A Retrospective Service-Evaluation of Implant Success, Survival, Peri-implant Health and Prosthetic Complications in a Cohort of Head and Neck Cancer Patients

Keywords

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ABSTRACT

Objectives: To determine the success, survival, peri-implant health and prosthetic complications in head and neck cancer patients receiving oral rehabilitation utilising dental implants between 2008 and the present day. Materials and methods: Service-evaluation. Survival Group: Retrospective review of records to determine implant survival and prosthetic complications. Success Group: Examination to determine implant success and health. Results: Survival Group: 260 implants in 81 individuals, median follow up 49.2 months. 89.3% implant survival at 96 months, no further failures up to 133 months. 40.9% individuals required repair or remake of prosthesis by 72 months - mostly denture re-lines. Success group: 164 implants in 48 individuals, median follow up 56 months. Peri-implant mucositis detected in 22% of fixtures (37.5% individuals); peri-implantitis in 12.8% (25% individuals); 33.3% fixtures exhibiting peri-implantitis at 120 months. Previous smoking significantly associated with development of peri-implantitis (HR 2.372, p=0.032, 95CI:1.232, 93.317). Compromised survival (e.g. peri-implantitis), absolute (not in mouth) or clinical failure estimated to occur in 28.1% fixtures at 101 months, mostly due to peri-implantitis. Conclusions: There is a large burden of ongoing care in this cohort, requiring interventions to improve peri-implant health and maintain complex prostheses. Oral rehabilitation and ongoing maintenance in this cohort is complex and multi-disciplinary.

INTRODUCTION

Cancer is a leading cause of morbidity and mortality worldwide and in the United Kingdom (UK), one in two people born after 1960 will receive a cancer diagnosis during their lifetime.[1,2] In the UK, roughly 367,000 new cases of cancer are recorded each year, of which over 12,200 will involve the head and neck region.[2,3] The prevalence of Head and Neck Cancer (HNC) has been steadily rising over the last decade. At present men are twice as likely to suffer from HNC compared to women, however, the incidence of HNC in women over the last 10 years has been increasing at faster rate that in men, 24% vs 17% respectively.[3]

The management of HNC may involve ablative surgery with or without reconstruction, radiotherapy, chemotherapy, or a combination of these modalities.[4] Treatment of HNC can lead to significant disability including alterations to oral soft and hard tissue anatomy, muscle imbalance, loss of teeth, alterations to facial appearance, as well as impaired speech, swallow and mastication.[5] As a result, oral rehabilitation can be challenging, with traditional removable prostheses achieving limited success at addressing aesthetic and functional requirements.[4,6-8] Dental implants are increasingly used in this cohort to help retain removable prostheses and reduce tissue loading, and can negate the need for a removable device entirely.[6,9,10] Improved function, comfort and aesthetics are reported as benefits of dental implant rehabilitation, exceeding that achievable with traditional removable prosthodontics.[7,8]

At present, the evidence regarding implant success and survival in HNC patients mostly consists of case reports or case series.[11,12] Randomised controlled trials are challenging to conduct in this cohort, so retrospective designs tend to be used. A recent large retrospective analysis examined implant survival in 167 HNC patients treated with 779 dental implants in a Restorative Dentistry Department, United Kingdom.[11] The results showed 95.5% survival at 5-years with no significant influence of gender, radiotherapy, or chemotherapy on implant failure. However, failure rates in reconstructed bone were higher than native bone ($p<0.01$). Implant success is more challenging to determine than survival, and it is a common finding when reviewing the implant literature that studies reporting 'success' are in fact often reporting survival.[13] To prove success, a detailed clinical and radiographic examination of the dental implants must be performed, whereas survival (mere presence) could be determined through a telephone discussion with the patient.[14] Whilst survival data is of use to clinicians, it should be remembered that a surviving implant could have active peri-implantitis, bleeding, suppuration and/or be causing discomfort during function.[14,15] In addition, survival statistics rarely consider prosthetic complications or function. A large multicentre International Team for Implantology study performed in the French general population examined 1022 consecutively placed implants over 7 years and found survival and success rates of 92.2% and 83.4% respectively.[16] Other large studies in healthy individuals have found 10-year success and survival rates as high as 98.8% and 97.0-% respectively, although supportive programmes and definitions of success are extremely variable.[13,17] This highlights the importance of making clear the distinctions between survival and success when conducting studies.

The primary objective of this study was to examine implant success rates and peri-implant health in a cohort of patients provided with dental rehabilitation after treatment for HNC in the South West of England. The secondary objectives were to determine incidence of prosthetic complications, implant survival, and covariates of implant success, peri-implant health and implant failure. Measures of quality of life (QoL) were explored post-rehabilitation, and the details are described in another paper. The resultant information is likely to be useful for clinicians planning dental rehabilitation and providing ongoing support in HNC patients.

MATERIALS AND METHODS

This service evaluation was performed within the Department of Restorative Dentistry, Musgrove Park Hospital, Taunton. Relevant written ethical approval was granted as part of the governance process provided by the Surgical Directorate at Musgrove Park Hospital, who confirmed that formal NHS ethical approval was not required for this service evaluation. All head and neck oncology patients that had undergone oral rehabilitation within the department using dental implants were invited to attend for a review examination, most of these patients had been discharged to the care of their general dental practitioners previously. The sample population consisted of 81 patients, who had a total of 260 dental implants placed between January 2008 and April 2021. Potential participants were invited to attend a review day on 29th February 2020 and 29 patients attended. A second review day was planned, however the Covid-19 Disease Pandemic broke out and the UK was sent into lockdown on the 23rd March 2020. Therefore, it was deemed unethical to invite patients into the hospital environment for a routine review appointment and further data was collected on an ad hoc basis as and when patients attended for review appointments between lockdowns, or if patients' initiated an appointment with the department for another reason. Data was collected until June 2021, with a further 19 participants being examined (48 out of 81 participants; 59%).

INCLUSION CRITERIA

Individuals:

1. With history of HNC.
2. Who had oral rehabilitation with the use of dental implant retained intra-oral prosthesis.
3. Who were rehabilitated within the Department of Restorative Dentistry, Musgrove Park Hospital, Taunton.
4. With at least one follow-up following: placement of dental implants in survival group; restoration of implants in success group.

EXCLUSION CRITERIA

1. Individuals receiving dental implants for indications other than head and neck cancer.
2. HNC patients who did not receive dental implants as part of their oral rehabilitation.
3. Where the minimum data set could not be collected.

STUDY VARIABLES

A data collection proforma was developed. The required data for inclusion in the implant and prosthetic survival analysis ("survival group") were: demographics; medical history; dental history; tumour diagnosis; primary oncological treatment including surgery, chemotherapy and radiotherapy (field and timing); site of implant placement; type of bone at site of implant placement (e.g. native, grafted); details of implant placed (date of placement, system, timing, diameter, length, tissue or bone level, documented complications; type of prosthesis (e.g fixed, removable); documented review of implants and prostheses. In addition to this, for the success and peri-implant health assessment ("success group") the following were required: detailed clinical and radiographic examination of dentition/dental implants including probing depths, presence of bleeding or suppuration, amount of keratinised mucosa; detailed examination of prosthesis.

