# A Study of Success Rate of Dental Implant in Irradiated Jaw Bone

# การศึกษาอัตราสำเร็จของรากฟันเทียมในกระดูกขากรรไกรที่ถูกฉายรังสี

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## ABSTRACT

The aim of this prospective study is to evaluate the success rate of dental implants in irradiated jaw bone. Five patients with a mean age of 56 ± 8.54 years were treated with dental implants after radio-chemotherapy. A total of 13 implants were placed into irradiated jaw with the healing period of 3 months. The mean implant stability (ISQ) measured by resonance frequency analysis at the time of implant placement (ISQ 0), after 2 (ISQ 2) and 3 months (ISQ 3) were 70.85 ± 5.71, 63.62 ± 10.38 and 72 ± 6.71, respectively. All implants were considered successful when fulfilling the following criteria of Buser et al. 1990 and the overall implant success rate was 100% without occurrence of ORN.

## บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อประเมินอัตราสำเร็จของรากฟันเทียมในกระดูกขากรรไกรที่ถูกฉายรังสี โดยทำการฝังรากฟันเทียมจำนวน 13 ราก ในคนไข้จำนวน 5 ราย ซึ่งมีอายุเฉลี่ย 56 ± 8.54 ปี และมีประวัติเคยได้รับรังสีรักษาร่วมกับการใช้เคมีบำบัด หลังจากทำการฝังรากฟันเทียมในขากรรไกรที่ได้รับการฉายรังสี จะรอให้มีการหายของแผลเป็นระยะเวลา 3 เดือน โดยในระหว่างนี้ ทำการวัดค่าเสถียรภาพของรากฟันเทียมโดยใช้วิธีประเมินจากคลื่นความถี่ที่สะท้อนออกมาในวันที่ทำการฝังรากฟันเทียม 2 และ3 เดือนหลังการฝัง ได้ค่าดังนี้ 70.85 ± 5.71, 63.62 ± 10.38 และ 72 ± 6.71 ตามลำดับ ประเมินอัตราสำเร็จของรากฟันเทียมโดยอ้างอิงจากเกณฑ์ของ Buser และคณะในปี 1990 ได้ค่าอัตราสำเร็จที่ 100% โดยไม่พบการเกิดภาวะกระดูกตาย

**Keywords:** Dental implant, Success rate, Irradiated jaw
**คำสำคัญ:** รากฟันเทียม อัตราสำเร็จ ขากรรไกรที่ถูกฉายรังสี

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**Introduction**

Dental implants have become a treatment of choice for replacement of missing teeth in totally and partially edentulous patients. The efficacy of implants in oral rehabilitation has been documented with success rates of over 95%. (Mangano et al., 2014; Cochran et al., 2002) Influent factors on dental implant success include local bone factor, smoking behavior, systemic condition, periodontal status, oral hygiene, implant surface and occlusal force. (van Steenberghe et al., 2002; Sakakura et al., 2007; Holzinger et al., 2014; Gabay et al., 2015; Sun et al., 2011; Zhou et al., 2016)

Radiotherapy is a local factor that may interfere with the success of the implants. (van Steenberghe et al., 2002) The sequence of radiation was summarized by many authors. In 1983, Marx proposed the "three H" theory as follows: (a) radiation, (b) hypoxic-hypovascular-hypocellular tissue, (c) tissue breakdown (cellular death and collagen lysis exceed synthesis and cellular replication), and (d) nonhealing wound (a wound in which energy, oxygen, and metabolic demands exceed supply). (Marx, 1983)

In 2004, Assael claimed that cellular radiogenic effects in bone occurred earlier than the well-known vascular alterations ("three H" principle). Osteoradionecrosis (ORN) occurs by the same mechanism as other types of osteonecrosis (e.g. bisphosphonate-related osteonecrosis) and results from decreased osteoclastic bone resorption. (Assael, 2004)

The pathophysiology of ORN was also proposed as a "radiation-induced fibroatrophic" mechanism including free radical formation, endothelial dysfunction, inflammation, microvascular thrombosis, fibrosis and remodelling and finally bone and tissue necrosis. (Delanian, Lefaix, 2004)

Although the concept of ORN is controversial, all of these indicate a decreased capacity of bone healing and remodeling, and this may have a negative effect on implant "osseointegration" which is essential for early implant success. (van Steenberghe et al., 2002)

Benefits of oral rehabilitation with the implants over conventional prostheses have been reported from comparative studies in terms of retention, stability, comfort, masticatory function, esthetic and patient satisfaction, and all of these have a positive impact on quality of life of the edentulous patients. (Allen et al., 2001; Pan et al., 2014; Hartog et al., 2014)

Eventhough irradiation may compromise wound healing around implants. Concerning many benefits of dental implants and the success of implants in irradiated patients that could be shown from studies with a range from 62.5% to 100%, patients with head and neck radiotherapy should not be considered as a contraindication for dental rehabilitation with implants. (Zen et al., 2016)

As a result of wide range of the implant success rate, the implant outcome in irradiated patients is confusing. Moreover, there have been few studies of implant success rate in irradiated jaw bone. The aim of this prospective study is to evaluate the early success rate of dental implants in irradiated jaw bone.

