Life Table Analysis and Clinical Evaluation of Oral Implants Supporting Prostheses After Resection of Malignant Tumors

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Seventeen mostly elderly patients, 13 men and 4 women, were consecutively admitted for implant-prosthodontic treatment after they had undergone resection of malignant tumors in the oral cavity. A total of 53 dental implants (ITI-Straumann) was placed, 12 in the maxilla, 41 in the mandible. The prosthetic rehabilitation consisted of overdenture therapy in 15 patients, and 2 patients were treated with fixed partial prostheses. Thirty-three implants were prescribed for patients who received radiotherapy either before or after implant placement. The average dose varied between 50 and 74 Gy. Eighteen implants were located in grafted bone from the fibula, scapula, or hip. For 2 patients, hyperbaric oxygen therapy was also prescribed after osteoradionecrosis had developed. One implant was lost before prosthetic loading. During an observation period of up to 7 years after loading, 3 more implants were removed. All implant losses occurred in the mandibles of patients who had received radiotherapy. A life table analysis was performed, and the cumulative survival rates, calculated for 2, 3, and 5 years, were 93%, 90%, and 90%, respectively. No failures or complications were observed with technical components of the implants or prostheses. All prostheses could be maintained during the entire observation time. Although in the present investigation the survival rate of implants was slightly lower than under standard conditions, the treatment with implant-supported prostheses seemed to be advantageous for patients who had undergone intraoral resections.
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Key words: implant prosthesis, irradiated bone, life table analysis, malignant tumors, oral implants

The use of oral implants for the prosthetic rehabilitation of partial and complete edentulism in routine situations has become a reliable treatment modality, and high success rates have been reported with different implant systems.[1–3] The use of implants also appears to be advantageous for fixation of various types of oral and maxillofacial prostheses in patients with malignant oral tumors.[4,5] After resection of oral tumors, most patients require a prosthesis to compensate for lost teeth and tissues. Adaptation and stabilization of conventional prostheses may become difficult, if not impossible, because of unfavorable local oral conditions. Since many patients with malignant oral tumors are elderly,[6–8] they may already be edentulous or will lose their remaining teeth when undergoing tumor resection. Thus, removable prostheses, including complete dentures, are the most frequently prescribed prosthetic rehabilitation for these patients.[8]

Current treatment modalities for patients with oral tumors include considerations for the placement of oral implants. However, the required therapy for oral tumors is also associated with specific complications that may jeopardize the short- and long-term success of implants. Therapy for malig-

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nant oral tumors usually involves resection of the malignant tissue, combined with radiotherapy. Further, reconstructive tissue grafting procedures may be accomplished for restitution of lost hard and soft tissues. Thus, these treatment protocols imply that implants are often placed in maxillary and mandibular bone that has been or will be irradiated, or implants are placed in grafted bone. It is known that when implants are placed in irradiated bone, the failure rate increases[9–12] because the healing capacity of the bone is diminished and the process of osseointegration may be impaired. It is also known that irradiation of tissues that contain integrated implants increases the risk of soft tissue dehiscences around the implants, and osteoradionecrosis may lead to loss of the implants.[12,13] It has been shown that hyperbaric oxygen (HBO) therapy positively affects the local conditions of bone and soft tissues, improving the healing capacity and enhancing the process of osseointegration.[11,14–16]

The aim of the present follow-up study was to describe the evaluation of oral implants supporting prostheses in the maxillae and mandibles of patients who received treatment for oral malignant tumors and to analyze the survival rate of the implants in this population group.

Materials and Methods

Patients and Implants. From the years 1990 to 1996, 25 patients (17 male and 8 female) were referred to the Department of Removable Prosthodontics, University of Bern, Switzerland, and were consecutively admitted for prosthetic rehabilitation after resection of malignant tumors. For 17 patients, implants had been prescribed. The selection criteria were set up by the surgeons and were based on local and general conditions of the patients to include: number and distribution of remaining teeth, possibility for fabrication of conventional prostheses, bone quantity for placement of implants, size and structure of the oral defects, and systemic health. While a sufficient number of teeth was still available to provide 4 patients with conventional dental and prosthodontic treatment, 2 other patients were excluded from implant surgery because of very poor general health. Two more patients presented with extremely unfavorable intraoral and local bone conditions after failure of grafting procedures, which would not allow the placement of implants. The remaining 17 patients (13 males and 4 females) were treated with fixed or removable implant-supported prostheses.

