Int. J. Oral Maxillofac. Surg. 2021; xx: 1–7
https://doi.org/10.1016/j.ijom.2024.03.001, available online at https://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Dental Implants

Guided placement of zygomatic implants in head and neck cancer patients: implant survival and patient outcomes at 1–3 years of follow-up☆

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N. Vosselman, J. Kraeima, K. Ng Wei Siang, G. M. Raghoebar, M. J.H. Witjes, S. A.H. J. de Visscher: Guided placement of zygomatic implants in head and neck cancer patients: implant survival and patient outcomes at 1–3 years of follow-up. Int. J. Oral Maxillofac. Surg. 2021; xx: 1–7. © 2024 The Author(s). Published by Elsevier Inc. on behalf of International Association of Oral and Maxillofacial Surgeons. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Abstract. Zygomatic implants (ZI) are a valuable option for supporting an obturator prosthesis after maxillary resection. This study was performed to assess the clinical outcomes of a digitally validated guided technique for ZI placement, followed by immediate prosthetic obturation. The primary objective was to evaluate implant survival, while the secondary objective was to assess patient-reported quality of life post-rehabilitation. Twelve patients treated for head and neck cancer received a total of 36 ZI after ablative surgery. The mean duration of ZI follow-up was 30.1 months. The survival rate of ZI placed in non-irradiated patients was 100%, while it was 85% in irradiated patients. Patient-reported outcomes were evaluated using the Liverpool Oral Rehabilitation Questionnaire (LORQv3) and the University of Washington Quality of Life Questionnaire (UW-QOL v4). Most patients reported satisfactory outcomes in the oral function domain of the LORQv3 (mean score 17.7 ± 4.5; possible range 12–48, with lower scores indicating better outcomes). Regarding the UW-QOL v4, the swallowing and chewing domains had the highest scores (mean 97.5 ± 8.7 and 95.8 ± 14.4, respectively; maximum possible score of 100). In conclusion, this treatment approach improves function and quality of life after maxillary ablative surgery. However, irradiated patients showed a noticeable trend of higher implant failure, and this was influenced by tumour position and size impacting the radiation dose to the zygomatic bone.

Keywords: Head and neck cancer; Maxilla; Zygoma; Dental implants; Dental prosthesis; Computer-assisted surgery.

Accepted for publication 4 March 2024
Available online xxxx

☆ This study has been registered in the PaNaMa RMS research management system (register ID: 9296).

0901-5027/xx0001 + 07

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The standard treatment for patients with a maxillary malignancy consists of a (partial) maxillectomy, often in combination with postoperative radiotherapy. The resulting maxillary defect has a profound impact on the patient's functional abilities[1]. The impaired oral functions are often further compromised if post-surgical radiotherapy is needed, due to related radiation-induced sequelae[2].

The repair of maxillary defects after oncological surgery is possible by means of reconstructive surgery or a prosthetic obturator, depending on patient characteristics, the tumour location, and the surgical team[3]. The overall objective in patients with these maxillary defects is to restore oral function by following a prosthetic-driven reconstruction approach[4]. The choice of reconstruction method in cases of extensive maxillary resection involves a comprehensive evaluation of individual patient factors. While free flap reconstruction remains a robust option for many, the patient's age and health status can influence the decision-making process. Zygomatic implants (ZI) with an obturator prosthesis offer a viable alternative that provides adequate closure of the defect and dental rehabilitation in cases where a less invasive approach is preferred or contraindications for extensive bony reconstruction are present.

In cases where an obturator prosthesis is selected as the primary method of reconstruction, enhancing its retention and stability is crucial. One of the options for improving the retention and stability of obturator prostheses is the application of ZI[5]. These implants can significantly enhance the functional and aesthetic outcomes for patients while maintaining a patient-centred approach that prioritizes their overall wellbeing and long-term quality of life. The ablation surgery, reconstructive surgery, and prosthetic rehabilitation can be planned preoperatively with the support of three-dimensional (3D) virtual surgical planning (VSP) and computer-aided design. The accuracy of this approach has been confirmed in cadaver and feasibility studies[6,7]. The question that still needs to be answered through long-term follow-up is whether this advanced technique results in high implant survival and satisfactory patient outcomes in the long term. Therefore, the aim of this study was to assess the ZI survival rate overall and according to post-surgical radiotherapy data, as well as to determine the patients' self-reported quality of life at 1–3 years after the treatment.