**Objectives of the study**

The aim of this prospective study is to evaluate the early success rate of dental implants in irradiated jaw bone.

**Methodology**

**Patient selection**

Between February and September 2016, patients who have history of nasopharyngeal carcinoma or other head and neck cancers which treated by external beam radiotherapy and need to restore the missing teeth with dental implant were considered for inclusion in the study. Inclusion and exclusion criteria were listed in table 1.

**Table 1** Inclusion and exclusion criteria.

| Inclusion criteria | Exclusion criteria |
|---|---|
| (i) free of tumor | (i) radiotherapy completed less than 6 months |
| (ii) both male and female with age 20-70 years | (ii) poor oral hygiene or poor compliance in oral care |
| (iii) missing one or more teeth in any areas of the jaws | (iii) severe periodontitis or poor periodontal health |
| (iv) adequate bone volume for implant placement | (iv) heavy smoking (more than 10 cigarettes per day) |
| (v) controlled systemic diseases | (v) severe bruxism or clenching habits |
| | (vi) need bone augmentation with implant placement |
| | (vii) history of tooth extraction or any bone surgery within 3 months at the operation site |
| | (viii) systemic immune disorder |
| | (ix) patients who have taken bisphosphonate |
| | (x) limit mouth opening less than 3 cm |
| | (xi) unable to comply throughout the study |

The study protocol was explained to each subject, and signed inform consent was obtained. The study protocol was approved by the ethics committee of Faculty of Dentistry, Chulalongkorn University. This prospective clinical study was conducted at the department of Oral and Maxillofacial Surgery, Faculty of Dentistry in Chulalongkorn University.

**Preoperative work-up**

The preoperative planning was based on clinical and radiographic examinations. Panoramic radiographs were used for primary investigation of the jaw bones, teeth and surgical site. Cone-beam computerized tomography (CBCT) was used for final investigation in some particular cases. The prostheses in this study could be implant-supported single crown, bridge or implant-retained denture. Each patient could have one or more implants in the jaw bones.

**Surgical protocol**

All patients were prescribed with 1 gm of amoxicillin 1 hour orally before operation, for patients who were allergic to penicillin, 600 mg of oral clindamycin was prescribed.

The operation was started with local anesthesia (2% lidocaine with epinephrine 1:100,000), followed by a midcrestal incision, elevation of full-thickness flap and crestal alveoloplasty if necessary. Implant site preparation was performed regarding the manufacturer's protocol, under constant irrigation. SuperLine™, Dentium implants (double-threaded and taper design with SLA surface) were placed to prepared site. Cover screws were placed and flaps were closed with primary closure. Panoramic and periapical radiographs were taken immediately to confirm an alignment of the implants, to determine any abnormalities and to be a baseline of peri-implant crestal bone change. Postoperative medication was paracetamol 500 mg prn q 6 h and amoxicillin 1 gm twice times daily for 5 days. For patients who were allergic to penicillin, 300 mg of clindamycin was prescribed three times daily for 5 days instead. All patients who had previous removable denture were not allowed to wear the denture after implant placement.

At 8 weeks after implant placement, the second stage surgery was conducted to gain access to the underlying implants, and healing abutments were placed. All surgical treatments were carried out by one operator.