DATA COLLECTION

Patients were identified using the Electronic Patient Report Outcome system (ePRO, Bluewire Technologies[Tr]). The case notes (combination of electronic notes and paper records) of all potential individuals were retrieved and reviewed to ensure eligibility. Eligible participants were sent a letter inviting them to participate in the study. Included with the letter of invitation was a consent form and stamped addressed envelope.

Individuals expressing an interest in participation were invited to the department for assessment. When participants arrived, a clinician (MPJ) reviewed the consent form and there was an opportunity to ask questions. Once valid informed consent was confirmed the participant was asked to complete the Liverpool Oral Rehabilitation Questionnaire version 3 and answer five open questions regarding the experience of their dental rehabilitation before undergoing a full clinical examination (AP).[18]

The full examination was undertaken following the data collection proforma and recorded in the clinical notes. A radiographic examination of the dentition and dental implants was performed only if clinically justified.[19] If participants had received an appropriate radiographic examination with their own dentist, a copy was requested. Clinical photographs were taken for all patients after consent.

Participants identified as requiring specialist level treatment after examination (e.g. for peri-implantitis or prosthetic failures) were managed within the Department of Restorative Dentistry. Any routine dental treatment required was requested to be completed by participants' own dentists.

OUTCOME MEASURES

The standard for implant success was based on the definitions provided by the International Congress of Oral Implantologists Consensus Report.[14] These definitions provide a Dental Implant Success Scale where: I) Success/Optimum health; II) Satisfactory survival; III) Compromised survival; IV) failure. In addition, the 2017 World Workshop Classification of Peri-implant Diseases and Conditions were used to give a rating of: I) Health; II) peri-implant mucositis; III) peri-implantitis.[15] The use of the two scales allowed for both clinical and functional measures of success and recording of peri-implant health.

DATA ANALYSIS

Data were extracted anonymously to a Microsoft Excel form for descriptive analysis of demographics. Kaplan-Meier survival analyses were performed at the implant level for success (success group), peri-implant health (success group) and survival (survival group). Survival curves for prosthetic complications (survival group) were performed at the patient level. Modelling of covariates utilised Cox proportional hazard models to identify covariates associated with time to event, and log-rank tests were used to determine the significance of differences between groups of co-covariates on the event of interest. Statistical analyses were performed with participants as the unit of analysis for participant-based variables (e.g. gender, smoking, history of periodontitis), and implants as the unit of analysis for examining the nature of the implant site (e.g. implant position, amount of keratinised mucosa). Deceased participants were included in the analysis of implant survival and prosthetic complications (using the most recent examination details), but not in determining success. Data were analysed using SPSS statistical software (SPSS (IBM® Version 27) with a statistical significance level set at alpha 0.05.

RESULTS

DEMOGRAPHICS

The minimum data set for examining implant survival and prosthetic complications was available for 260 implants placed in 81 individuals *(Figure 1, survival group*). Of these, 8 (9.9%) were deceased. Of the surviving patients, 48 (65.8%) attended for clinical and radiographic examination resulting in a success group (i.e. those who were clinically examined to determine success) of 164 implants in 48 people. The demographics of the study populations are outlined in Table 1.

The survival group had a variety of type and site of tumour *(Table 2*), with 87.7% having resection and 38.3% having reconstructive surgery via a variety of means *(Figure 2*). Eight participants (9.9%) had primary implant placement at the time of resection, whilst the remaining 73 (90.1%) had delayed placement. Twelve patients (14.8%) had implants placed by Oral and Maxillofacial Surgeons (OMFS) alone, a further 12 patients (14.8%) had placement jointly between OMFS and specialists in Restorative Dentistry, whilst the remaining 57 patients (70.4%) had implants placed by Restorative Specialists. Only 10 implants (3.8%) were placed into non-native reconstructed bone, with the remaining 250 implants

Figure 1: Flow diagram of study recruitment.

Table 1. Demographics of study populations. Most participants received several treatment modalities, so results do not tally to 100%.

	Survival group	Success group
Number of participants	81	48
Total implants in group	260	164
Median number implants per individual (Min, Max)	3 (1, 7)	3 (1, 7)
Gender – female/ male	30.9%/ 69.1%	31.3%/ 68.7%
Median age in years (Min, Max)	69.5 (23, 89)	69.5 (23, 89)
Smoking history – Ex/ Never	63%/ 37%	64.6%/ 35.4%
Median follow up in months (Min, Max)	49.2 (2, 133)	56 (18, 132)
% resective surgery	87.7	83.3
% reconstructive surgery	38.3	37.5
% radiotherapy	71.6	72.9
% chemotherapy (all of these patients also received radiotherapy)	30.9	27.1

placed into native bone with no use of bone augmentation at the time of placement. Fifty-eight (71.6%) patients underwent radiotherapy treatment, with 180 (69.2%) dental implants placed in bone that received ≤40 Gy dose, 11 (4.3%) placed in areas ≥40 Gy and the remaining 69 (26.5%) placed in patients not receiving radiotherapy treatment. As so few implants were placed in the direct field of irradiation (≥40 Gy), dichotomous analysis (radiotherapy/no radiotherapy) was performed. Only a small number of patients underwent chemotherapy (30.9%), using various regimens not temporally related to implant placement, so this covariate was not entered into analysis. The median time from the Restorative Department at Musgrove Park Hospital receiving referral for oral rehabilitation to implant placement was 11 months (min 0, max 91). The median time from primary surgery, or dental extractions prior to radiotherapy, to placement of dental implants was 24 months (min 0, max 93). Once implants were placed, patients waited a median of 12 months (min 4, max 28) before definitive restorations were placed.

DETAILS OF IMPLANTS AND PROSTHETIC TECHNIQUES UTILISED

Three implant systems were used during the follow up period, 102 (39.2%) implants were Astra Tech TX, 150 (57.7%) were Astra Tech EV (both Dentsply Implants, Mannheim, Germany), and 8 (3.1%) Straumann fixtures were placed (Institut Straumann, Basel, Switzerland). All Astra Tech implants were bone level and all Straumann implants were tissue level. 89.6% of implants placed were between 3.5 and 4.2mm diameter (minimum 3.0mm, maximum 4.5mm).

Figure 3 shows a breakdown of the types of prosthesis utilised at the patient level in the survival group. Fixed prostheses such as fixed bridges or single unit crowns (N=38; 46.9%) and removable prostheses such as locator retained dentures (N=25; 30.9%), were the most used methods for rehabilitating patients. Hybrid removable devices such as two-part dentures (bar with precision fit sleeve incorporated into the denture) were used in 10 (12.3%), and the remainder of participants had a combination of the above restorative methods. Two (5.3%) fixed restorations were cement retained whilst the remaining 36 (94.7%) were screw retained.

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Table 2. Summary of tumour site and type in the survival group. SCC - squamous cell carcinoma.