Methods

Study design and patients

The study was designed as an ongoing follow-up study for monitoring ZI survival and patient outcomes over the long term. All included patients, who were treated for oral malignancies, underwent guided maxillectomy followed by reconstruction with an obturator prosthesis, which was supported by immediately placed ZI. The treatment protocol utilizes a novel full 3D workflow. This paper reports the initial phase of the study, at 1–3 years of follow-up after the single-stage treatment procedure.

A VSP was developed for ZI placement and restoration with a screw-retained immediate obturator prosthesis. Before surgery, the patients underwent diagnostic imaging for surgical planning (computed tomography (CT) and magnetic resonance imaging (MRI)). Dentulous patients had their teeth digitally scanned and matched to 3D models, while edentulous patients had additional cone beam computed tomography (CBCT) scans with radiopaque markers on their prostheses. In the constructed 3D models, the ZI were virtually planned based on the occlusion and prosthetic considerations.

The zygomatic oncology implants (Zygex; Southern Implants, Irene, South Africa) were placed by one of two surgeons (G.R. or S.V.). Immediately after guided maxillary resection, the ZI guide was accurately positioned and stabilized, and guided drilling was performed following the manufacturer's recommended drill sequence (Southern Implants protocol). The zygomatic oncology implants were all placed as pairs in the zygomatic bone. Both ZI were placed through the guide into the preferred prosthodontic positions determined before the surgery. Good primary stability was achieved for all of the ZI at the time of insertion. Subsequently, the obturator prosthesis was fitted and the temporary polyether ether ketone (PEEK) abutments were bonded with ultraviolet light curing resin. This enabled stability and retention of the obturator prosthesis and provided the necessary maxillary obturation directly after surgery.

This guided procedure has been described in detail in previous studies[6,7]. All 10 patients from the feasibility study[7] were included in this follow-up study. Following the completion of the feasibility study, two additional patients were treated using this technique and were subsequently included in this study. The patients were assessed in the Department of Oral and Maxillofacial Surgery of the University Medical Centre Groningen, the Netherlands. The study was approved by the Medical Ethics Review Board of the University Medical Center Groningen following the guidelines of the Declaration of Helsinki (WMO 202000569).

Assessments

The primary outcome measure was ZI survival. As part of the standard oncological follow-up protocol of the Dutch Cooperative Head and Neck Group, overall disease control is monitored every 3 months. As part of this protocol, a multidisciplinary consultation that included a maxillofacial prosthodontist was conducted to provide the necessary prosthodontic aftercare. All of the patients were monitored closely and had been checked by the maxillofacial prosthodontist (N.V.) within the 3 months prior to the study cut-off date of April 28, 2023.

A CBCT scan was performed and a panoramic radiograph of the implants was obtained directly after surgery. Further panoramic radiographs were obtained after installation of the definitive obturator prosthesis and at 1 year after prosthetic delivery. Regarding the patients who needed postoperative irradiation, the radiotherapy contouring, 3D treatment planning, fractionation, and total dose were reviewed retrospectively. The zygomatic bones of the patients were marked on the CT scan images with specific lines to precisely delineate their size, shape, and location. The implant bed was subsequently verified by imaging until an exact match was found. In this way, accurate radiation doses, including the maximum dose within the ZI implant bed, could be calculated for all of the patients who underwent postoperative radiotherapy.

