6-B

Fig. 6-C

FIGURE ⑤

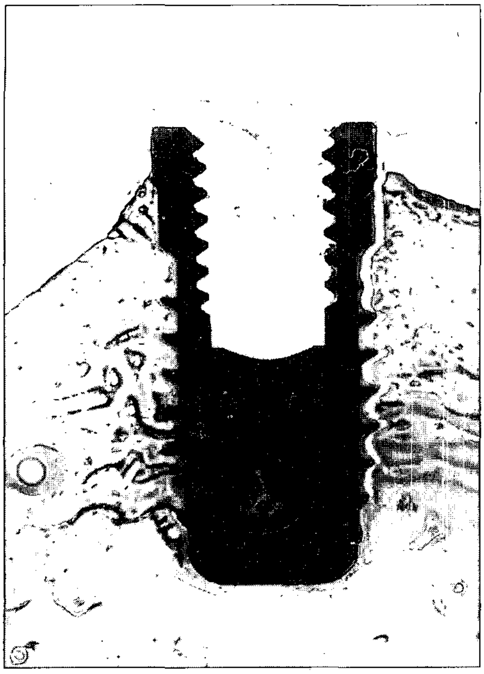

Fig. 7-A

Fig. 7-B

Fig. 7-C

FIGURE ⑥

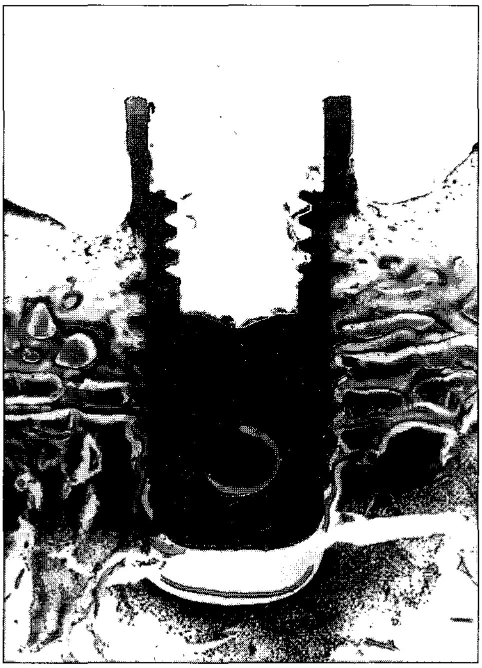

Fig. 8-A

Fig. 8-B

Fig. 8-C