	Hypopharynx, Larynx, trachea, parapharyngeal space	Nasal Cavity, paranasal sinus, skull base	Nasopharynx	Neck and lymph nodes	Oral cavity - hard and soft tissues	Oral cavity - hard tissues	Oral cavity - soft tissues	Oropharynx (Base of tongue, tonsils)	Salivary gland	Total
Acinic cell carcinoma									1	1
Adenocarcinoma							2		1	3
Adenoid cystic carcinoma					1					1
Ameloblastoma						3				3
Giant cell granuloma					1	1				2
Myoepithelial carcinoma									1	1
SCC	1	1	1	3	5	15	24	19	1	70
Total	1	1	1	3	7	19	26	19	4	81

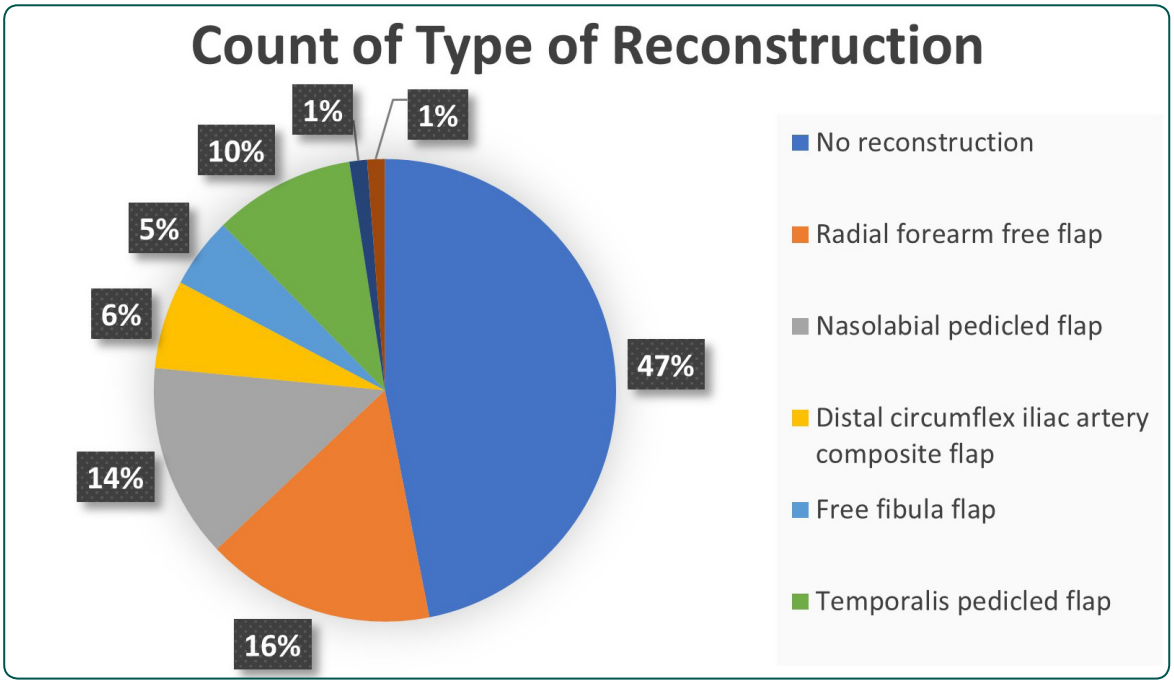

Figure 2: Type of reconstructive surgery in the survival group.

IMPLANT SURVIVAL ANALYSIS

Implant survival analysis (survival group) was performed at the implant level with local factors as co-variates and a median follow-up of 49.2 months. An event was classified as the implant no longer present in the mouth, with data censored if the implant was still present at the last documented review. In total, 16 implants (6.2%) were lost in 12 patients (14.8%), and there was 89.3% survival rate at 96 months with no further failures until the last patient was censored at 133 months (*Figure 4*). Implants were lost at a low but steady rate throughout the analysis period. Cox regression analysis was

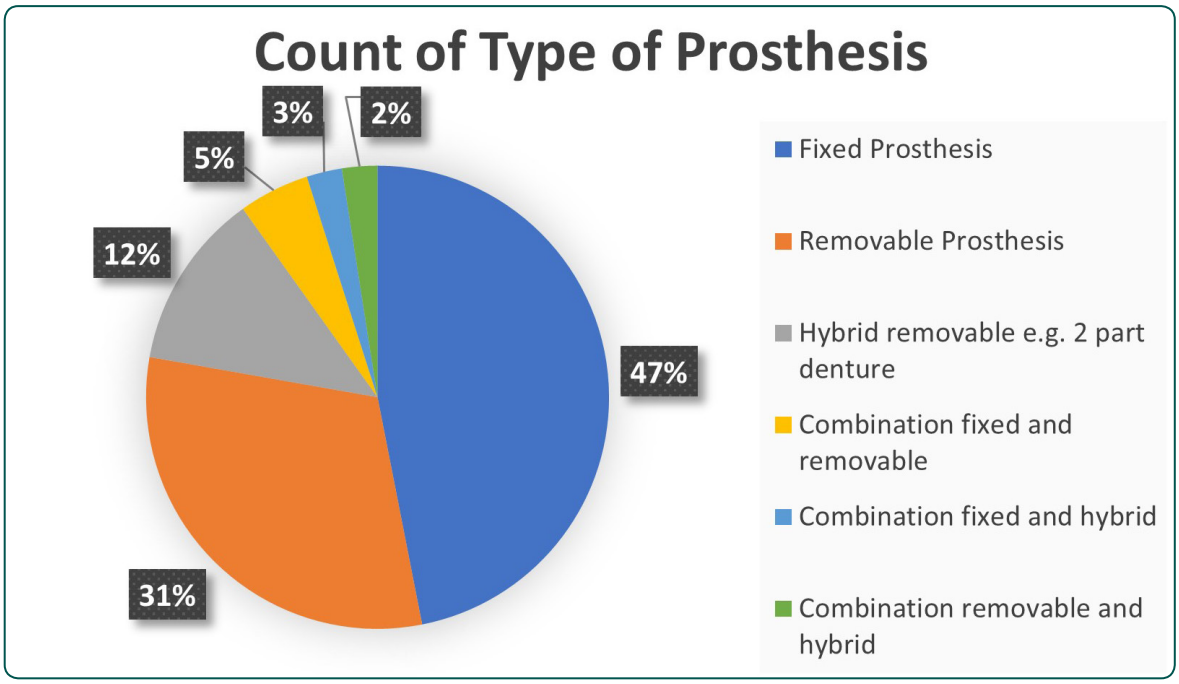

Figure 3: Type of prosthesis utilised in the survival group.