Patient-reported quality of life after rehabilitation was assessed by administering two questionnaires 4 weeks after the definitive implant-supported obturator prosthesis was placed. The first questionnaire was the Liverpool

Oral Rehabilitation Questionnaire (LORQv3; Dutch version). From the overall questionnaire, 27 questions can be divided into four domains consisting of (A) oral function, (B) orofacial appearance, (C) social interaction, and (D) patient/prosthetic satisfaction. The items are rated on a 1–4 Likert scale, with 1 = never, 2 = sometimes, 3 = often, and 4 = always; lower scores indicate better outcomes.

The second questionnaire, the University of Washington Quality of Life Questionnaire version 4 (UW-QOL v4)[8], is a widely used tool for the evaluation of health-related quality of life in patients with head and neck cancer[9]. It consists of 12 questions concerning pain, appearance, activity, recreation, swallowing, chewing, speech, shoulder function, taste, saliva, mood, and anxiety domains. The answers to each question are scored from 0 to 100, with 100 being the best score.

Statistical analysis

The statistical analysis was restricted to descriptive statistics, which were calculated using IBM SPSS Statistics version 28 (IBM Corp., Armonk, NY, USA).

Results

At the data cut-off point (April 28, 2023), 12 patients (seven female, five male), with a median age of 66 years (range 45–87 years), had undergone the procedure and had been followed-up for a minimum of 1 year post-rehabilitation. The maxillary abnormality diagnoses are summarized in Table 1. In total, 36 guided ZI were placed. Among the 12 patients, eight were edentulous when treatment started, of whom six received four ZI, while two received two ZI on the defect side and endosseous implants (Nobel Parallel; Nobel Biocare, Gothenburg, Sweden) were placed in the contralateral native maxilla. The other four patients were dentulous, and they all received two ZI on the defect side; three of them also received endosseous implants (Nobel parallel) in the shortened contralateral dental arch for further prosthetic retention. All of the patients received a definitive implant-retained obturator prosthesis to replace the fixed surgical obturator prosthesis. Six patients needed postoperative radiation due to the T and N cancer stage. The postoperative radiotherapy dose to the ZI site ranged from 2 Gy to 128 Gy (median dose 40 Gy). An overview of the patient characteristics is shown in Table 2.

Table 1. Maxillary abnormality diagnoses (12 patients).

Diagnoses	Number of patients
Squamous cell carcinoma	8
Melanoma	2
ORN maxilla	1
Osteosarcoma	1

ORN, osteoradionecrosis.

Table 2. Patient characteristics.

Characteristics	
Patients, *n*	12
Sex, *n*	
Female	7
Male	5
Age at start of treatment (years)	
Mean ± SD	64 ± 11.8
Median (range)	66 (45–87)
Therapy, *n*	
Surgery	6
Surgery and postoperative RT	4
Preoperative RT, surgery, and postoperative RT	2
RT dose at the zygomatic implant site (Gy)	
Mean ± SD	40
Median (range)	40 (2–128)
Dentulous maxilla, *n*	4
Edentulous maxilla, *n*	8
Zygomatic oncology implants, *n*	36
Endosseous implants, *n*	7
Obturator prostheses, *n*	12

RT, radiotherapy; SD, standard deviation.

Implant survival

At the data cut-off point, the overall ZI survival rate was 91.7%, with a 100% survival rate in the non-irradiated group of patients and 85% survival rate in the irradiated patient group; the mean ± standard deviation implant follow-up period was 30.1 ± 11.1 months (Table 3).

A total of three ZI failed in two irradiated patients: one patient lost one implant and the other patient lost two. One failure was a ZI placed on the dorsal side of the defect, which had received 57.4 Gy post-surgically. Implant mobility was observed during the prosthetic aftercare. The same patient had received a second more ventrally placed ZI during the same surgery. Despite receiving an equal dose of radiotherapy, the implant functioned successfully while loaded with a magnet attachment to achieve prosthetic retention within the defect area. Thus far, no postoperative complications have been observed for this implant. The two other failures were in a patient who received pre- and postoperative radiotherapy. Before the ablative surgery, the zygoma bone was subjected to irradiation, up to a dose of 58 Gy, and unfortunately shortly after surgical treatment a recurrence was observed. An additional dose of 70 Gy was then delivered, bringing the total dose to 128 Gy. The guiding principle is to achieve the desired dose coverage to the target volume while sparing organs at risk (OAR) as much as possible. The dose–volume histograms of both radiotherapy treatment plans were used to evaluate the re-irradiation constraints for the OAR such as the brainstem, spinal cord, larynx, and bone (including the ZI). The boundaries for 'acceptable damage' are therefore different for the re-treatment situation than for the initial treatment, and in this situation maximum doses higher than 100 Gy to the bone are unfortunately not uncommon in head and neck cancer patients, especially when the OAR lie within the target regions[10,11].

