Endosseous Implants in Irradiated Tissues

1Samar Teja, 2Ashish Jain

1Senior Lecturer, Department of Prosthodontics, Swami Devi Dyal Hospital and Dental College, Barwala, Panchkula Haryana, India
2Professor and Head, Department of Periodontology, Dr HSJ Institute of Dental Sciences, Panjab University, Chandigarh, India

Correspondence: Ashish Jain, Professor and Head, Department of Periodontology, Dr HSJ Institute of Dental Sciences Panjab University, Chandigarh, India, e-mail: samarteja@yahoo.co.in

Abstract
This paper discusses the use of endosseous implants in irradiated bone. The success rate of endosseous implants in irradiated bone is reviewed and controversy over optimal time prior to implant placement is described. The advantages and disadvantages of pre- and postimplant radiotherapy are addressed. Implant therapy and osteoradionecrosis (ORN) and evidence of potential role of hyperbaric oxygen (HBO) are also reviewed. Strategies for improving the clinical outcome of endosseous implants are suggested.

Keywords: Endosseous implants, osseointegration, irradiation, osteoradionecrosis, hyperbaric oxygen

INTRODUCTION

The irradiation of head and neck tumors leads to changes in bone, skin and mucosa, like reduced vasculature, loss of osteoprogenitor cells, fatty degeneration, susceptibility to osteoradionecrosis and compromised remodeling. All these changes at micro and macro levels affects predictability of endosseous implants. The long-term function of endosseous implants depends on availability of viable bone that should be capable of remodeling and turnover as implant undergoes forces to support, retain and stabilize prostheses. The remodeling apparatus, which requires the presence of osteocytes, osteoblasts and osteoclasts is turned off by the cancerocidal doses of radiation. In cases of irradiated bone, the viability is not sufficient to ensure longevity, particularly in sites such as supraorbital rim and body of mandible. In maxilla as well as and when exposed to high doses of radiotherapy (above 5000 cGy), is affected to the extent wherein the implant, subjected to functional stresses, cannot be sustained.

When and if implants are considered for irradiated patient, several factors should be given careful thought such as potential benefit of implants, morbidity associated with implant failure, complications such as osteoradionecrosis (ORN) and usefulness of hyperbaric oxygen (HBO).

HOW PREDICTABLE ARE IMPLANTS PLACED IN IRRADIATED BONE?

The survival rate of endosseous implants in irradiated bone depends on anatomical site selected, dose to the site and use of HBO. Animal experiments have shown that quantity of bone at bone-implant interface (bone implant appositional index) is reduced at irradiated sites.1,2 Hum and Larsen1 studied the interface using New Zealand adult rabbit. IMZ implants were placed in proximal tibia and 2 weeks later received 4050 cGy. The specimens were recovered 2 months after implant placement. The bone implant appositional index was calculated by examining non-decalcified histologic sections using a grid technique. The appositional bone index for nonirradiated specimens was 94.8% and for irradiated specimens 76.2%. Weinlander2 and others tested 3 different types of implants using a dog model. Three implants, Branemark, IMZ and HA coated were placed on one side of mandible in 7 dogs. After 3 months of healing, 21 implants in 7 dogs were recovered in block section and they served as controls. Following suitable period of healing, the 3 selected implants were inserted into contralateral mandible of each of 7 dogs. After 3 weeks, radiation dose equivalent to 5000 cGy was delivered to these sites. The specimens were recovered 3 months later and histomorphometric analysis of bone implant interface was done. The appositional bone index for Branemark implant was 34% for nonirradiated control specimens vs 24% for irradiated specimens: for IMZ implant, 50% nonirradiated controls vs 45% irradiated specimens and for HA coated implant, 69% nonirradiated controls vs 72% irradiated specimens.