From the 17 patients with implants, the following data were collected: age at the time of tumor diagnosis; habits of drinking and smoking; specification of the tumor and its localization; surgical procedures, including grafting of hard and soft tissues; and adjunctive therapy, such as radiotherapy or HBO. The average age at the time of tumor diagnosis was 59.6 years. For 8 patients, a history of smoking and drinking was recorded, and 3 patients had a history of smoking only. In 6 patients no habits of tobacco or alcohol abuse could be elicited. A total of 53 ITI implants (Straumann, Waldenburg, Switzerland) was placed, either during resection of the tumor or in a delayed staged surgical procedure. All implants were ITI full-body screws 8 to 12 mm long and with a diameter of 3.4 or 4.1 mm.

Tumors, Surgery, and Radiotherapy. In 14 patients, squamous cell carcinoma was diagnosed, 2 patients had amelanotic melanoma, and 1 patient had a chondrosarcoma. In 14 patients, the tumor had its origin in the lower part of the oral cavity, ie, in the mandibular ridge (7 patients), in the mouth floor (5 patients), or in the tongue (1 patient). In 1 of these 14 patients, the tumor had also infiltrated maxillary alveolar bone. In 2 patients, the tumor originated from the maxillary sinus, and in 1 patient it originated from the nasal cavity. For 13 patients, soft tissue grafts became necessary, and for 9 patients bone grafts were also prescribed, ie, bone from the fibula (7 patients), from the ilium (1 patient), and from the scapula (1 patient). For 3 patients, fibular grafts had become necessary, since osteoradionecrosis had developed after irradiation of the tumor in the mandibular region. A total of 8 patients had 18 implants placed in grafted bone. Six patients with a total of 20 implants did not undergo radiotherapy, while 7 patients underwent radiotherapy after implant placement. In 4 patients, the implants were placed after the irradiation protocol was carried out. Three of these 4 patients had developed osteoradionecrosis; therefore, 2 of these patients received adjunctive HBO therapy when additional grafting and implant surgery became necessary. The total average dose of irradiation varied between 50 and 74 Gy. Tables 1 and 2 give an overview of patients, implants, tumor location, and radiotherapy.

Prosthodontic Treatment and Maintenance. The prosthodontic protocol consisted of individual treatment planning, completion of the implant prosthodontic rehabilitation (including treatment of the opposing arch), and enrollment of all patients in a strict maintenance care program. Fifteen patients were provided with implant-supported overdentures, consisting of 11 in the edentulous mandible (Fig 1) and 3 in the edentulous

Table 1 Overview and Patients

Patient	Age	Tumor	Bone graft	No. of implants	Prosthesis and attachment	Observation period (mo)
1	69	scc	Fibula	2	OD, bar	32
2	71	scc	—	2	OD, bar	32
3	53	scc	Fibula	4	OD, bar	38
4	44	scc	Scapula	5	OD, bar	52
5	55	scc	Fibula	2	OD, bar	53
6	56	scc	Fibula	3	FPP	17
7	70	c	—	4	OD, bar	12
8	51	scc	—	4	FPP	25
9	66	scc	—	2	OD, bar	84
10	63	scc	Fibula	2	OD, bar	32
11	77	m	—	3	OD, bar	48
12	49	scc	—	2	OD, bar	68
13	38	scc	Fibula	3	OD, bar	53
14	44	scc	Fibula	4	OD, ball	13
15	81	m	—	3	OD, bar	18
16	46	scc	Ilium	4	OD, ball	23
17	52	scc	—	4	OD, bar	37

scc = squamous cell carcinoma; c = chondrosarcoma; m = amelanotic melanoma; OD = overdenture; FPP = fixed partial prosthesis; ball = ball anchors.

maxilla (Fig 2). The patients were either already completely edentulous (8 patients) or had their remaining teeth extracted in the mandible when the tumor was resected (6 patients). Two partially edentulous patients received screw-retained fixed partial prostheses in the mandible.