Patient-reported outcomes

All of the study patients completed the LORQv3 and UW-QOL v4 questionnaires at 4 weeks after the final obturator prosthesis had been placed. An overview of the questions and domains of the LORQv3, and the mean ± standard deviation scores for the 12 patients, are given in Table 4. The domains of the UWQOL v4 and the mean

Table 3. Implant data.

	Number placed	Number lost	Survival rate	Implant follow-up (months), mean ± SD
Zygomatic implants (Zygex)	36	3	91.7%	30.1 ± 11.1
Endosseous implants (Nobel Parallel)	7	0	100%	38.5 ± 8.8

Table 4. Liverpool Oral Rehabilitation Questionnaire (LORQv3) scores for the 12 patients with zygomatic oncology implant-supported obturators.

Question number	Question	Score[a] Mean ± SD	Domain/ subtotal scores Mean ± SD (Possible score range)
Chewing			
1	Difficulty with chewing	1.33 ± 0.49	
2	Pain when chewing	1.17 ± 0.39	
16	Chewing ability influences choice of food	1.50 ± 0.67	
Subtotal			4.25 ± 1.36 (3–12)
Swallowing			
3	Difficulty with swallowing solids	1.33 ± 0.65	
4	Difficulty with swallowing liquids	1.00 ± 0.00	
Subtotal			2.33 ± 0.65 (2–8)
Salivation			
5	Food particles collect under tongue	1.33 ± 0.65	
6	Food particles stick to palate	1.58 ± 0.79	
7	Food particles stick inside cheeks	1.33 ± 0.65	
8	Mouth dryness	1.58 ± 0.69	
9	Problems with drooling	1.83 ± 0.72	
Subtotal			7.67 ± 2.53 (5–20)
10	Problems with speech	1.50 ± 0.67	
17	Difficulty with opening the mouth	1.92 ± 0.99	
(A) Oral function			17.67 ± 4.54 (12–48)
Question number	Question	Score Mean ± SD	Domain/ subtotal scores Mean ± SD (Possible score range)
11	Upset by your facial appearance	1.17 ± 0.39	
12	Upset by the appearance of your mouth	1.25 ± 0.45	
13	Upset by the appearance of your lips	1.08 ± 0.29	
14	Upset by the appearance of your teeth	1.17 ± 0.39	
(B) Orofacial appearance			4.66 ± 1. 07 (4–16)
15	Chewing ability affects social life	1.50 ± 0.67	
(C) Social interaction			1.50 ± 0.67 (1–4)
Patient satisfaction			
20	Embarrassed about conversing	1.17 ± 0.39	
21	Refuse dinner invitations	1.08 ± 0.29	
22	Feel loss of self-confidence	1.17 ± 0.39	
23	Difficult to open your mouth	1.33 ± 0.65	
Subtotal			5.83 ± 1.47 (4–16)
Prosthetic satisfaction			
26	Dissatisfied with your upper implant-retained teeth	1.17 ± 0.39	
27	Teeth cause soreness/ulceration of the gum	1.42 ± 0.51	
28	Food particles collect under your upper implant-retained teeth	2.08 ± 1.00	
29	Have to take out your upper teeth when eating	1.00 ± 0.00	
30	Feel insecure with your upper implant-retained teeth	1.08 ± 0.29	
31	Worried that your teeth might fall out	1.00 ± 0.00	
Subtotal			7.83 ± 1.80 (6–24)
(D) Satisfaction			13.67 ± 2.93 (10–40)

SD, standard deviation.
[a]Score on a 1–4 Likert scale, ranging from 1 'never' to 4 'always'; lower scores indicate better outcomes.