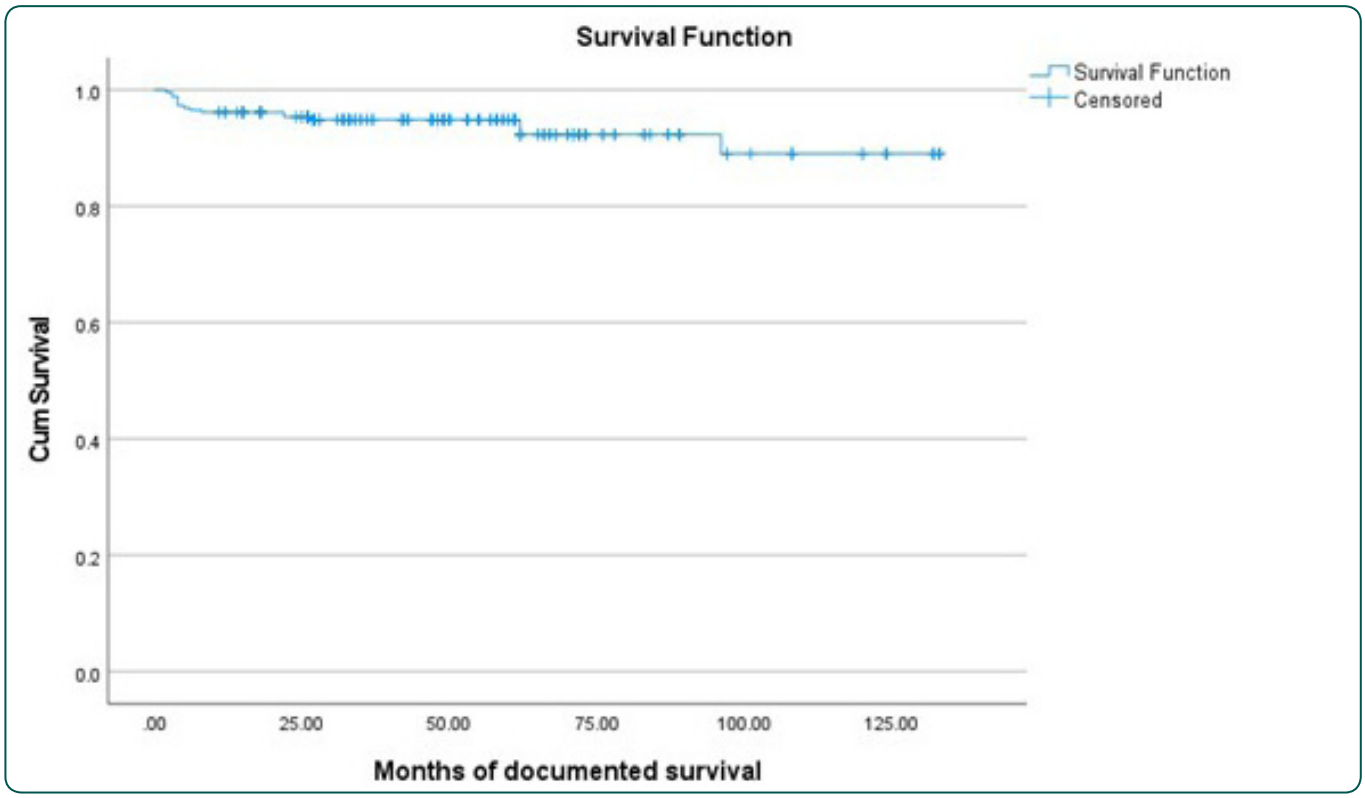

Figure 4: Kaplan-Meier showing pooled survival of 260 dental implants.

performed with site of implant defined as anterior/posterior and mandible/maxilla. Placement in irradiated bone compared to non-irradiated was also analysed. Results showed that there was no statistically significant effect of site of implant or placement in irradiated bone to implant loss (p=0.427 and p=0.799 respectively).

IMPLANT HEALTH ANALYSIS

The Cox proportional hazards model for implant health (success group) was performed at the patient level with co-variates including gender, smoking history (ex-smoker vs never smoker, number of pack years), and history of

radiotherapy, periodontitis or xerostomia. Log-rank test was performed at the implant level for width of peri-implant keratinised mucosa (<2mm vs ≥2mm). Peri-implant health and mucositis were censored, with the presence of an implant with peri-implantitis marked as an event for that patient. The median follow-up in the success group was 56 months. In total, 21 (12.8%) implants in 12 patients (25%) had peri-implantitis at examination. Kaplan-Meier plots estimated that at the implant level, 12 (7.3%) fixtures had peri-implantitis at 56 months, median survival free of peri-implantitis was not calculable but 33.3% were estimated to have peri-implantitis at 120 months *(Figure 5)*. There were no incidences of peri-implantitis recorded in the first 28 months of function.

Peri-implant mucositis was found in 36 implants (22%) in 18 participants (37.5%) during the evaluations. Log-rank test was not significant for width of keratinised mucosa (Chi-squared 0.411, *p*=0.521). Table 3 shows that the only variable significantly associated with the development of peri-implantitis was history of smoking (HR 2.372, *p*=0.032, 95CI: 1.232, 93.317).

IMPLANT SUCCESS ANALYSIS

The Cox proportional hazards model for implant success (success group) was performed at the patient level with co-variates including gender, smoking history (ex-smoker vs never smoker, number of pack years), and history of radiotherapy, periodontitis or xerostomia. Log-rank test was performed at the implant level for peri-implant keratinised mucosa width (<2mm vs ≥2mm). Implant success and satisfactory survival were censored, with compromised survival, absolute or clinical failure marked as an event for that patient. The median follow-up in the success group was 56 months. In total, 17 (10.4%) implants in 9 patients (18.8%) exhibited compromised survival, absolute or clinical failure at examination *(Table 4)*. Kaplan Meier plots estimated that at the implant level the median survival without an event (compromised survival, absolute or clinical failure) was not calculable but 28.1% were estimated to have an event by 101 months *(Figure 6)*. Events occurred throughout this period.

Log-rank test was not significant for width of keratinised mucosa (Chi-squared 2.175, *p*=0.140). Table 5 shows that the only variable associated with the development of compromised survival, absolute or clinical failure was history of radiotherapy, which was statistically significantly associated with an improved survival (HR -1.955, *p*=0.040, 95CI: 0.022, 0.916).

PROSTHETIC COMPLICATION ANALYSIS

The Kaplan-Meier analysis for prosthetic success (survival group) was performed at the patient level and there were sufficient data in the medical notes to make judgements regarding prosthetic complications in all 81 individuals in this group. The design of prostheses and materials used were too heterogeneous for a statistical analysis to be performed. Ongoing prosthetic success or minor complication with no need for repair were censored, but if a patient had any prosthesis that required repair or remake this was marked as an event. In total, 20 patients (24.7%) had 22 prostheses with prosthetic complications requiring repair or remake, of these