Nishimura3 has shown that at high radiation dose levels quality of bone in implant random to 6 test groups. The
radiation was given to either the proximal or diaphyseal segments of both tibias. Equivalent dosage ranged from 4000 to 7000 cGy. After 3 months of radiation treatment, 5 mm screw type implants were inserted into each half of left tibia of surviving 38 rabbits. Polyfluorochrome labeling was done 3 months after implant placement and 2 days before sacrifice. Ground nondecalcified sections were prepared and evaluated. The results showed steady decrease in label, more so when equivalent dosage exceeded 5800 cGy, showing reduced cellular activity. When viewed under polarized light, the specimens receiving highest levels of dosage showed more incidence of woven bone in comparison to dense lamellar bone in controls and lower dosages in appositional zone. Roumanas reported results of 33 implants placed in irradiated maxillae of 13 patients. All the patients received 5000 cGy to implant sites. Eleven out of 33 failed and were removed and 2 others buried beneath mucosa, for success rate of 60.6%. The remaining implants showed moderate to severe bone loss (bone loss extending to at least level of fourth thread).

In summary, it is clear from the current data and recent short-term clinical reports, that a high percentage of implants in irradiated tissues show advanced bone loss at an early stage of healing. The implants in irradiated tissues have lower success rates than implants in nonirradiated sites, particularly the orbit and the mandible. The survival rates are less than in normal individuals, even in maxilla, inspite of its excellent blood supply. The osseointegration is impaired in bone that has received dosage in excess of 5000 cGy. The bone-implant interface is compromised, making the implant less tolerable to functional loads.

WHEN AFTER IRRADIATION SHOULD IMPLANTS BE INSERTED?

The optimal time of implant placement following irradiation is a controversial issue. Some of the authors have shown that radiation-induced bone destruction leads to irreversible progressive deterioration over time, so much so that bone never regains its preirradiation regenerative capacity. Marx and Johnson conducted a study of serial biopsy specimens from irradiated patients and showed that there was continuous loss of capillaries over time after irradiation, with no evidence of spontaneous revascularization. In a study by Asikaenin et al on 11 beagle dogs, wherein the effect of different doses of irradiation on dental implants in situ was investigated. The dogs received either 4000, 5000 or 6000 cGy at baseline. After two months TPS screw type implants were placed in all the dogs. After a period of 4 months, the implants were loaded. The success rates evaluated later for the implants in irradiated bone was 100% when the dosage of radiation was 4000 cGy. It was 20% with the dosage of 5000 cGy and the success rate was 0% with the dosage of 6000 cGy. On the basis of these studies, the authors recommended that with 'proper' fractionation, 'careful' planning, case selection, adequate design and blood supply, insertion of titanium implants is possible within first 6 months postirradiation depending largely on the doses received of the radiations preinsertion.

On the other hand, Jacobsson et al quantified bone regeneration capacity after administration of 15 Gy cobalt 60 irradiation using a bone growth chamber model method inserted in tibia of rabbits. After 4 weeks of irradiation, bone regeneration capacity was reduced by about 70%, but at 1 year it was less than 30%. Supporting the above findings, Hum & Larsen studied the effect of irradiation on osseointegration of endosseous implants inserted into proximal tibia of rabbit. Osseointegration (measured as percentage of bone-implant contact area) was reduced from 95% in nonirradiated sites to 76% in irradiated specimens. Some of the studies indicate that the risk of developing ORN is greater in the first 12 months after radiotherapy and reduces thereafter. Taking the above findings into account, many of the authors advocated that implant placement would probably be more successful, longer the time interval between radiotherapy and surgery ( till at least 1 year after irradiation).

PRE-VERSUS POSTIMPLANT RADIOTHERAPY

In a study, Schoen et al reported a higher survival rate in preimplant radiotherapy group (90.5%) in comparison to postimplant radiotherapy group (83.4 to 85.7%), but still recommended inserting implants immediately after ablative surgery and prior to radiotherapy. They argued that post-implant radiotherapy allows osseointegration to take place before irradiation, avoids placement of implants in compromised area, allows early prosthetic rehabilitation and limited surgical intervention of irradiated tissues (i.e. exposure and abutment connection). Brogniez et al supported the above recommendation and demonstrated in an experiment on dogs, that osseointegration is possible either before or after radiotherapy, but with higher...
bone-implant contact when implants were placed before irradiation.