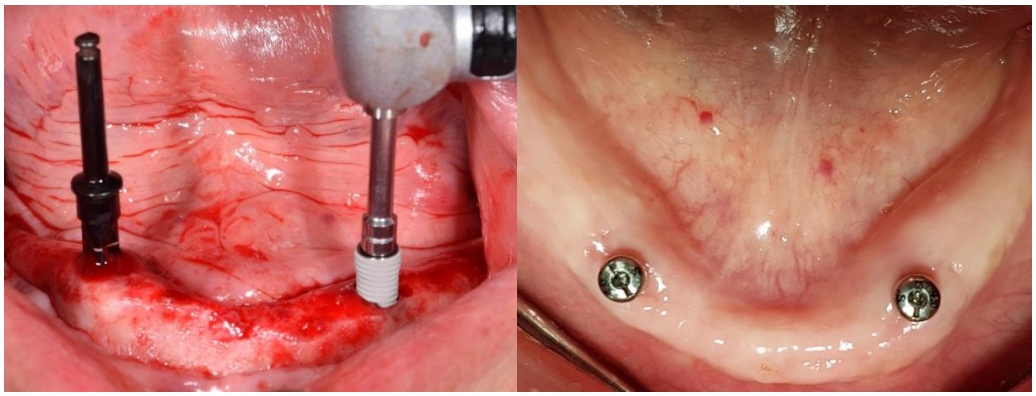

**Figure 1** First and second stage implant placement

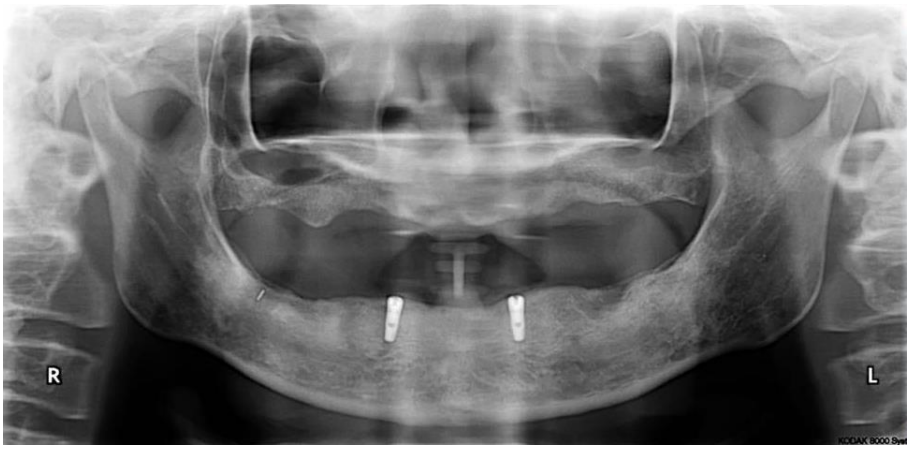


**Figure 2** Postoperative panoramic radiograph

**Clinical and radiographic evaluation**

The patients were recalled for clinical and radiographic examination during healing period of 3 months. In addition, the implant stability was measured using resonance frequency analysis (RFA) at the time of implant placement, after 2 and 3 months. The same SmartPeg was hand screwed into each implant. The implant stability quotient (ISQ) values were obtained from Osstell ISQ (Ostell AB, Göteborg, Sweden) at buccal, lingual, mesial and distal site of implant, and the average value for each implant was recorded.


**Figure 4** RFA measurement with smartpeg type 7

After healing period of 3 months, the implants with the ISQ values above 60 and no any abnormality were sent for prosthetic treatment. If the values were below 60, implants were considered unstable and still left for healing. (Rodrigo et al., 2010)

**Criteria of success**

All implants were considered successful when fulfilling this following criteria (Buser et al., 1990):

(i) absent of persistent subjective complaints, such as pain, foreign body sensation and/or dysesthesia

(ii) absent of recurrent peri-implant infection with suppuration

(iii) absent of mobility

(iv) absent of a continuous radiolucency around the implant

(v) possibility for restoration

The restoration was performed by screwing the abutment at 25-30 Ncm according to manufacturer protocol.

**Statistical analysis**

Data collection and analyses were performed by one examiner. Descriptive analysis was performed with all available data including ISQ values and the implant success rate. The repeated measures ANOVA was used to analyze the difference of ISQ values at different points of healing period. The success rate of implants was calculated by an implant-based assessment. Statistical analysis was performed using the IBM SPSS Statistics version 22.0. A p-value of $<0.05$ was considered statistically significant.

**Results**

**Patients and implants**

A total of thirteen implants were placed into five irradiated patient. All patients participated in the study are men with a mean age of 56 ± 8.54 years. Among these patients, 2 (40%) were non-smoker and 3 (60%) were previous smokers. Three patients (60%) had history of tumor at nasopharynx, remaining at oropharynx and hypopharynx. Radiation dose to primary site of 4 patients treated with intensity-modulated radiotherapy (IMRT) was 70 Gy, and one patient treated with 2 dimensional radiotherapy (2DXRT) was 64 Gy. The average post-radiation time was 45.6 ± 30.19 months. All patients were treated with concurrent chemo-radiation therapy (CCRT) and 3 (60%) were followed with adjuvant chemotherapy.

Of the 13 implants, 8 (61.5%) were inserted in the posterior mandible and remaining in anterior mandible. Two (15.4%) implant sites were loss of teeth less than 6 months, and the others were loss more than 1 year. All implants had 10 mm in length. The implant diameter was 3.6 mm with 4 implants (30.8%), 4.0 mm with 5 implants (38.4%) and 4.5 mm with 4 implants (30.8%).