During the entire observation period, the patients were regularly seen by the prosthodontist, with an average of 2 visits per year. The implants were regularly assessed according to the criteria of Buser et al for ITI implants[17]:

- Absence of persistent complaints such as pain or dysesthesia,
- Absence of repeated peri-implant infection, fistula, or abscess,
- Absence of mobility, and
- Absence of continuous radiolucency around the implants.

In the context of this study all patients were recalled in early 1998. No drop-outs for unknown reasons were registered, but 5 patients died before this date. The time between their last check-up and the date of death was calculated and was from 2 weeks to 9 months, with an average of 4.9 months.

Statistical Analysis. In a descriptive statistical analysis, the survival of the implants was assessed with respect to their location in the oral cavity, grafting procedures, irradiation, and HBO therapy and with respect to the type of prosthesis. To determine the long-term survival of the implants, life table analysis according to Kaplan and Meier[18] was applied. The cumulative survival rate of the implants was calculated after 6 months and 1, 3, and 6 years.

Table 2 Implant Localization

Bone	Jaw		Total no. of implants
	Maxilla	Mandible	
Irradiated bone	2	31	33
No irradiation	10	10	20
Grafts			
Fibula	—	14	
Ilium	—	4	
Scapula	—	5	23
No grafts	12	18	30

Results

Before completion of the prosthetic treatment, 1 implant was lost; after completion of the prostheses and loading of the implants, 3 more implants in 3 different patients required removal. All implants were mobile, and 2 implants also exhibited large soft tissue dehiscence. A total of 8 implants had failed and were removed. These implants were located in the mandible of patients who had undergone radiotherapy. In completely edentulous mandibles, all implants were designated for overdenture support. Transient minor soft tissue problems that could be managed were

Fig 1a Male patient with squamous cell carcinoma of the mandibular ridge. The post-surgical radiograph shows a fibular graft on the left side of the mandible. Two implants were placed in grafted bone, 2 were in the remaining mandibular bone.

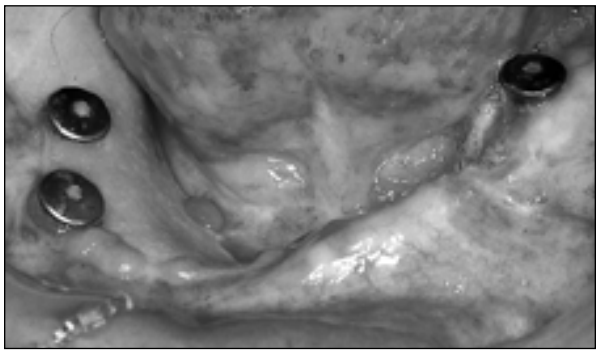

Fig 1b Clinical intraoral situation with 3 implants still in situ after an early failure had occurred. The overdenture is connected by means of ball attachments.

found around 11 implants. These were mostly related to hyperplasia, which resulted in increased probing depths. At the patients' last check-up in early 1998, 1 implant was found with radiolucency surrounding the implant body, but no mobility could be detected. However, it must be considered a failure after 7 years in function. During the whole observation period, the implants were loaded and no further osteoradionecrosis was diagnosed after completion of the prostheses. Table 3 provides an overview of implant failures and complications. Figure 3 presents the life table analysis of the 53 ITI implants. Table 4 shows the statistical analysis of the cumulative survival rate after 2, 3, and 5 years with a confidence interval of 95%. The peri-implant radiolucency was detected only after 7 years; therefore, the cumulative survival rate after 3 and 5 years was identical.

In all patients, the initial prosthesis was maintained throughout the observation period. This means a prosthesis survival rate of 100%. No fractures of any component parts, including abutment screws or prosthetic components, were observed. After the late loss of 3 implants, the dentures were easily adapted by relining, and there was no need for new prostheses. Minor corrections, such as relief of sore spots, was part of the regular maintenance service.