**IRRADIATION OF EXISTING IMPLANTS**

Irradiation of titanium implants, already in place, results in backscatter; therefore tissues on radiation source side of implants receive an ‘overdose’ and the tissue behind the implant will receive an ‘underdose’. The dose is increased by about 10 to 15% at 1mm from implant surface. The clinicians queried, if osseointegrated implants should be removed in patients who are to undergo radiotherapy for head and neck tumors due to backscatter. The question was answered by Granstorm in his report of 11 patients, with 33 existing titanium implants, who were scheduled to be irradiated. The dosage ranged from 5000 to 6000 cGy. On the basis of the above findings, Granstrom suggested that all abutments and superstructures should be removed before radiation and mucosa closed over implant. The radiotherapy can begin, when the soft tissue healing has completed. The abutments and superstructures are reattached and prosthesis readapted or remade after completion of radiation.

**RISK OF OSTEORADIONECROSIS**

It has been claimed that localized inflammatory responses have been reported without progression to ORN inspite of the fact that osteoradionecrosis occurs in patients with implants placed in irradiated bone. The above problem can be taken care of by simply removing the failed fixture. ORN results as a infection of irradiated bone due to trauma, tooth extraction, pulpal or active periodontal disease. There are two general preceding factors for development of ORN: compromised vascularity in conjunction with reduced reparative ability of bone and exposure to microbial contamination. The reduced vascularity leads to diminished supply of nutrients to bone-forming cells and also changes cellular signaling patterns and biological interactions with titanium surface. The exposure can be chronic, e.g. periodontal or pulpal disease or sudden, e.g. exposure of bone to contaminated oral cavity after extraction or trauma.

What is so different about implant therapy of irradiated bone, that makes incidence of ORN uncommon? Most of the documented histological and clinical studies have shown that most of the implants, which are placed in irradiated bone failed as a result of inability to osseointegrate at the time implant uncovering. The most judicious of preparations of implant site cannot prevent formation of necrotic margin to the defect. The osteoblasts osteocytes are much more sensitive to radiotherapy than osteoclasts. The necrotic bone layer undergoes resorption with differentiation of mesenchymal tissue to form fibrous tissue instead of bone. This results in encapsulation and exfoliation of the implant. The bone will not be exposed to the external contaminated environment because at the time of implant placement it will be covered by mucosa and by fibrous and epithelial tissues surrounding implant surface at the time implant uncovering. Therefore, there will be a minimal opportunity for bacterial colonization which is necessary for development of ORN.

In mandible, the risk of osteoradionecrosis is determined by analyzing bone necrosis rate observed in postradiation extractions. On the basis of this data, it is safe to place implants in irradiated mandible, if the dosage is less than 5500 cGy and high-risk for doses above 6500 cGy. Esser et al, 199933 reported in retrospective analysis, 2 patients out of 60 (3.4%) developed ORN in the mandible after receiving the dosage of 6000 cGy postoperatively via opposed mandibul at field. In patients with dosage to implant sites between 5500 and 6500 cGy, individual patient considerations, such as dose per fraction, a previous radical neck dissection are important cofactors in assessing the risk. In these patients, if implants are elective in nature, they should be deferred and if deemed mandatory, they should be placed in combination with HBO as suggested by Granstorm. The implants can be placed with a high percentage of success rate in the symphyseal region as it does not receive radiation. In maxilla, the risk of bone necrosis is negligible. HBO is used only for improving success rates.