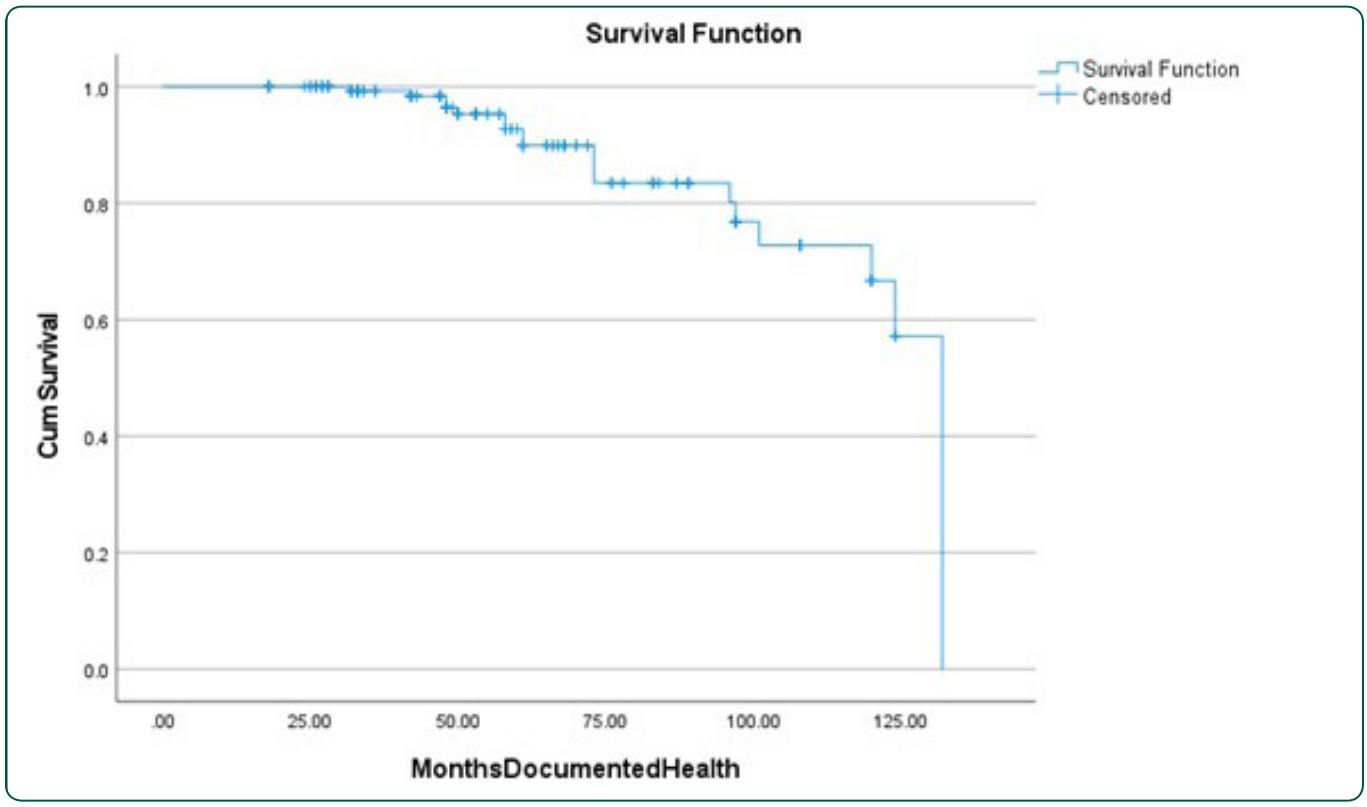

Figure 5: Kaplan-Meier survival graph of time to peri-implantitis at implant level.

Table 3. Summary of Cox regression for co-variates related to development of peri-implantitis at the patient level. * p<0.05.

	Variables				
	Hazard rate	Standard error	p value	95CI lower	95CI upper
Gender	-0.876	1.047	0.403	0.053	3.244
Patient had radiotherapy	-0.549	0.806	0.496	0.119	2.803
History of smoking	2.372	1.104	0.032*	1.232	93.317
Pack years	-0.107	0.065	0.099	0.792	1.020
History of periodontitis	-0.460	0.905	0.611	0.107	3.723
Xerostomia	0.960	1.215	0.430	0.214	28.266

Table 4. Breakdown of success judgments at implant level.

Assessed outcome	Number of implants affected	Details
Success	128	N/A
Satisfactory survival	19	All due to bone loss indicative of early peri-implantitis
Compromised survival	7	4 sites with peri-implantitis and bone loss >4mm but <50% 3 periodontally healthy implants with pocket depths >7mm due to placement within nasolabial flap leading to discrepancy between health and success judgments
Absolute failure	7	3 with severe peri-implantitis 4 osseointegration failure
Clinical failure	3	1 not restored due to poor angulation, sufficient other implants to compensate prosthetically 2 embedded within lip due to soft tissue retraction post-oncology resection, these are planned for removal

18 (81.8%) prostheses were of acrylic suprastructure and four (18.2%) were porcelain. All seven repairs were related to re-lines of acrylic implant retained obturators or complete dentures. Of the 15 prostheses requiring remake: five were fractured acrylic implant retained dentures or two-part dentures; three were fractured acrylic bridges; three were fractured porcelain bridges; one obturator no longer provided satisfactory oro-nasal seal; one patient lost two implants, so the two-part denture was replaced with an implant retained complete denture. All six fractured bridges were remade with composite suprastructure. It was not possible to calculate a median survival time to prosthetic complication but at 72 months this was estimated to occur in 40.9% of participants (*Figure 7*). Prosthetic complications occurred at a relatively steady rate throughout this period.

DISCUSSION

In the United Kingdom, the oral and dental management of patients with HNC is undertaken by a multi-disciplinary team that includes Consultants in Restorative Dentistry.[20] Dental implants are commonly used in this cohort of patients and can support oral and facial prostheses.[11,20] Implants can also facilitate the rehabilitation of patients where more traditional removable prostheses are unable to provide satisfactory functional or aesthetic outcomes, for instance if the oral architecture has been significantly altered by ablative or reconstructive surgery.[11] The South West region of England is geographically large, extending over 200 miles in length and incorporating a number of populated islands, with a population of nearly six million people.[21] Currently, there are 6 whole time equivalent NHS Consultants in Restorative Dentistry covering the region of which 4.5 posts are filled, and between 2015 and 2020 Musgrove Park Hospital, Taunton, had the only Consultant led NHS Restorative Dentistry service

