"Implant osseointegration in the irradiated mandible. A comparative study in dogs with a microradiographic and histologic assessment"

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Abstract
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Implant osseointegration in the irradiated mandible
A comparative study in dogs with a microradiographic and histologic assessment

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Key words: bone remodeling, dental implants, dogs, irradiation, osseointegration

Abstract: This research focuses on the effects of radiotherapy on the osseointegration of dental implants placed before or after radiotherapy in 11 male beagles. After the extraction of all mandibular premolars 1st and 2nd molars, three dogs were implanted without radiotherapy (Control group), four dogs were irradiated 4 weeks after implantation (IrA group) and four dogs were irradiated 8 weeks before implantation (IrB group). Eight implants were placed in each dog, in an alternating pattern: four nonsubmerged ITI Bonefit titanium plasma spray-coated and four submerged Steri-Oss hydroxyapatite-coated. The irradiated dogs received 4.3 Gy daily for 10 days. Two different fluorescent markers were administered at the time of implantation and of irradiation. The dogs were sacrificed 6 months after implantation, i.e. 5 months after radiotherapy for the IrA group and 8 months for the IrB group. Each mandible was submitted to histological and microradiographic analysis. Bone formation occurred around 85 of the 88 implants and consisted mostly of the successive deposit of woven and lamellar bone. Both irradiated groups showed obvious bone remodeling in alveolar bone as well as in the basilar part of the mandible. Nevertheless, in the IrA group, the resorption phenomena predominated over osteogenesis. The balance between these two opposite processes seemed to be restored 8 months after the end of radiotherapy (IrB group). In spite of focal lesions of radiation-specific bone destruction emphasized in some irradiated dogs, we conclude from our results that osseointegration of dental implants is possible in irradiated bone tissue.

Patients suffering from advanced oral and maxillofacial tumors are usually treated by wide surgical resections, bone and soft tissue reconstruction and postoperative radiotherapy. Thereafter, the dental rehabilitation should ideally be performed to restore both the oral function and the esthetics of the operated face. For these purposes, the use of oral implants seems a valuable option. Although radiation is still believed to impair the vitality of skeletal tissue, many encouraging results of implant osseointegration have been obtained in irradiated patients (Jacobsson 1988; Niimi et al. 1993; Taylor & Worthington 1993; Granstrom et al. 1994; Franzén et al. 1995; Eckert et al. 1996; Brogniez et al. 1996, 1998; Andersson et al. 1998). According to several clinical studies, success rates of oral implants placed after radiotherapy vary from 83% to 99% and partly depend on the delay between radiotherapy and implantation; the longer the delay, the better the outcome [Jacobsson 1988; Franzén et al. 1995; Eckert et al. 1996]. Nevertheless, aiming both to avoid bone radiation damage at the time of surgery and to suppress any delay between the initial treatment and the oral rehabilitation, some authors have developed the opposite strategy of im-
plantation before radiotherapy (Sclaroff et al. 1994; Granström & Tellström 1997; Roumanas et al. 1997).

In order to obtain original information about the best of these two controversial procedure sequences, we designed an experimental animal study in which implants were placed before or after radiotherapy [Brogniez et al. 2000]. Two types of implants, which differed in their coating and placement method (submerged or not), were evaluated by a morphometric analysis, comparing their bone-covered surface as a function of the selected therapeutic sequence. The results showed that osseointegration occurred before as well as after radiotherapy. However, the direct bone-implant contact was more extensive when integration occurred before as well as after radiation.

In the present qualitative study, the calcified tissues formed around the implants were investigated in further detail to evaluate the dynamic effects of the irradiation on the histological structure of the dog's implanted mandible, and to precise whether the timing of radiotherapy has a decisive influence on the final stability of dental implants placed in the residual alveolar bone.

Material and methods

Eleven male 1-year-old beagle dogs, of similar weight (about 12 kg) and size, were randomly assigned to three groups:

1. a control group, including three nonirradiated dogs (C),
2. a group of four dogs that were irradiated after implantation (IrA), and
3. a group of four dogs that were irradiated before implantation (IrB).

In each dog, both mandibular premolars and two mandibular molars were extracted from each side so as to create two edentulous areas.