± standard deviation scores for the 12 patients are listed in Table 5.

The mean overall score for section A of the LORQv3, covering oral function, was 17.7 ± 4.5 (possible range 12–48, with 12 representing the best oral function). This indicates a satisfactory outcome for this domain, and is comparable to the results of other studies[12].

Regarding the UW-QOL v4, the scores for the 12 domains were normally distributed; the mean values are shown in Table 5. Swallowing and chewing were the best scoring domains, with a mean score of 97.5 ± 8.7 and 95.8 ± 14.4, respectively; 11 out of the 12 patients gave responses for these domains with the best possible score of

Table 5. Mean scores for the 12 domains of the University of Washington Quality of Life questionnaire (UW-QOL v4), for the 12 patients with zygomatic oncology implant-supported obturators.

Domain	Score[a] Mean ± SD	Total patients scoring 100, *n* (%)
Pain	83.3 ± 22.2	7 (58.3)
Appearance	89.6 ± 16.7	8 (66.7)
Activity	87.5 ± 16.9	7 (58.3)
Recreation	87.5 ± 19.9	8 (66.7)
Swallowing	97.5 ± 8.7	11 (91.7)
Chewing	95.8 ± 14.4	11 (91.7)
Speech	87.5 ± 15.4	7 (58.3)
Shoulder	91.7 ± 21.2	10 (83.3)
Taste	75.8 ± 25.7	5 (41.7)
Saliva	77.5 ± 13.6	3 (25)
Mood	83.3 ± 12.3	4 (33.3)
Anxiety	70 ± 0.0	0 (0)

SD, standard deviation.
[a]Score on a scale of 0–100, with higher scores indicating better outcomes.

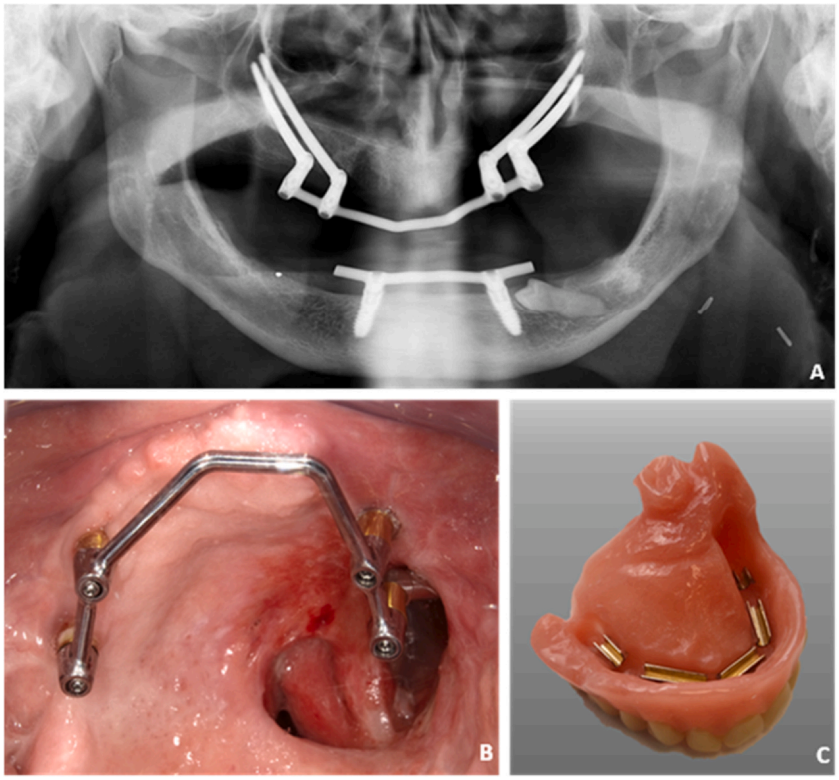

Fig. 1. (A) Panoramic radiograph and (B) intraoral views of a patient with a U-shaped cross-arch suprastructure on four zygomatic oncology implants, two positioned in the defect and two on the contralateral side. (C) The matching definitive implant-retained obturator prosthesis.