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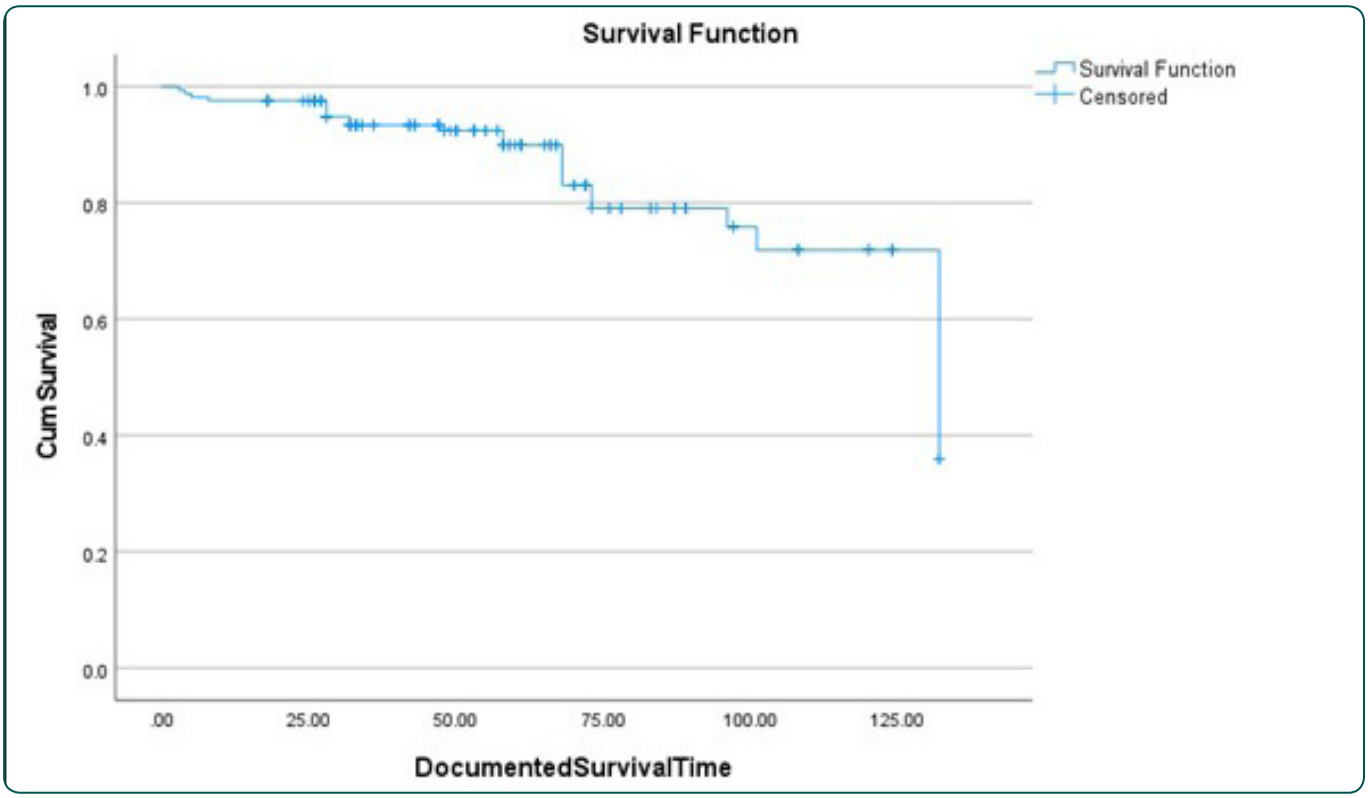

Figure 6: Kaplan-Meier graph of time to compromised survival, absolute or clinical failure at implant level.

Table 5. Summary of Cox regression for co-variates related to compromised survival, absolute or clinical failure at the patient level. * p<0.05.

	Variables				
	Hazard rate	**Standard error**	**p value**	**95CI lower**	**95CI upper**
Gender	-0.183	0.954	0.848	0.128	5.396
Patient had radiotherapy	-1.955	0.953	*0.040	0.022	0.916
History of smoking	0.674	1.352	0.618	0.139	27.798
Pack years	-0.005	0.032	0.887	0.934	1.061
History of periodontitis	--1.898	1.015	0.062	0.021	1.096
Xerostomia	1.482	1.143	0.195	0.469	41.326

South of Bristol. It is therefore unsurprising that there was a median time of 24 months from primary surgery, or extractions prior to radiotherapy, to placement of dental implants. However, the median time from receipt of referral to placement of implants was 11 months, so some of the wait for implants may be due to delayed referrals. After placement, it is the departmental protocol to allow three months for osseointegration prior to restoration, and the median time from placement to delivery of prostheses was 12 months. This ranged from 4 months in simple cases to 28 months in the more complex rehabilitations.

The results of this service evaluation show high rates of implant survival (89.3% at 133 months), comparable to the body of literature which has demonstrated survival ranging from 75 to 97.1% in people with history of HNC at an average follow up of 30.1 to 64.8 months.[11,12,22-26] In this study, site of implant and radiotherapy were not associated with increased risk of failure, which is in line with other similar studies.[11,26] It should be noted that in patients receiving radiotherapy, it is usual practice within the department to place implants in tissue receiving ≤40 Gy, thus conclusions cannot be drawn about the effect of higher doses on survival.

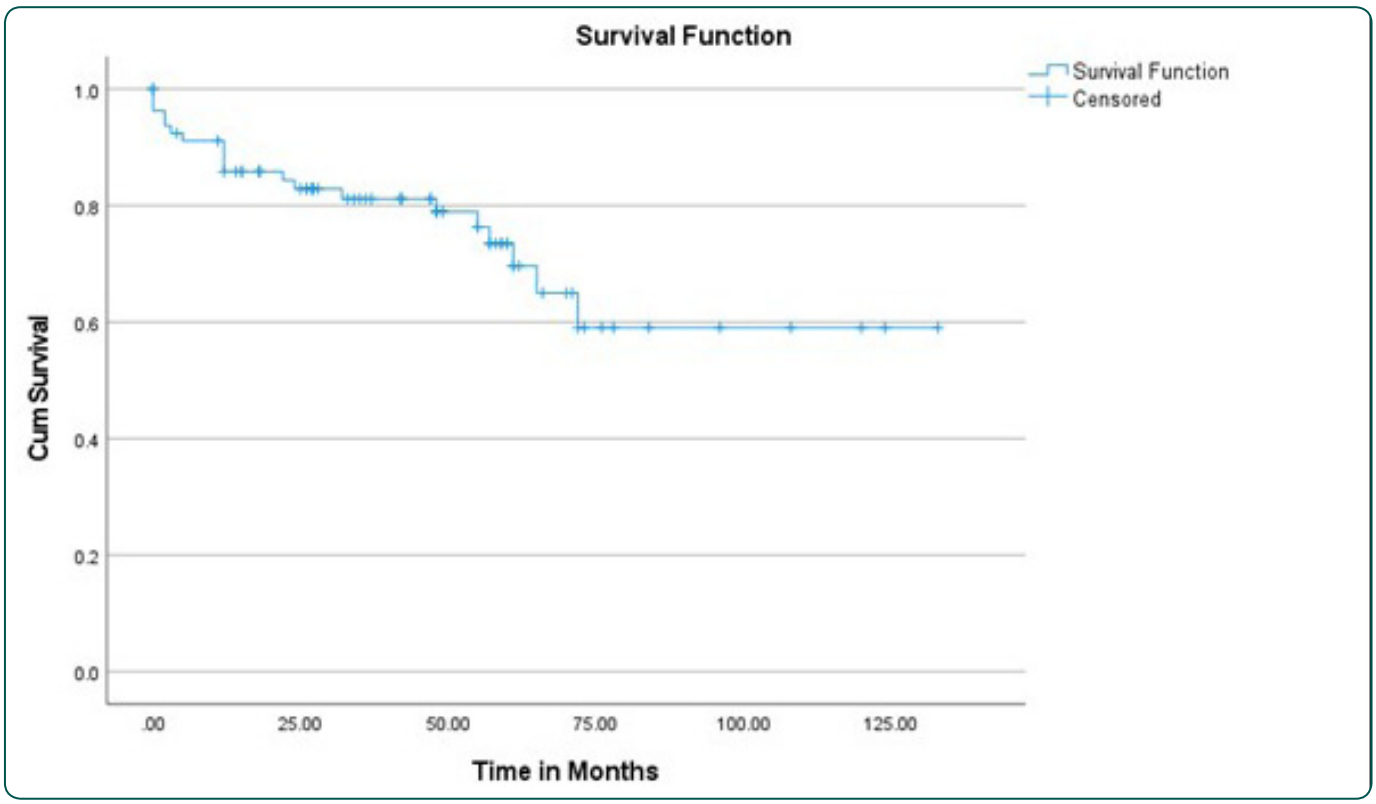

Figure 7: Kaplan-Meier graph of time to prosthetic complication requiring remake or repair at the patient level.