Two different implants were selected for the present investigation:

1. Steri-Oss® (Steri-Oss, Yorba Linda, CA, USA) submerged, hydroxyapatite-coated implant, 3.8 mm of diameter and 8 mm of length,
2. ITI Bonefit® (Straumann, Waldenburg, Switzerland) nonsubmerged implant with Ti plasma-sprayed (TPS) coating, 4 mm of diameter and 8 mm of length.

In each dog, eight implants were placed in the edentulous areas, four on each side, alternating Steri-Oss and ITI Bonefit implants; a total of 88 implants. Surgery was performed under Nembutal® [Abbott Laboratories, Louvain-la-Neuve, Belgium] general anesthesia with laryngeal intubation and under sterile conditions. Intravenous cefazolin was used for antibiotic prophylaxis.

In each group of dogs, a specific sequence of treatment was followed, as indicated in Fig. 1. Groups C and IrA were implanted 8 weeks after extraction. In the IrA group, the dogs were irradiated 4 weeks after implantation. In the IrB group, the irradiation was delivered 6 weeks after extraction, then the implantation was performed 8 weeks after the end of the radiotherapy.

Irradiation was delivered with a telecobalt therapy unit. Irradiated dogs first underwent a simulation to accurately localize the irradiation fields. Field marks were drawn on the outer cheek to allow reproducibility of positioning across sessions. A daily dose of 4.3 Gy was administered during 10 consecutive days, for a total dose of 43 Gy. According to Arnold, this schedule is equivalent to a total dose of 60 Gy delivered in a 6-week period, with five sessions a week [Arnold 1988; Arnold et al. 1995].

During the irradiation period, dogs were given daily intramuscular injections of ketamine hydrochloride for sedation. As mucositis appeared in all dogs 1 week after the end of irradiation, 0.2% chlorhexidine digluconate mouthrinses were administered daily for 7 days. No other treatment or intervention was done.

To study the dynamics of bone formation, two different fluorescent markers of osteogenesis were given at similar times: intraperitoneal calcein green was delivered at a dose of 30 mg/kg at the time of implantation, and terramycin was injected by intramuscular at a dose of 50 mg/kg at the time of irradiation. The latter was also given to the nonirradiated dogs (group C) at the equivalent time.

Intraoral radiographs were taken immediately after implantation, at the time of irradiation or after an equivalent period for the control group, and 6 months after implantation. After 6 months of implantation, the dogs were sacrificed with a lethal dose of Nembutal® [Abbott Laboratories]. The guidelines for the care and use of laboratory animals have been always observed.

Each mandible was dissected out and divided into segments to isolate the implants and their surrounding bone. Each segment was then fixed in 10% phosphate-buffered neutral formalin for 4 weeks. Thereafter, the specimens were successively dehydrated in methanol, stained with 1% basic fuchsin and embedded in methyl methacrylate without preliminary decalcification. After polymerization, specimens were cut with a diamond saw (Leitz, Wetzlar, Germany) into serial sections, parallel to the main axis of the implant. The sections were then polished and reduced to a uniform thickness of 80 μm with a rotating grinding machine (Planapol 2, Struers, Copenhagen, Denmark).

Microradiographs were obtained by placing the sections in contact with a fine grain emulsion (Spectroscopic Plate 649-o,
no implant failure was observed during the experiment (Fig. 2a,b). However, three of the 88 implants demonstrated mobility at 6 months. These were ITI Bonefit implants placed in the IrB group, and two of these were in the same dog (Fig. 2c).

Observations

No implant failure was observed during the experiment (Fig. 2a,b). However, three of the 88 implants demonstrated mobility at 6 months. These were ITI Bonefit implants placed in the IrB group, and two of these were in the same dog (Fig. 2c).