**Clinical and radiographic parameters**

Base on clinical and radiographic examination, no any complication occurred with all implants and surgical sites. The mean insertion torque of all implants placed was 40 Ncm (range: 35-40). The ISQ values of each implant at different examination periods were listed in Table1. As the ISQ values were compared with dependent statistics (repeated measures ANOVA) as well as Post Hoc test, significant differences were observed between ISQ 0 vs ISQ 2 (P = .039) and ISQ 2 vs ISQ 3 (P = .012) but no difference between ISQ 0 vs ISQ 3 (P = 1.00).

**Table 2** Descriptive statistics of implant stability quotient (ISQ) at different healing periods.

| No. of implant | Implant placement (ISQ 0) | Second month (ISQ 2) | Third month (ISQ 3) |
|---|---|---|---|
| 1 | 72 | 81 | 81 |
| 2 | 80 | 81 | 81 |
| 3 | 78 | 53 | 69 |
| 4 | 66 | 58 | 73 |
| 5 | 71 | 58 | 65 |
| 6 | 68 | 54 | 75 |
| 7 | 73 | 72 | 73 |
| 8 | 66 | 63 | 61 |
| 9 | 71 | 66 | 68 |
| 10 | 59 | 57 | 62 |
| 11 | 78 | 75 | 80 |
| 12 | 70 | 53 | 74 |
| 13 | 69 | 56 | 74 |
| Mean ± SD | 70.85 ± 5.71 | 63.62 ± 10.38 | 72 ± 6.71 |

**Implant success**

Following the healing period of 3 months, no patient dropped out. All implants were stable without any subjective complaints, free of infection and no detectable mobility. The periapical radiographs taken at that time did not show any signs of peri-implant radiolucencies. Moreover, all implants were allowed to restore by screwing the abutment at 25-30 Ncm without mobility. Thus, the early success rate of dental implants was 100%.

**Discussion and Conclusions**

The use of dental implants in irradiated jaw bone has been reported with a wide success rate from the studies. (Zen et al., 2016) According to systematic review in 2016, 8 clinical studies on human who undergo dental implant placement after head and neck RT and had no history of hyperbaric oxygen adjuvant therapy were finally summarized. The osseointegrated success rates ranged between 62.5% and 100%. In this study, all dental implants integrated to bone with the ISQ values above 60 at 3 months of healing period and no mobility was found when screwing the prosthetic abutment at 25-30 Ncm. The success rate of dental implants was 100%. These results are similar to the recent study that showed the ISQ values around 60 at the third month and no reported any failed implants. (Karayazgan-Saracoglu et al., 2015)

Although the good outcomes of dental implants in irradiate jaw bone were mentioned above, the decreased success rate of implants could be seen from studies. Nack et al. found that the 12-month, 3-year and 5-year survival rate of 97 SLA implants was 92%, 80% and 75.8%, respectively. (Nack et al., 2015) Overall number of failing implants was 20 after 5 years, only 2 implants were lost before loading and the others were counted as lost because the patients had died after prosthetic rehabilitation. This is in accordance with other investigations of tumor patients after radiotherapy, in which the poor implant survival rate was due to a high mortality rate rather than lack of osseointegration. (Nelson et al., 2007; Schoen et al., 2007)

A number of factors responsible for implant failure have been described such as smoking, bone quality, radiotherapy and chemotherapy. Heavy smoking behavior (>10 cigarettes/day) was showed as a predisposing factor on implant failure. (van Steenberghe et al., 2002) However, heavy smokers were excluded from this study.

In terms of localization, implant placement in the mandible showed a better prognosis over the maxilla from many studies. (Sun et al., 2011; Geckili et al., 2014; Visch et al., 2002) The higher survival rate of implants placed in mandible could be caused by the increase in bone density and hence better primary stability. However, current prospective studies showed a good result of SLA implants in both upper and lower jaws and reported no significant difference of implant survival and implant success rates with respect to implant location. (Mangano et al., 2014; Karayazgan-Saracoglu et al., 2015; Nack et al., 2015) Concerning the anatomical structure and differences in blood supply between mandible and maxilla, irradiated mandible often faces with decreased vascularity, delayed wound healing and may result in development of ORN. (Chrcanovic et al., 2010) In our study, all implants were placed in the mandible with a good primary stability and no implant failure or ORN were reported.