This was the first evaluation that the authors are aware of that implements the 2017 Classification of Peri-implant Diseases and Conditions in HNC patients.[15] The peri-implant health assessments *(Figure 5)* demonstrated comparable levels of peri-implant mucositis and peri-implantitis when compared to studies in the general population that document implant level prevalence as 35.1% (32% of patients) and 25.6% (45% of patients) respectively at 9 years.[27] This was despite a high level of smoking history in this cohort, which was found to be a statistically significant risk factor for the development of peri-implantitis (HR 2.372, *p*=0.032, 95CI: 1.232, 93.317). The role of smoking in the development of peri-implantitis is commonly cited in the literature, and it is department protocol to place implants only in individuals who demonstrate effective cessation.[28,29]

Definitions of implant success vary in the literature with at least eight different composite outcome measures used, making external comparison difficult.[13] The success outcome utilised in this study was chosen because it incorporated measures of clinical function, which was felt to be important in this cohort.[14] There were common domains between the health and success outcome measures, such as radiographic bone loss, although with different boundaries. The success outcome also included the unclear descriptor of exudate history, which by definition refers to the serous fluid of inflammation or purulent exudate (pus) but is not inclusive of bleeding.[30] This meant that here, bleeding on probing did not register in the success outcomes. Whilst the functional parameters were considered useful, it is acknowledged that there is currently no optimal outcome measure for implant success in this cohort and the one utilised is outdated when considering domains for peri-implant health.[13-15] The results showed that at 101 months 28.1% implants had compromised survival, clinical failure or absolute failure. The majority of the compromised or failed cases were due to established peri-implantitis, but the success outcomes also recognised healthy implants that had failed for other reasons such as mal-positioning *(Table 4)*. During the service evaluation it was found that soft tissue flaps, commonly used during reconstructive surgery in this cohort, can create deep probing depths with no clinical signs of inflammation, so radiographic bone levels, changes in probing depth from baseline, and bleeding/suppuration on probing may be more useful for determining peri-implant health, as emphasised by the 2017 World Workshop classification.[15] Therefore, the authors recommend that probing pocket depths are charted at the time of definitive restoration so that changes can be detected going forward, rather than relying on a set probing depth for determining success. When considering the effect of radiotherapy on this outcome, the results of the analysis must be interpreted with caution. Of the 191 implants placed in irradiated bone, only 6% were placed in areas of the jaw receiving a dose >40Gy with the other 94% placed in areas of ≤40Gy. To allow analysis to take place the ≤40Gy group were combined with the >40Gy group. The results showed a small but statistically significant improvement in implant survival in this group, but this largely reflects the ≤40Gy group and as no power calculation or post-hoc analysis was performed the

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authors interpret this result as follows: In patients receiving radiotherapy, doses up to 40 Gray do not appear to have a detrimental effect on peri-implant health.

A variety of prosthetic methods were used in this cohort (*Figure 3*) and it was not possible to perform a statistical analysis due to heterogeneity of prosthesis design and material composition. It was possible to observe a trend towards replacing catastrophically fractured acrylic and porcelain bridges with composite suprastructures, which senior staff explained was due to the ability to perform chairside repairs if required. Overall, there was a high burden of prosthetic complications with an estimated 40.9% of patients requiring intervention for repair or remake at 72 months, which is not surprising given the complexity of many of the rehabilitations in this group. The authors acknowledge that implant placement and maintenance protocols vary between departments, and this may limit the generalisability of these results.

This retrospective service evaluation is one of a small number in this cohort that clinically examined participants, however there are several limitations. The sample sizes, especially for the subgroup analyses, are small and the data is heterogenous for several outcomes particularly type and site of tumour and type of treatment received. In addition, no sample size calculation was performed so the statistical analyses should be interpreted with caution. In future, it may be interesting to examine whether site of implant placement was important to survival or success, however the subgroups would have been too small to analyse in this data set.

In conclusion, when we consider the number of individuals requiring intervention for either peri-implant mucositis, peri-implantitis or prosthetic complications we can see that there is a considerable burden of ongoing care in this cohort. The oral rehabilitation and ongoing management of HNC patients is complex. However, the survival and peri-implant health were found to be comparable to studies examining the general population. These results highlight the importance of a comprehensive maintenance programme covering peri-implant health and prosthetic upkeep for patients in this cohort. The unique role of Restorative Specialists within the NHS places them in the ideal position to manage the oral rehabilitation in this cohort.

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Patient consent statement: All patients gave written informed consent to be involved in the service evaluation

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Clinical trial registration: This was a service evaluation and therefore registered with the relevant hospital department.

MeSH term key words: Head and Neck Neoplasms; dental implants; dental prosthesis; dentistry; peri-implantitis.

REFERENCES

1. Ferlay, J., Soerjomataram, I., Dikshit, R., Eser, S., Mathers, C., Rebelo, M., Parkin, D., Forman, D. and Bray F. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. *Int J Cancer*. 2015; **136**:E359-86.
2. Cancer Research United Kingdom (CRUK). [Online] 2021a. Cancer Statistics for the UK . Available at: https://www.cancerresearchuk.org/health-professional/cancer-statistics-for-the-uk#heading-Three Accessed on: 5/6/2021.
3. Cancer Research United Kingdom (CRUK). [Online] 2021b. Head and neck cancer statistics. Available at: https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/head-and-neck-cancers#heading-Zero Accessed on: 5/6/2021.
4. Vosselman, N., Alberga, J., Witjes, M.H.J., Raghoebar, G.M., Reintsema, H., Vissink, A. and Korfage, A. Prosthodontic rehabilitation of head and neck cancer patients—Challenges and new developments. *Oral Dis*. 2020; **27**:64-72.
5. Pace-Balzan, A., Shaw, R.J. and Butterworth, C. Oral rehabilitation following treatment for oral cancer. *Periodontology 2000*. 2011; **57**:102–117.
6. Schoen, P.J., Reintsema, H., Raghoebar, G.M., Vissink, A. and Roodenburg, J.L.N. The use of implant retained mandibular prostheses in the oral rehabilitation of head and neck cancer patients. A review and rationale for treatment planning. *Oral Oncol*. 2004; **40**:862–71.
7. Barrowman, R.A., Wilson, P.R. and Wiesenfeld, D. Oral rehabilitation with dental implants after cancer treatment. *Aust Dent J*. 2011; **56**:160–165.
8. Cuesta-Gil, M., Ochandiano Caicoya, S., Riba-García, F., Duarte Ruiz, B., Navarro Cuéllar, C. and Navarro Vila, C. Oral rehabilitation with osseointegrated implants in oncologic patients. *J Oral Maxillofac Surg*. 2009; **67**:2485-2496.