Analysis of the bone–implant interface

Specific bone tissue reactions around the implants were studied on microradiographs from the control animals (Fig. 3). In these specimens, numerous bone–implant contact areas were observed, not only on the peripheral surface of the implants, which was put in direct contact with bone tissue at the time of surgery (Fig. 3a), but also in the hollow parts of the implant (Fig. 3b). In these various sites, new bone formation was recognizable by the deposit of woven bone (WB), which is highly mineralized and contains numerous randomly distributed cellular lacunae. It was secondarily covered by lamellar bone (LB) in which the osteocytes are fewer and show a more regular and parallel arrangement (Fig. 3a). This lamellar bone apposition sometimes gave rise to primary osteons (Fig. 3b). Bone remodeling, which occurred thereafter, was characterized by a cement line, i.e. a clear-cut transition between woven bone and more recent, less calcified lamellar bone (Fig. 3b, arrow). The bone–implant interface showed the same microradiographic and histological appearance in each implant of the experimental groups and was not influenced by the nature of the implant coating. In both types of implants, however, specific surface damage was emphasized, respectively, characterized by a crumbling of HA (Fig. 4a) or by a tearing of TPS particles (Fig. 4b).

Bone reactions due to inadequate implant positioning

Besides the above description of bone reactions to correctly placed implants, other phenomena were observed in cases of less optimal positioning. Among these, the oblique implant insertion within the mandibular body was responsible for an important subperiosteal bone resorption on the inclination side of the implant, while a compensatory bone apposition took place on the other side (Fig. 5). Moreover, no apical bone formation occurred when the tip of the implant reached the inferior alveolar nerve (Fig. 6a,b).

Comparative effects of irradiation on the mandible

In the IrA dogs, which were irradiated after implantation and sacrificed 5 months later, the peri-implant alveolar bone underwent an important remodeling (Fig. 7a). Micro-
scopic examination under ordinary light showed that it was bored by numerous large polycyclic resorption cavities containing osteoclasts (Fig. 7b). However, bone apposition was also active in neighboring areas, as demonstrated by the presence of osteoblasts lining a preosseous layer (Fig. 7b).

In the basilar part of the mandible, the intense bone remodeling was emphasized by the presence of early osteons showing a large Haversian canal and a low mineral density (Fig. 8a, frame). Under UV light, the bone which was depositing on the Haversian canal wall appeared underlined by the fuchsin staining. Moreover, microradiography revealed some mature osteons, characterized by a narrow Haversian canal and which presented a hypercalcified ring. The latter is marked by the calcein green fluorescent labeling and is contemporary with the implantation (Fig. 8b). In the same osteon, the terramycin delivered just after irradiation appeared as a second smaller concentric yellow ring, located a short distance from the Haversian canal (Fig. 8b). Furthermore, the osteocytes were also stained orange by fuchsin (Fig. 8b). All these observations suggest that the implantation–irradiation sequence did not definitively impair the bone apposition in the mandibular body. Nevertheless, several giant multilobular resorption cavities were visible under the peristemeum and on the endosteal side of the IrA dog mandibles (Fig. 7a, arrow; Fig. 8a, arrow). Numerous osteoclasts were observed in these bone destruction foci (Fig. 8c), which were never observed in the control group of nonirradiated animals.

In the IrB dogs, which were irradiated before implantation and sacrificed 8 months after irradiation, the mandibular bone remodeling also looked intense (Figs 6a and 9a). However, in comparison with the microradiographs taken from animals of the IrA group, both the peri-implant alveolar bone and the mandibular body contained significantly fewer resorption cavities.

The bone apposition phenomena were prevalent, as attested by the large presence of mature osteons in which the bone deposit was recently accomplished. These osteons were characterized by a small canal and a low mineral content of the newly deposited lamellae (Fig. 9a). As in other groups, active bone formation took place in the hollow parts of the implants (Figs 6a and 9a). Under UV light, the young osteons presented two fluorescent rings, the outermost, yellow one corresponding to the ter-
Fig. 7. Steri-oss implant in the IrA group. (a) Microradiographic aspect (×7) showing an important bone remodeling. Arrow: multilobulated resorption cavity. (b) Enlargement of the framed area in Fig. 7a observed in section (×330). Arrow: osteoclast in a resorption lacuna. *Closing Haversian canal lined by preosseous layer and numerous osteoblasts.

Fig. 8. Basilar part of a mandible in the IrA group. (a) Microradiographic aspect (×35) showing an intense bone remodeling. Frame: osteon with a large canal and a poorly mineralized new bone deposit, osteons with hypercalcified ring. Arrow: a large multilobulated resorption cavity under the peristomeum. (b) Enlargement of the frame (×140) observed in the section under UV light. Osteon with two fluorescent rings: the peripheral, green one, is labeled by calcein green [C] injected at the time of implantation; the innermost, yellow one is labeled by terramycin [T] delivered at the time of irradiation. Osteocytes stained in orange by fuchsin. (c) Enlargement of the multilobulated resorption lacuna indicated by an arrow in (a) and (×340) observed in the section. Osteoclasts in Howship’s lacunae.