100. The worst score was for anxiety, with a mean score of 70 ± 0.0; all 12 patients marked the box "I am anxious about my cancer" (score 70). When selecting the three most important domains, activity was considered by the patients to be the most important.

Discussion

This study showed that ZI placed under guidance and immediately loaded with an obturator prosthesis had a high survival rate after a minimum period of 12 months. The overall implant survival rate of 91.7% is consistent with other studies in which ZI have been used to improve prosthetic management in head and neck cancer patients[13]. Compared to the use of ZI for prosthetic rehabilitation in patients with extreme resorption of the maxilla, with a mean survival rate of 96.5%, the rate in the current study is slightly lower[14].

In terms of compromising the soft tissues, the placement of endosseous implants has a less invasive impact when compared to ZI. Endosseous implant placement should be considered when the bone volume in the native maxilla remains sufficient after a maxillectomy. In this study, the residual maxillary bone volume in two of the edentulous patients was good and it was possible to place endosseous implants in the contralateral maxilla instead of ZI. However, the combination of ZI and endosseous implants had drawbacks regarding the time to prosthetic delivery. Compared to the edentulous patients rehabilitated with four ZI, there was a delay of 3 months for installation of the definitive implant-retained obturator prosthesis in these patients. Despite needing additional prosthodontic appointments, as well as interim obturator prostheses, the final prosthetic result was within expectations (Figs. 1 and 2).

Implant and prosthetic success are not the only outcomes that should be evaluated in terms of treatment success. The importance of patient quality of life after cancer treatment has become more significant over the past decade[15]. Rehabilitation with the definitive implant-retained obturator prosthesis resulted in favourable patient-reported outcomes, as shown by the results for the UW-QOL v4. Overall quality of life several months after the treatment was good or very good. Regarding the LORQv3, the worst scores were obtained for the domain 'salivation' and for the question on problems with mouth opening. The patients who reported that they often or always experienced problems with these items had all undergone postoperative radiotherapy. Thus irradiation leads to a higher risk of impaired oral function, specifically in relation to mouth dryness and trismus[16].

Caution should be taken with implant placement when radiation is part of the treatment plan[17]. Metallic artefacts, such as in ZI, still pose a major challenge for radiation therapy, as they