Discussion

Squamous cell carcinoma was the most frequently found malignant tumor in the patients included in this study, ie, about 80%. This percentage corresponds to epidemiologic data reported in the literature.[19,20] Abuse habits, such as smoking and drinking, were recorded in 12 patients, and it is known that this is frequently associated with the development of pharyngeal and oral tumors.[21] The dominance of male patients in the present study is also in accordance with the findings of other studies on oral tumors and corresponds to a male-female ratio of 4:1; currently a ratio of 2:1 may also be found.[6–8,19] This means an increase in female patients with oral tumors. This increase may be explained by an increase in smoking among women, or other habits that may impair the health of the oral cavity. The most frequent location of tumors among the patients in the present study was the alveolar ridge, followed by the floor of the mouth. In other reports the floor of the mouth has been the most common location.[6,22,23]

The therapeutic protocol for the patients was highly individual, as was the topography and size of the defects after resection. This means a limitation in the interpretation of results if comparative conclusions of treatment outcomes within a rather

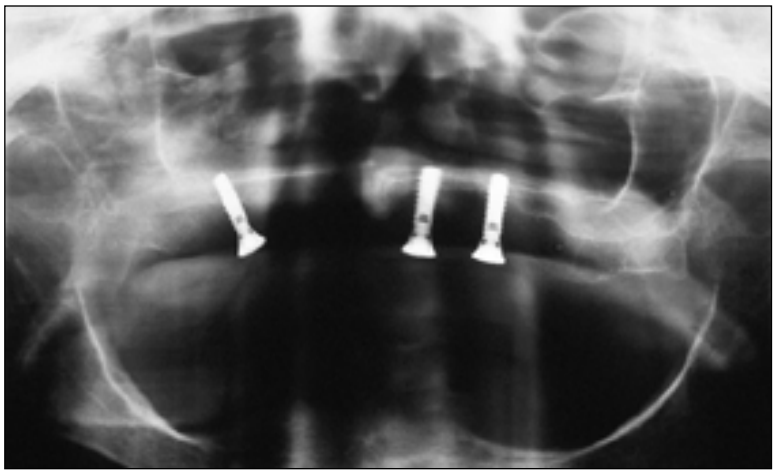

Fig 2a Female patient with a melanoma of the floor of the nasal cavity. The radiograph shows 3 implants in residual maxillary bone. The anterior bony defect after resection is visible. No bone graft was performed.

small group should be drawn. For 4 patients, radiotherapy was prescribed as the initial therapy for the tumor, before resection. However, surgery became necessary because of the development of extended radionecrosis. It is usually suggested that surgical intervention in irradiated tissues be avoided,[24] and resection of tumors should precede irradiation by at least 3 weeks. The osteogenetic capacity of bone is significantly decreased after irradiation. If necessary, plastic reconstructive surgery, including implant placement, should be carried out after an interval of at least 6 months after radiotherapy. It seems to be advantageous for extensive surgery, such as tumor resection, hard and soft tissue grafting, and implant placement, to be accomplished in a 1-stage procedure. This was in fact accomplished for 9 patients in the present study. Nevertheless, some complications were observed, and grafted soft tissues required special management, particularly with regard to the neck portion of the implants.

Fig 2b Clinical intraoral situation. The soft tissue could be maintained. The 3 implants are splinted with a bar designed to support an overdenture.

Further, optimal placement of the implants with respect to prosthetic reconstruction and design was not always achieved. During the healing phase after resection of tumors and placement of implants, additional corrective treatment often became necessary before the prosthodontic treatment could take place. Thus, the time lag between surgical placement of the implants and fabrication of the implant-supported prosthesis varied from 3 to 16 months. This is distinctly different from routine patients who undergo a healing period of 3 to 6 months after implant surgery.