Radiation-specific effects on the medullary cavity
The general histological aspect of the mandibular medullary cavity varied considerably from the irradiated groups [IrA or IrB] to the control group (Fig. 11a,b). In irradiated mandibles the bone marrow appeared fibrous. Strong connective tissue reaction led to a progressive hyaline replacement of the fatty alveolar tissue. Several signs of venous blood congestion or arteriolar thrombosis were also observed (Figs 6b and 11b).

Discussion
All but three implants of our experimental work were macroscopically osseointegrated after 6 months (Fig. 2). In all groups and for both types of material, the tissue in contact with the implants consisted of woven bone secondarily covered and replaced by lamellar bone (Fig. 3), as described by Albrektsson et al. (1981) and Tanaka et al. (1994). Woven bone first stabilizes the implant. Thereafter, as osteogenesis slows down, the lamellar organization and the remodeling activities (Fig. 3b) strengthen the implant stability while confirming its biocompatibility. These successive events are identical to those ob-
they advised being cautious with the use of HA-coated implants. Instead of HA particle tearing, we only found a thinly layer of disintegration [Fig. 4a]. As for loose titanium fragments [Fig. 4b], this has been reported by Gottfredsen et al. [1991] and Lange et al. [1993].

As shown by Buser et al. [1995], we observed bone resorption of the thinnest alveolar wall in the cases of oblique implant positioning [Fig. 5]. If this process is not counteracted, it may result in implant loss.

Several investigators have studied the effects of radiotherapy on bones [Nathanson & Bäckström 1978; Jacobsson 1988; Dambrain 1989; Schweiger 1989; Larsen et al. 1993; Matsui et al. 1994; Schön et al. 1996, Asikainen et al. 1998; Libersa et al. 1998]. An objective comparison of these data with ours however, remains difficult because of considerable differences in many parameters, such as the animal model, the irradiated anatomical site, the total dose of X-rays delivered and the fractionation schedule. According to the relative importance of all these parameters, the bone radiation damage as well as the reconstructive phenomena appeared more or less extensive. All previous authors have agreed that, first of all, the irradiated bone tissue shows a significant increase of its remodelling, which is mostly characterized by resorption. This initial destruction has been attributed to three specific mechanisms. The first, most usual mechanism consists of a classical osteoclastic resorption [Nathanson et al. 1978]. The other two mechanisms are characterized, respectively, by partially demineralized areas of bone tissue with empty osteocyte lacunae and by large multilobular areas of non osteoclastic resorption [Dambrain et al. 1979].

In the rabbit mandible [Nathanson et al. 1978], up to 6 weeks after a cumulative dose of 20 Gy, the bone tissue contained a significantly higher number of resorption cavities. Osteocyte death occurred when the doses reached 30 Gy. In the same animal model, loss of osteoblastic cells in Haversian systems, combined with accentuated osteoclastic resorption, led to increased bone porosity after progressive doses of 25, 50 and 100 Gy [Takahashi et al. 1994]. Lange et al. [1993] reported empty osteocytic lacunae in the bones of dogs after irradiation equivalent to 65 Gy. Jacobsson et al. [1987] observed no difference between irradiated and nonirradiated bone.

served in the rapid bone healing process [Coutelier 1969]. Histological studies of implant osseointegration after membrane bone-guided regeneration [Buser et al. 1995] or bone distraction [Block et al. 2000; Nosaka et al. 2000] in dog mandibles showed the predominant lamellar aspect of the peri-implant bone after 6–12 months.