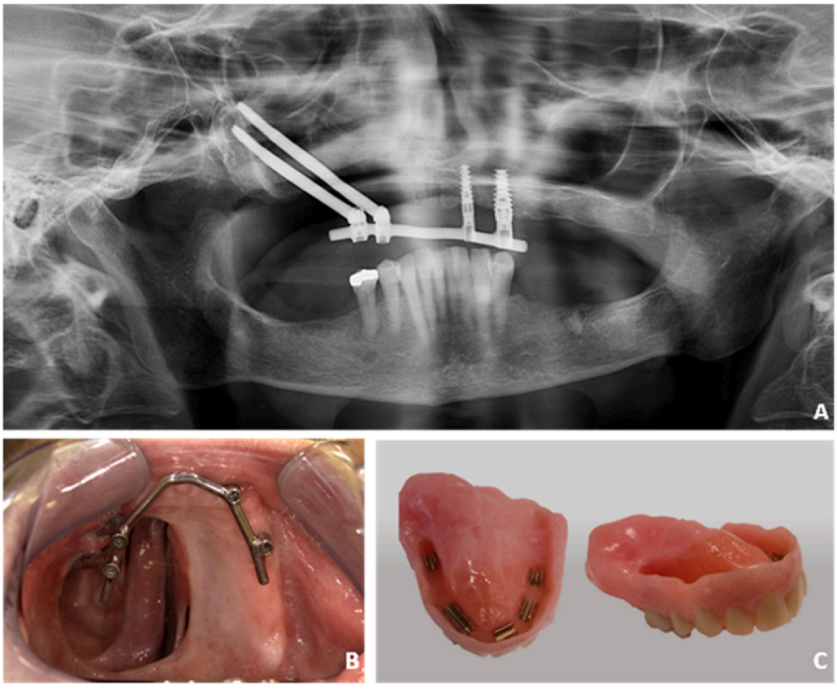

Fig. 2. (A) Panoramic radiograph and (B) intraoral views of a patient with a U-shaped cross-arch suprastructure on two zygomatic oncology implants positioned in the defect and two endosseous implants in the maxilla on the contralateral side. (C) The definitive implant-retained obturator prosthesis.

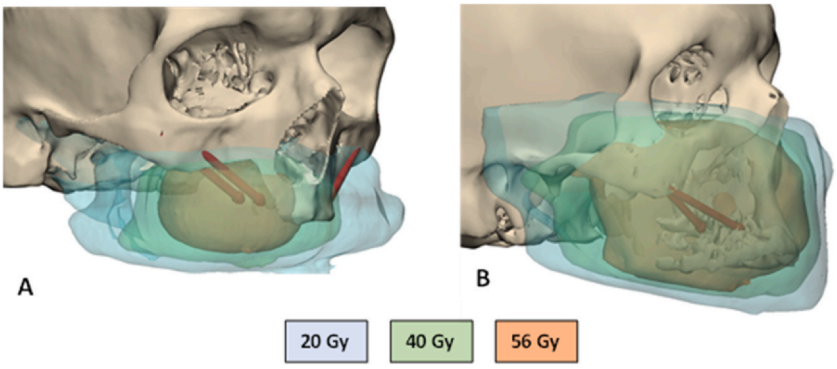

Fig. 3. Images A and B show accurate radiotherapy dose distributions (orange 56 Gy, green 40 Gy, and blue 20 Gy) for the primary tumour site, zygomatic bone, and zygomatic implants. Comparison of images A and B shows the significant differences in implant bed-specific dosages based on the location of the primary tumour.

impact the target volumes, type of radiation, and dose of radiation[18]. In the case of maxillary tumours, the zygomatic bodies are often subjected to irradiation, which therefore reduces the osseointegration potential. Although several papers have reported significant ZI failure rates of up to 31% in irradiated patients[19–21], it appears that the specific radiotherapy dose to the zygomatic bone in maxillary tumour patients has thus far not been specifically analysed or correlated with ZI failure. In this study, the radiation dose for each ZI was visualized. Implant bed-specific dosages differ significantly depending on the location of the primary tumour[22] (Fig. 3), and more than 55 Gy seems to be a risk factor for peri-implant bone resorption and ZI loss.

The implant survival rates in this study with follow-up of 1–3 years are favourable, and the patients reported favourable functional outcomes, which suggests that this a worthwhile therapeutic solution. Although the integration of the ZI was successful in the irradiated patients, there was a trend of higher ZI implant failure in the group of patients who underwent postoperative radiotherapy.

A limitation of this study is the sample size of head and neck cancer patients who received ZI; this may limit the generalizability of the findings. Long-term, prospective, longitudinal research involving a larger cohort of participants is required. Additionally, there is a need for an increased dataset that includes information on radiotherapy fields in relation to ZI.

The position and size of the tumour have a direct impact on the radiation dose to the zygoma bone. Greater insight into these relationships would contribute to a better understanding of the expected survival rate of zygomatic implants in patients who need adjuvant radiotherapy. Good dialogue and exchange of information between the surgical team and radiation oncologists is important and could contribute to the long-term success of zygomatic implant-based rehabilitation in head and neck cancer patients.

Ethical approval

The study was approved by the Medical Ethics Review Board of the University Medical Center Groningen (M21.282070).

Patient consent

Written patient consent was obtained.

Funding

None.

Competing interests

None.

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