After completion of the prostheses, no further development of osteoradionecrosis was observed, although it is known that irradiation doses above 65 Gy may significantly increase the risk.[25,26] However, development of osteoradionecrosis may also be a reason for late failures after many years, and the average observation period in the present study was rather short. Those 3 patients who developed osteoradionecrosis after only a few months had received irradiation doses of 50, 65, and 72 Gy, respectively. From the present data, the effectiveness of HBO therapy could not be assessed, since only 2 patients underwent this adjunctive treatment. The literature reveals contradictory opinions and experiences. Animal studies[15,27] indicate that HBO therapy may enhance the process of osseointegration, and some clinical reports seem to support these experimental results.[28,29] Otherwise, reports on mandibular implants in small groups of patients who all underwent radiotherapy without HBO treatment show a high survival rate of 95%.[30,31]

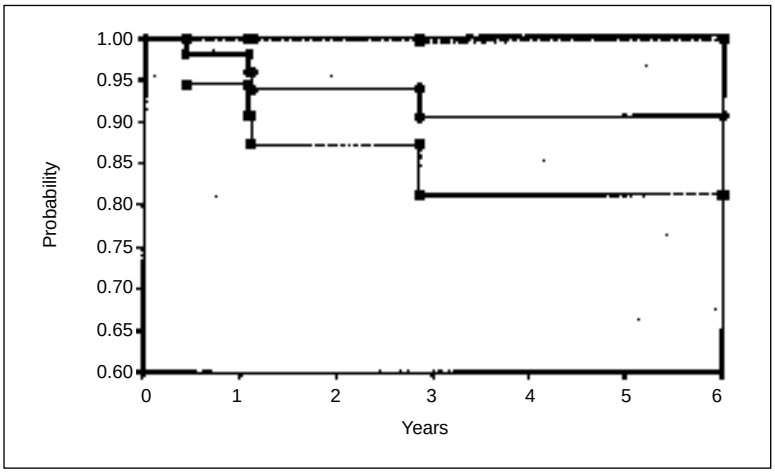

Fig 3 Life table analysis: The diagram shows 3 curves. Dotted lines exhibit the probability within a 95% confidence interval, and the solid line represents the cumulative survival rate of the 53 implants.

Table 3 Failures and Complications

Implantation and radiotherapy	Total no. of implants placed	Early loss	Late loss	Complication
Implantation after osteoradionecrosis	9	1	1	—
Implantation after radiotherapy	7	—	—	—
Implantation before radiotherapy	17	—	2	—
No radiotherapy	20	—	—	1
Total no. of implants	53	1	3	1

Table 4 Statistical Analysis

Time	Overall survival rate (%)	At 95% confidence interval
2 y	93.9	87.3 to 100%
3 y	90.5	81.2 to 99.7%
5 y	90.5	81.2 to 99.7%

The implants in the present study were assessed according to criteria for implants placed in routine situations.[17] As a consequence, symptoms such as pain or dysesthesia are not reliable parameters for tumor patients. Dysesthesia, paresthesia, or complete anesthesia are often the result of extended tumor surgery. Reliable parameters for long-term monitoring of implants and determining implant success or failure in special indications such as those presented in this study are not yet available. Therefore, it seems appropriate to calculate the cumulative survival rate as the best way to express the effectiveness of implant therapy in tumor patients. A total of 4 implants in 3 patients was lost; all were located in the mandible. The survival rate of mandibular implants in this study was similar to comparable findings with tumor patients[4]; however, it was distinctly lower than that reported for mandibular implants under normal conditions.[3] Interestingly, the survival rate in the maxilla was significantly better than in the mandible (no implants were lost in the maxilla), although in general, the literature documents higher failure rates for maxillary implants, be it in routine situations[32,33] or in tumor patients.[29] This change in the ratio of failures of maxillary and mandibular treatment in the present study can be explained by the fact that *(1)* more implants were placed in the mandible than in the maxilla (thus more mandibular implants were at risk); *(2)* only 2 of the 12 maxillary implants were located in irradiated bone, but 31 of the 41 implants located in the mandible were located in irradiated bone; and *(3)* all 3 patients with implant losses had a history of heavy smoking and had not stopped smoking after tumor surgery.

In a previous survey[8] that comprised 23 tumor patients treated before 1990, only 3 patients with a total of 6 implants were found; all implants had been placed in the anterior mandible. All of these 6 implants had been placed in nonirradiated bone. This clearly shows actual changes in the treatment modality for patients with malignant oral tumors and in patients with increased risk toward a more frequent use of implants. From a clinical point of view, implants significantly facilitate prosthodontic procedures and enhance the treatment outcomes of oral rehabilitation in many patients after tumor resection. Most patients have been or become edentulous, and therefore the overdenture is the preferred prosthetic restoration. Overdentures may favor and facilitate oral hygiene procedures, are less expensive than fixed prostheses, and may better compensate for lost tissues and remaining defects after tumor resection. Minor adjustments can easily be carried out. Since the life-span prognosis for most patients with oral malignant tumors is rather poor[8] and the 5-year survival rate is reached by approximately 50% of the patients, it is difficult to collect long-term data on implants placed in patients with resection of malignant tumors.