Whereas the implant coating does not influence the type of new bone, it plays a role in the apposition speed. After implantation of beagle mandible, Matsui et al. [1994] observed the presence of woven bone in contact with the HA coating as early as the 2nd week. Furthermore, they reported HA particles in the cytoplasm of mono- and multinucleated cells. Therefore, in spite of this osseointegration speed,
new bone formation. In the dogs of the IrB process were partially counteracted by irradiated animals, the bone destructive osteoclasts (Fig. mandible, all of them appeared occupied by mainly located in the basilar part of the multilobular areas of bone destruction, vere bone damage was never observed and, olysis. In our material, however, such se-

phenomenon, analogous to osteocytic oste-

by way of a pericellular bone resorption

the radio-induced bone destruction process

radiotherapy to sacrifice time in-

Lange et al. [1993] mentioned the existence of a neo-osteogenic phase beginning 10 weeks after the end of a 65 Gy treat-

ment. Although irregular, this compensa-
tory new bone formation attested to the preser-
vation of a substantial osteogenic poten-
tial. This is clearly illustrated in our ex-

iment since woven bone was formed around the implants, even in the group of dogs implanted after irradiation [Figs 6a and 9a]. Furthermore, by means of the sequential fluorescent labeling [Figs 8b and 9b], we observed the completion of osteon closure after irradiation as well as after im-

plantation, although osteogenesis under-

went a temporary interruption in all ani-

mals, as attested by the appearance of a hypercalcified ring within some Haversian systems [Fig. 8a]. These typical arrest lines [Weinmann & Sicher 1955], which co-

incided with calcein labeling under UV light examination, obviously occurred just after implantation [Fig. 8b]. Similar resting lines were evidenced in pig mandibles after irradiation [Libersa et al. 1998]. A short ar-

rest of osteogenesis could thus be induced by any bone tissue trauma. In our experi-

ment, this phenomenon was not neces-
sarily linked to radiation damage since it accompanied only the implantation and was also observed in the nonirradiated dogs.

As they describe the compensatory osteogenesis following the initial bone de-

struction phenomenum induced in ir-

radiated mandibles, Dambrain [1989] and Libersa et al. [1998] point out the deposit of woven bone and chondroid tissue in sub-

periosteal Howship’s lacunae. Dambrain [1989] also mentions a slow lamellar appo-
sition on the basilar part of the mandible. In the same areas of all irradiated dogs, we observed mainly a lamellar bone formation proceeding without any preliminary de-

posit of chondroid tissue or woven bone. [Figs 6a, 7a, 8a and 9a]. The amount of new bone created was, however, more impor-
tant in the IrB animals than in the IrA ani-

mals. Once again, this difference between the intensity of basilar subperiosteal osteo-
genesis in IrA and IrB groups has to be linked to their respective irradiation to sa-

crifice time intervals.

Finally, in the bone marrow of all treated animals, the irradiation induced diffuse fi-

brosis but also random signs of blood stagna-
tion [Fig. 11b]. Similar images of vas-

dilation followed by intraluminal throm-

bosis had been reported in immobilization osteoporosis, which is also characterized by large Haversian canals and numerous resorption cavities [Lacroix & Dhem 1967]. Both situations were consequently marked by the coexistence of histological and func-
tional modifications affecting simulta-

naneously the bone tissue and its vascular network. In disuse osteoporosis, the im-

pairment of the skeletal blood supply has been suggested to be immediately respon-
sible for the break out of the cellular events leading to bone resorption. This vascular mediation, the biomolecular bases of which are still under study, also exists in nearly all morphogenetic phenomena in-

volved in the embryogenesis of membra-
nous or endochondral bones [Bernard & Pease 1969; Lenglé 1997], as well as in the

growth or repair of mature skeletal pieces [Coutelier 1969; Delloye 1990; Lenglé 1997]. It should probably also operate in the pathogenesis of radio-induced bone damage, although until now it has re-
mained impossible to predict the precise nature of the initial cellular target which ini-

tiates the vascular, osteoclastic and then osteoblastic reactions we have observed within the irradiated mandible.