9. Nelson, K., Heberer, S. and Glatzer, C. Survival analysis and clinical evaluation of implant-retained prostheses in oral cancer resection patients over a mean follow-up period of 10 years. *J Prosthet Dent.* 2007; **98**:405–410.
10. Fierz, J., Hallermann, W. and Mericske-Stern, R. Patients with oral tumors. Part 1: prosthetic rehabilitation following tumor resection. *Schweiz Monatsschr Zahnmed.* 2013; **123**:91–105.
11. Laverty, D.P., Addison, O., Wubie, A., Heo, G., Parmar, S., Martin, T., Praveen, P., Pearson, D., Newsum, D., Murphy, M. and Bateman, G. Outcomes of implant-based oral rehabilitation in head and neck oncology patients – a retrospective evaluation of a large, single regional service cohort. *Int J Implant Dent.* 2019; **5**:1-12.
12. Ch'ng, S., Skoracki, R.J., Selber, J.C., Yu, P., Martin, J.W., Hofstede, T.M., Chambers, M.S., Liu, J. and Hanasono, M.M. Osseointegrated implant-based dental rehabilitation in head and neck reconstruction patients. *Head Neck.* 2016; **38**:E321-327.
13. Needleman, I., Chin, S., O'Brien, T., Petrie, A. and Donos, N. Systematic review of outcome measurements and reference group(s) to evaluate and compare implant success and failure. *J Clin Periodontol.* 2012; **39**:122-132.
14. Misch, C.E., Perel, M.L., Wang, H.L., Sammartino, G., Galindo-Moreno, P., Trisi, P., Steigmann, M., Rebaudi, A., Palti, A., Pikos, M.A., Schwartz-Arad, D., Choukroun, J., Gutierrez-Perez, J.L., Marenzi, G. and Valavanis, D.K. Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. *Implant Dent.* 2008; **17**:5-15.
15. Berglundh, T., Armitage, G., Araujo, M.G., Avila-Ortiz, G., Blanco, J., Camargo, P.M., Chen, S., Cochran, D., Figuero, E., Hammerle, C.H.F., Heitz-Mayfield, L.J.A., Huynhba, G., Lacono, V., Koo, K.T., Lambert, F., McCauley, L., Quirynen, M., Renvert, S., Salvi, G.E., Schwartz, F., Tarnow, D., Tomasi, C., Wang, H.L. and Zitzmann, N. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Clin Periodontology.* 2018;S286-S291.
16. Brocard, D., Barthet, P., Baysse, E., Duffort, J.F., Eller, P., Justumus, P., Marin, P., Oscaby, F., Simonet, T., Benqué, E. and Brunel, G. A multicenter report on 1,022 consecutively placed ITI implants: a 7-year longitudinal study. *Int J Oral Maxillofac Implants.* 2000; **15**:691-700.
17. Buser, D., Janner, S.F., Wittneben, J.G., Brägger, U., Ramseier, C.A. and Salvi, G.E. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: a retrospective study in 303 partially edentulous patients. *Clin Implant Dent Relat Res.* 2012; **14**: 839-851.
18. Pace-Balzan, A., Cawood, J.I., Howell, R., Lowe, D. and Rogers, S.N. The Liverpool Oral Rehabilitation Questionnaire: a pilot study. *J Oral Rehabil.* 2004; **31**:609-617.
19. Faculty of General Dental Practice (FGDP). [Online] 2018. Radiographs in Implant dentistry. Available at: https://www.fgdp.org.uk/selection-criteria-dental-radiography/7-radiographs-implant-dentistry Accessed on: 5/6/2021.
20. Restorative Dentistry United Kingdom (RDUK). [Online] 2016. Predicting and Managing Oral and Dental Complications of Surgical and Non-Surgical Treatment for Head and Neck Cancer. Available at: https://www.restdent.org.uk/uploads/RD-UK%20H%20and%20N%20guideline.pdf Accessed on: 5/6/2021.
21. National Health Service England and National Health Service Improvement (NHSE&I). [Online] 2021. Oral Health Needs Assessment Main Report – South West England. Available at: https://www.england.nhs.uk/south/wp-content/uploads/sites/6/2021/02/South-West-OHNA-Main-Report.pdf Accessed on: 6/7/2021.
22. Shaw, R.J., Sutton, A.F., Cawood, J.I., Howell, R.A., Lowe, D., Brown, J.S., Rogers, S.N. and Vaughan, E.D. Oral rehabilitation after treatment for head and neck malignancy. *Head Neck.* 2005; **27**:459-470.
23. Teoh, K.H., Huryn, J.M., Patel, S., Halpern, J., Tunick, S., Wong, H.B. and Zlotolow, I.M. Implant prosthodontic rehabilitation of fibula free-flap reconstructed mandibles: a Memorial Sloan-Kettering Cancer Center review of prognostic factors and implant outcomes. *Int J Oral Maxillofac Implants.* 2005; **20**:738-746.
24. Yerit, K.C., Posch, M. and Seemann, M. Implant survival in mandibles of irradiated oral cancer patients. *Clin Oral Implants Res.* 2006; **17**:337–344.
25. Linsen, S.S., Martini, M. and Stark, H. Long-term results of endosteal implants following radical oral cancer surgery with and without adjuvant radiation therapy. *Clin Implant Dent Relat Res.* 2012; **14**:250–258.
26. Hessling, S.A., Wehrhan, F., Schmitt, C.M., Weber, M., Schlittenbauer, T. and Scheer, M. Implant-based rehabilitation in oncology patients can be performed with high long-term success. *J Oral Maxillofac Surg.* 2015; **73**:889-896.
27. Derks, J., Schaller, D., Håkansson, J., Wennström, J.L., Tomasi, C. and Berglundh, T. Effectiveness of Implant Therapy Analyzed in a Swedish Population: Prevalence of Peri-implantitis. *J Dent Res.* 2016; **95**:43-49.
28. Ferreira, S.D., Silva, G.L., Cortelli, J.R., Costa, J.E. and Costa, F.O. Prevalence and risk variables for peri-implant disease in Brazilian subjects. *J Clin Periodontol.* 2006; **33**:929-935.
29. Renvert, S. and Quirynen, M. Risk indicators for peri-implantitis. A narrative review. *Clin Oral Implants Res.* 2015; **26**:15-44
30. American Academy of Periodontology (AAP). [Online] 2021. Glossary of Terms. Available at: https://members.perio.org/libraries/glossary?ssopc=1 Accessed on: 5/6/2021.