Conclusions

In recent years, an increasing number of patients received treatment with implants after resection of malignant oral tumors. This may facilitate the adaptation and fixation of oral prostheses. In this patient population, an increasing number of implants have also been placed in irradiated bone, which may impair short- and long-term survival. In the present study, all implants that were lost had been placed in irradiated bone. Nevertheless, life table analysis showed that the survival rate of implants was rather high within a limited time period, in spite of impaired conditions, such as soft and hard tissue grafts and irradiation.

All prostheses in the present study were maintained during the entire time period observed, representing a survival rate of 100%. The life-span prognosis is often shortened for patients with oral malignant tumors. Five patients (30% of the patients) included in the study were lost because of early death. No implant had failed in the patients who were lost.

References

1. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of tissue-integrated implants in the treatment of the totally edentulous jaw. Int J Oral Maxillofac Implants 1990;5:347–359.
2. Van Steenberghe D, Quirynen M, Calberson L, Demanet M. A prospective evaluation of the fate of 697 consecutive intraoral fixtures ad modum Brånemark in the rehabilitation of edentulism. J Head Neck Pathol 1987;6:53–58.
3. Buser D, Mericske-Stern R, Bernard JP, Behneke N, Hirt HP, Belser UC, Lang NP. Long term evaluation of non-submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2953 implants. Clin Oral Implants Res 1997;8:161–172.
4. Esser E, Wagner W. Dental implants following radical oral cancer surgery and adjuvant radiotherapy. Int J Oral Maxillofac Implants 1997;12:552–557.
5. Van Steenberghe D, Brånemark P-I, Quirynen M, De Mars G, Naert I. The rehabilitation of oral defects by osseointegrated implants. J Clin Periodontol 1991;18:488–493.
6. Fröhlich M, Bernstein P, Metelmann HR, Möhner M. Zur Epidemiologie der Lippen- und Mundhöhlenmalignome. In: Schuchardt K, Schwenzer N (eds). Fortschritte der Kiefer- und Gesichtschirurgie, vol 37: Therapie des Mundhöhlenkarzinoms. Stuttgart/New York: Thieme, 1992:1–3.
7. Schwenzer N, Grimm G. Zahn-Mund-Kiefer-Heilkunde: Spezielle Chirurgie, vol 2. 2 Überarbeitete und erweiterte Auflage. Stuttgart/New York: Thieme, 1990.
8. Mericske-Stern R, Mericske E, Berthold H, Geering AH. Resektionsprothetik. Aspekte der Behandlung von Patienten mit oralen Defekten nach Tumorresektion: Eine retrospektive Studie. Schweiz Monatsschr Zahnmed 1994;104: 58–72.
9. Granström G, Tjellström A, Brånemark P-I, Fornander J. Bone-anchored reconstruction of the irradiated head and neck cancer patient. Otolaryngol Head Neck Surg 1993; 108:334–343.
10. Granström G, Bergström K, Tjellström K, Brånemark P-I. A detailed study of titanium implants lost in irradiated tissues. Int J Oral Maxillofac Implants 1994;9:653–662.
11. Jacobsson M, Tjellström A, Thomsen P, Albrektsson T, Turesson I. Integration of titanium implants in irradiated bone. Histological and clinical study. Ann Otol Rhinol Laryngol 1988;97:337–340.
12. Granström G, Tjellström A, Albrektsson T. Post-implantation irradiation of titanium implants for head and neck cancer treatment. Int J Oral Maxillofac Implants 1993;8: 495–501.
13. Schön R, Ohno K, Kudo M, Michi K. Peri-implant tissue reaction in bone irradiated the fifth day after implantation in rabbits: Histologic and histomorphometric measurements. Int J Oral Maxillofac Implants 1996;11:228–238.
14. Nilsson P, Albrektsson T, Granström G, Röckert HO. The effect of hyperbaric oxygen treatment of bone regeneration. Int J Oral Maxillofac Implants 1988;3:43–48.
15. Johnsson K, Hansson Å, Granström G, Jacobsson M, Turesson I. The effects of hyperbaric oxygenation on bone-titanium implant interface strength with and without preceding irradiation. Int J Oral Maxillofac Implants 1993;8:415–419.