In conclusion, the present experimental study indicated that implants may be ade-

quately osseointegrated in the ir-

radiated mandible, whether they are placed before or after radiotherapy. Even if our pre-

liminary quantitative study initially led us
to conclude a better bone–implant contact of the implants placed before the irradiation [Brogniez et al. 2000], the present qualitative histological analysis delivers no decisive argument favoring a specific treat-
ment sequence, i.e. irradiation–implantation–irradiation. We have shown without a doubt that the dif-
ference between both sequences can be explained simply by the longer postir-
radiation delay in IrB dogs, allowing the bone apposition phenomena to invade all the uncovered or hollow parts of the im-
plants. Nevertheless, the prominent bone resorption reactions which immediately follow any radiotherapy should incite the surgeon to a careful rational therapeutic planning. Early implantation in the ir-
radiated alveolar bone, when osteoclasts are obviously more active than osteoblasts, probably increases the risk of osseointegra-
tion problems. Implants put in place later on during the compensatory bone appo-
sition phase should benefit from better local conditions and so have a greater chance of good osseointegration. We believe that in the irradiated mandible, the bone vi-
tality and its osteogenic potentials are not definitively impaired when the treatment is carried out according to a consistent clinical protocol. Consequently, adequately irradiated patients may receive safe dental implants.

Résumé
Cette recherche met en évidence les effets de la radiothé-
rapie sur l‘osseointégration d‘implants dentaires placés avant ou après une radiothérapie chez onze beagles mâ-
les. Après l‘extraction des prémolaires et des premières et secondes molaire à la mandibule, trois chiens ont été implan-
tés sans être irradiés (groupe contrôle), quatre chiens ont été irradiés quatre semaines après l‘implanta-
tion (groupe IrA) et quatre chiens ont été irradiés huit semaines avant l‘implantation (groupe IrB). Huit im-
plants ont été placés chez chaque chien, alternativement quatre implants ITI Bonelite® recouverts d‘un plasma spray titane, placés suivant la technique enfouie et quatre implants Steri-Oss® recouverts d‘hydroxyapatite et placés suivant la technique non-enfoncé. Les chiens irradiés ont reçu une dose quotidienne de 4,5 Gy pendant dix jours. Deux marqueurs fluorescents de l‘osseostéogène ont été ad-
ministrés, l‘un au moment de l‘implantation et l‘autre au cours de l‘irradiation. Les chiens ont été sacrifiés six mois après l‘implantation, autrement dit, cinq mois après la radiothérapie pour le groupe IrA et huit mois après la radiothérapie pour le groupe IrB. Chaque hémimandible a été soumise à une analyse histologique et microradiogra-
phique. De l‘os néof ormé a été mis en évidence au tour de 85 implants sur les 88 placés. Cette formation osseuse est constituée d‘os fibreux réticulé suivi d‘une aposition d‘os lamellaire. Les deux groupes irradiés ont montré un incontestable remaniement osseux non seule-
ment au niveau de l‘os alvéolaire mais aussi au niveau de la partie basilaire de la mandibule. Toutefois, dans le groupe IrA, les phénomènes de résorption observés dominent ceux de l‘ostéogène. L‘équilibre entre la résorption et l‘aposition osseuse semble être rétabli huit mois après la fin de la radiothérapie (groupe IrB). Malgré la pré-
sence de lésions osseuses, typiques de l‘irradiation, rele-
vées au niveau de certains chiens irradiés, nous concluons, d‘après nos résultats que l‘osseointégration d‘implants dentaires est possible dans le tissu osseux ir-
radié.

Zusammenfassung
Diese Studie untersucht den Effekt der Radiotherapie auf die Osseointegration von dentalen Implantaten, welche vor oder nach Radiotherapie bei 11 männlichen Beagle-
Hunden eingesetzt wurden. Im Unterkiefer wurden alle Prämolaren, die ersten und zweiten Molairen extrahiert. Bei 3 Hunden wurden die Implantate ohne Radiotherapie eingesetzt (Kontrollgruppe), bei 4 Hunden wurde 4 Wo-
chen nach der Implantation eine Resorption durchgeführt (IrA Gruppe) und bei 4 Hunden wurde eine Bestrahlung 8 Wochen vor der Implantation durchgeführt (IrB Gruppe). Jeder Hund wurde 8 Implantate eingesetzt. Es wurden abwechselnd 4 transkutane ITI Bonelite® Implantate mit Titanplasmabeschichtung und 4 submukosale Steri-
Oss® Implantate mit Hydroxyapatitbeschichtung einge-
setzt. Die bestrahlten Hunde erhielten während 10 Tagen 4,5 Gy pro Tag. Zum Zeitpunkt der Implantation und der Bestrahlung wurden 2 verschiedene fluoreszierende Mar-
kern verabreicht. Die Hunde wurden 6 Monate nach der Implantation, d.h. 5 Monate nach Bestrahlung für die IrA Gruppe und 8 Monate nach Bestrahlung für die IrB Grup-
pe, geopfert. Jeder Unterkiefer wurde histologisch und hi-
 stomorphometrisch untersucht. Bei 85 der 88 Implantate trat eine Knochenbildung auf, welche zumeist aus einer sukzesiven Ablagerung von Geflecht- und Lamellen-
knochen bestand. Beide bestrahlten Gruppen zeigten
deutliche Knochenumbauvorgänge sowohl im Alveolar-
knochen als auch im basalen Teil des Unterkiefers. Je-
doch waren in der IrA Gruppe die Resorptionsphänome-
ne dominanter als die Osteogenese. Das Gleichgewicht zwi-
schen diesen beiden entgegengesetzten Prozessen schien 8 Monate nach Beendigung der Radiotherapie in IrB Grup-
pe wiederhergestellt. Obwohl einige lokale Läsionen von