**THE ROLE OF HYPERBARIC OXYGEN (HBO)**

HBO is used as a treatment modality for a wide variety of conditions, ranging from syphilis to multiple sclerosis, senility to myocardial infection and gangrene to decompression sickness. As regards to craniofacial region, its use so far, has been restricted to 'therapeutic role' in treatment of osteoradionecrosis (ORN). In the following discussion the current status of biological aspects and potential applications of HBO will be dwelled upon.

Larsen et al investigated the effect of HBO on osseointegration of endosseous implants in irradiated tissue of rabbit by using a radiation equivalent dose of 1850 ret in
order to simulate that of humans (1755 ret). The implants were placed following a postirradiation healing period of 16 weeks. The rabbit has a bone turnover rate which is 3 times faster than man, 16 weeks is equivalent to 1 year in a human model and so the animals were killed at 12 and 16 weeks after implant placement. HBO results in improved histologic integration (calculated as percentage of bone-implant contact) in irradiated bone at both 12(82.0%) and 16 weeks (84.4%) after implant placement in comparison with non-HBO irradiated subjects (47.3% and 79.6% respectively). It was also shown that HBO reduces soft tissue complications by 39%. The above study clearly demonstrates that in irradiated, non-HBO-treated rabbits, almost identical bone-implant contact was achieved by giving more time for osseointegration to occur.

HBO pre- and postoperative has been shown to improve the clinical survival rate of dental implants placed in irradiated bone. NIIMI et al26 presented a joint study in Japanese and American centers in relation to intraoral implants placed in irradiated bone with or without HBO. Out of the 39 implants placed in maxilla, 22 were in the non-HBO group and 17 were in HBO group. The implant survival rate was 62.5% for the non-HBO group and 80.0% for the HBO group. On the other hand, out of the 71 implants placed in the mandible, 57 were in non-HBO group and 14 were in the HBO group. The implant survival rate for mandible was 96.4% for the non-HBO group and 92.9% for the HBO group. The authors suggested that osseointegrated implants can be placed with the 'greatest care' in irradiated mandibles of selected patients without HBO. The endosseous implants have a high degree of predictability in mandible, while in maxilla it is low even if adjunctive HBO is used.27 This shows that HBO can enhance the vascularity of irradiated bone but it does not improve the inherent structure of bone, i.e. the percentage of cancellous and cortical bone and their capacity for remodeling. Franzen et al28 placed 20 implants in irradiated mandibles without HBO. The dose of irradiation was between 25 to 64 Gy and cases were followed for 3 to 6 years. Out of the 20 implants one failed to osseointegrate. It was pointed out by authors that there may be a difference between 'therapeutic' role of HBO and its usefulness in preventing development of ORN. The effectiveness of HBO is debatable as shown in some of the animal studies, which demonstrate no substantial difference between groups treated with or without HBO.20,29

However, HBO has its contraindications 30 and is a time-consuming and expensive procedure. It is not readily available everywhere6 and patient compliance is questionable.

**CONCLUSION**

Multicenter studies are required for standardized data recording and monitoring the clinical performance of endosseous implants in irradiated tissues at the level of bone, soft tissue and patient perception. For the development of newer methods to reliably determine the bone quality, comprehensive basic bone biology research is need of the hour. Taking into account the controversy surrounding HBO, alternative strategies have to be developed for enhancing survival rate of endosseous implants in irradiated tissues. The application of bone morphogenetic proteins (BMPs) demonstrate enhancement of osseointegration of intraoral implants.31 It is a proven fact that rough sand-blasted and acid etched implant surfaces have a better survival rate at intraoral sites known for their poor prognosis, such as posterior maxilla.32 Maybe in future, implants developed with different designs and surface texture are more compatible with compromised bone.

**REFERENCES**

27. Franzen L, Rosenquist JB, Rosenquist KI, Gustafsson I. Oral implant rehabilitation of patients with oral malignancies treated with radiotherapy and surgery without adjunctive hyperbaric oxygen.