Effect of radiation dose on implant survival rate could be seen from previous studies. (Visch et al., 2002; Granström, 2005) Moreover, higher incidence of ORN was observed in patients receiving doses higher than 50-65

Gy. (Chrcanovic et al., 2010) In recent prospective study, the implants were placed in patients with head and neck RT up to 72 Gy and no implant failure was described. (Karayazgan-Saracoglu et al., 2015) This coincided with our study which showed successful osseointegrated implants in patients with a mean radiation dose of 68.8 ± 2.68 Gy.

Although multiple sites of tumor were included in this study, both maxilla and mandible were exposed to the radiation. In addition, this study combined more than one radiation technique, most of these were IMRT which claimed to have an advantage in terms of dose distribution and minimizing the risk of ORN. (Lertbutsayanukul, Rojpornpradit; Studer et al., 2006; Parliament et al., 2005) These may contribute to no incidence of ORN in the study.

In determining the interval time between RT and implant placement, Granström found the influence of this time on implant failures and showed that irradiation more than 15 years before surgery significantly increased implant failures. (Granström, 2005) A recent study showed no association between time and implant failure. (Rodrigo et al., 2010) However, the post-radiation period in the review was limited to 20 years. In our study, the time from RT to implant surgery quite varied but it was less than 15 years. Concerning ORN, its onset can be very variable but most spontaneous cases developed in first few years. In cases associated with dental trauma, the occurrence of ORN is not time dependent and may evolve an infinite number of years after radiation. (Chrcanovic et al., 2010)

Chemotherapy is known to weaken an immune response by damaging a cellular immune system. The studies demonstrated high incidence of complications included implant failure and ORN in patients who undergo surgery after treated with combined radio-chemotherapy. (Chrcanovic et al., 2010; Granström, 2005) With the radio-chemotherapy, the time interval until the ORN occurred was observed to be shorter than RT alone. (Chrcanovic et al., 2010) Nonetheless, the effect of chemotherapy on implant survival was not clear studies demonstrated a high success rate of dental implants placing in patients who have a history of concurrent chemoradiation therapy at least 6 months. (Nack et al., 2015; Heberer et al., 2011) Therefore, chemotherapy might not inhibit the osseointegration of implants, but the time point of chemotherapy might be decisive. (Zen et al., 2016) In the present study, all patients had a history of chemotherapy. Though some were combined with adjuvant chemotherapy, it was completed before surgery more than 1 year, and all implants were osseointegrated with no any complications.

Implant surface was found to influence the implant success. (Sun et al., 2011) The implants with a roughed surface showed generally lower failure rates compared with machine surface ones. This may be due to an influence of roughed surface on bone response at the micro- and nanometer level and then the bone-implant contact increases. (Shalabi et al., 2006; Wennerberg, Albrektsson, 2009) Increasing diameter of implants may increase surface for bone-implant contact but these did not prove to have an effect on implant failure rates in recent literatures. (Sun et al., 2011; Pommer et al., 2011) In this study, various SLA implants diameters (3.6, 4.0 and 4.5 mm) were used and the results observed were correlated with many recent prospective studies, which demonstrated a high success rate of placing SLA implants in irradiated jaw. (Karayazgan-Saracoglu et al., 2015; Nack et al., 2015; Heberer et al., 2011)

There are two different concepts of implant stability. One is the primary stability playing a key role in osseointegration. While several studies have stated that only secondary stability values are able to predict implant outcomes. (Rodrigo et al., 2010; Kim et al., 2015) In our present study, almost all implants demonstrated high primary stability (ISQ $\geq$60 Ncm), but one was concerned unstable (ISQ < 60 Ncm). At 2 months, the ISQ values

decreased from once implants placed significantly (P = .039). This caused by initial bone resorption in the remodeling process that lead to the stability dip within the first 3 weeks. (Barewal et al., 2003) After this period, the secondary stability restored but it may not fully recover. Thus, the weak implant stability was seen at 2 months. However, the stability increased until no significant difference of ISQ values was seen between the time of placement and 3 months. (P = 1.00), and all implants were stable and did not present mobility when screwing with abutment. Regarding to insertion torque, all implants were placed with the torque of 35-40 Ncm in range. Nonetheless, recent study showed no correlation between insertion torque and ISQ at implant placement. (Levin, 2016)

The limitations of the present study include the small number of patients, short follow-up time, and unavailable data on radiation dose at implant sites. However, our study demonstrated all available data so that the reliable results could be inferred from these parameters. Moreover, all patients were routinely recalled for implant check after prosthesis was done and no complication was observed with mean follow-up 6 months.

Further prospective studies with larger number of patients with long follow-up incorporating analysis of the radiation dose at different implant sites should be performed to assess the impact of radiation on implant success and prevalence of ORN associated with dental trauma.

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