16. Granström G. The use of hyperbaric oxygen to prevent implant fixture loss in the irradiated patient. In: Worthington P, Brånemark P-I (eds). Advanced Osseointegration Surgery: Applications in the Maxillofacial Region. Chicago: Quintessence, 1992:336–345.
17. Buser D, Weber HP, Brägger U, Balsiger CH. Tissue integration of one-stage ITI Implants: 3-year results of a longitudinal study with hollow-cylinder and hollow-screw Implants. Int J Oral Maxillofac Implants 1991;6:405–412.
18. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. J Am Stat Assoc 1958;53: 457–481.
19. Mittermayer CH. Oralpathologie. Stuttgart/New York: Schatauer, 1981.
20. Martin E, Junod JP. Lehrbuch der Geriatrie, ed 2. Bern: Huber, 1986.
21. Granström G, Jacobsson M, Tjellström A. Titanium implants in irradiated tissue: Benefits from hyperbaric oxygen. Int J Oral Maxillofac Implants 1992;7:15–25.
22. Krutchkoff DJ, Chen J, Eisenberg E, Katz RV. Oral cancer: A survey of 566 cases from the University of Connecticut Oral Pathology Biopsy Service, 1976–1986. Oral Surg Oral Med Oral Pathol 1990;70:192–298.
23. Höltje WJ, Schwipper V, Klose G. 5-Jahres Überlebensrate von Patienten mit Plattenepithelkarzinomen der Mundhöhle; eine retrospektive Studie. Fortschr Kiefer-Gesichtschir 1992;37:26–29.
24. Marx RE, Johnson RP. Studies in the radiobiology of osteoradionecrosis and their clinical significance. Oral Surg Oral Med Oral Pathol 1987;64:379–390.
25. Nguyen TD, Panis X, Froissart D, Legros M, Coniux P, Loirette M. Analysis of late complications after rapid hyperfractionated radiotherapy in advanced head and neck cancers. Int J Radiat Oncol Biol Phys 1988;14:23–25.
26. Widmark G, Sague S, Heikel P. Osteoradionecrosis of the jaw. Int J Oral Maxillofac Surg 1989;18:302–306.
27. Larsen PE, Stronczek MJ, Beck FM, Rohrer M. Osseointegration of implants in radiated bone with and without adjunctive hyperbaric oxygen. J Oral Maxillofac Surg 1993;51:280–287.
28. Ueda M, Kaneda T, Takahashi H. Effect of hyperbaric oxygen therapy on osseointegration of titanium implants in irradiated bone: A preliminary report. Int J Oral Maxillofac Implants 1993;8:41–44.
29. Niimi A, Fujimoto T, Nosaka Y, Ueda M. A Japanese multicenter study of osseointegrated implants placed in irradiated tissues: A preliminary report. Int J Oral Maxillofac Implants 1997;12:259–264.
30. Franzén L, Rosenquist JB, Rosenquist KI, Gustafsson I. Oral implant rehabilitation of patients with oral malignancies treated with radiotherapy and surgery without adjunctive hyperbaric oxygen. Int J Oral Maxillofac Implants 1995;10:183–187.
31. Taylor TD, Worthington P. Osseointegrated implant rehabilitation of the previously irradiated mandible: Results of a limited trial at 3 to 7 years. J Prosthet Dent 1993;69: 60–69.
32. Jemt T, Chai J, Harnett J, Heath MR, Hutton JE, Johns RB, et al. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. Int J Oral Maxillofac Implants 1996;11: 291–298.
33. Enquist B, Bergendal T, Kallus T. A retrospective multicenter evaluation of osseointegrated implants supporting overdentures. Int J Oral Maxillofac Implants 1988;3:129–134.