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chased with a grant from the Fonds Na-
tional de la Recherche Scientifique (FNRS, Brussels, Belgium).

Resumen
Esta investigación enfocada sobre los efectos de la radiote-
rapia en la osseointegración de implantes dentales coloca-
dos antes o después de la radioterapia en 11 beagles ma-
chos. Tras la extracción de todos los premolares mandibu-
lares, primeros y segundos molares, 3 perros fueron implan-
tados sin radiotherapia (Grupo de control), 4 perros fueron irradiados 4 semanas fras la implantación (Grupo IrA) y 4 perros se irradiaron ocho semanas antes de la implan-
tación (Grupo IrB). Se colocaron 8 implantes en cada perro, con un patrón alternante: 4 ITI Bonelite® no sumergidos de titanio con cubierta pulverizada de plasma de titanio y 4 Steri-Oss® sumergidos cubiertos de hidro-
xiapatita. Los perros irradiados recibieron 4,5 Gy diaria-
damente durante 10 días. Se administraron dos diferentes marcadores fluorocentes en el momento de la implantación y de la irradiación. Los perros se sacrificaron 6 meses tras la implantación, esto es, 5 meses tras la radiotherapia para el grupo IrA y 8 meses para el grupo IrB. Cada mandi-
bula fue sometida a análisis histológico y microradiogra-
fico. La formación de hueso tuvo lugar alrededor de 85 de los 88 implantes y consistió mayoritariamente en depósi-
tos sucesivos de hueso entremezclado y lamelar. Ambos gru-
pos irradiados mostraron un obvio remodelado óseo en el hueso alveolar al igual que en la parte basilar de la mandi-
bula. Sin embargo, en el grupo IrA, el fenómeno de reab-
sorción fue predominante en aquellos de osteogenesis. El equilibrio entre estos dos procesos contrarios pareció re-
taurarse a los 8 meses del final de la radiotherapia (Grupo IrB). A pesar de las lesiones fósicas de destrucción ósea específica de la radiación en algunos perros irradiados, concluimos de nuestros resultados que la os-
seointegración de implantes dentales es posible en tejido óseo irradiado.

要旨
本研究は、11頭のビーグルにおいて放射線
照射の前あるいは後にインプラントを埋入し
て、放射線照射が骨性結合に及ぼす影響を調べた。
下顎の全ての小臼歯および第1及び第2大臼歯を抜去
した後、3頭の下顎は放射線照射なしでインプラ
ントを埋入し（対照群）、4頭ではインプラントを埋
入7週間後に放射線照射を行った（IrA群）、さら
に4頭ではインプラントを7週間後に放射線照
射を行った（IrB群）。各4頭に、非埋入型チン・
プラスマ照射インプラント（ITI Bonelite®）を埋
入型ハイドロキシアパタイト・コーティングの
Sterios®を4本、合計8本のインプラントを植え立
た。放射線照射を行ったのは、毎日4、3Gy
で10日間照射をした。インプラント埋入時および放
射線照射時に2つの異なる蛍光マーカーを投与し
た。インプラント埋入6ヶ月後に、すなわち
IrA群では放射線照射8ヶ月後に、IrB群では
8ヶ月後に屠殺した。下顎骨組織学的およびマ
イスラライオグラフィーによる分析を行った。イ
References


