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Beavertail modification of the radial forearm free flap in total oral glossectomy reconstruction: Technique and functional outcomes

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ABSTRACT

Objective: The total oral tongue (anterior 2/3 glossectomy) defect is seldom addressed in the literature. This is the first series to describe a consistent technique for its reconstruction. The aim of the study is to describe the use of the beavertail modified radial forearm free flap (BTRFFF) to reconstruct a total oral tongue defect and the functional and quality of life outcomes associated with it.
Study design: Retrospective review of prospectively collected data from 2000 to 2010.
Methods: All patients at the University of Alberta undergoing head and neck free flap surgery are enrolled in a prospective functional outcomes program. Pre-operatively and at set post-operative time points patients complete videofluoroscopic swallowing studies (VFSS), speech evaluations and quality of life questionnaires (EORTC H&N-35). Peri-operative outcomes were also measured.
Results: 17 consecutive patients were included. All were gastrostomy tube free at 12 months post-operatively and tolerating a full soft diet with aspiration scores of 0. Swallowing transit times increased by a mean of 0.4 s ($p = 0.32$). Speech intelligibility remained high with mean sentence intelligibility at 75% and single word intelligibility at 62%. Quality of life scores returned to baseline and remained satisfactory. Complications related to the BTRFFF were limited to scarring.
Conclusions: The BTRFFF provides a robust reconstructive option for the total oral tongue defect with excellent long term functional outcomes and quality of life.

Introduction

Advanced tongue cancer treatment has historically focused solely on survival. Aggressive surgical resections marginally increased survival and functions such as speech, chewing and swallowing became distant memories. Patients asked: "is this extension on life, actually worth living?" Consequently, a modern head and neck surgical oncology paradigm arose: eradicate the cancer and functionally reconstruct the defect.

Achieving this triad is highly dependent on the extent of surgery and the resultant tongue defect. Functional reconstruction for oral hemiglossectomy has been described by several groups and has led to excellent quality of life (QOL) outcomes [1–4]. Total glossectomy defects can also be functionally reconstructed to give patients acceptable speech/swallowing and quality of life [5–8]. However, the reconstruction of the more rare intermediate defects is not well-addressed in the literature.

The *total oral glossectomy* defect (anterior 2/3 glossectomy), from tongue tip to the anterior base of tongue (BOT), is seldom mentioned in the literature. Few papers have described any reconstructive approach to this defect [9,10]. Based on the work of Chepeha et al it is known that to create a functional tongue, the anterior tongue must be designed with enough bulk, pliability and motion to achieve appropriate palatoglossal contact [1,2]. This allows for intelligible speech and food bolus control and propulsion. The beavertail modified radial forearm free flap (BTRFFF) provides a soft tissue envelope that is highly pliable, light and mobile by the BOT; moreover, the fibrofatty tail allows for customization of the bulk of the flap. This is the first paper to be dedicated to describing a single reconstructive technique for the total oral tongue defect.

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The purpose of this study was to examine prospectively collected survival, speech, swallowing, and QOL data in patients with advanced tongue carcinoma undergoing total oral glossectomy with BTRFFF reconstruction.

Materials and methods

Prior to commencement this study was approved by the Health Research Ethics Board at the University of Alberta and informed consent was obtained from each patient.

Patients

All cases of advanced tongue carcinoma from 2000 to 2010 were identified in the University of Alberta's prospective head and neck cancer data base. Patients were included if treated with primary surgery and post-operative radiation therapy (PORT), the surgical defect encompassed 100% of the oral tongue (anterior 2/3 of the tongue) with at least 50% of the floor of mouth and if reconstruction was performed with a BTRFFF. All patients had at least 1 anterior digastric muscle and 1 mylohyoid muscle resected. Patients with resections extending beyond the oral tongue or floor of mouth or those with previous oral cancer surgery were excluded. No patient required hyoid/laryngeal suspension as all retained the entire BOT. All patients were enrolled in an intent to follow protocol at the University of Alberta's multidisciplinary head and neck cancer clinic, and all were followed prospectively.

Treatment

Patients with tongue cancer at the University of Alberta are thoroughly counseled on primary treatment options including surgery and chemo-radiation therapy (Chemo-RT). Patients who choose primary surgery, and their families, then meet with an advanced practitioner/speech-language pathologist who spends an additional 3 h explaining what to expect before, during and after their hospital stay.

A full metastatic work-up is conducted including computed tomography (CT) of the neck, chest and abdomen or a full body positron emission tomography-CT (PET-CT) scan in addition to pre-treatment panendoscopy and lesion biopsy. All patients are M_0 at the time of surgery.

All included patients underwent primary surgical extirpation of their tumors via a lip-splitting mandibulotomy approach [9]. Surgical margins were 2 cm and resections included 100% of the oral tongue. At least 50% of the floor of mouth was also excised including the suprahyoid muscles, thus creating a through and through defect into level Ib. No other adjacent structures were removed. All patients had a least one lingual and hypoglossal nerve as well as one lingual artery and vein intact at the end of surgery; this allowed optimal functional recovery [11]. Airway management consisted of a peri-operative mini-tracheostomy, which was reversed and sutured closed prior to discharge (i.e. within 3 weeks post-operatively). Prior to collecting any swallowing data, all stoma sites were allowed to fully heal. All patients underwent bilateral neck dissections. RT was initiated 4–8 weeks post-operatively with patients receiving fractions of 50–70 Gy of RT 5 times per week for 6 weeks. Some patients also received concomitant chemotherapy consisting of a standard cis-platin-based regimen.

All tongue reconstructions consisted of a *BTMRFFF* [3,4]. This is the preferred flap for total anterior tongue reconstruction by the authors as it allows the surgeon to customize and tailor the desired flap bulk and shape. It is versatile in thin and thick patients. Flap incisions are designed in the standard fashion to include the radial artery and cephalic vein(s). A consistent pear shape is used for the flap (Fig. 1). The incision is drawn from the antecubital fossa to the volar forearm skin paddle with the most distal aspect of the paddle 2 cm below the wrist. Subcutaneous flaps are elevated just deep to the dermis, in the proximal forearm. The fibrofatty tissue is then incised to the desired width down to the proximal forearm muscles. The beavertail and flap are then elevated off the flexor tendons and muscles, the radial artery in ligated and the pedicle is dissected from distal to proximal. Once the skin paddle and beavertail are elevated, the vascular pedicles can be dissected free from the beavertail allowing movement and flexibility in the fibroadipose tail. The beavertail can be trimmed, rolled, rotated and folded to meet the needs of reconstruction (Fig. 1).

Prior to insetting the beavertail is rolled under the flap with the vascular pedicles brought out laterally. Care is taken to orient the vessels so that they are not kinked or compressed by the beavertail. Fig. 1. The beavertail is then sewn to the fascia on the deep surface of the flap. The flap is brought into the defect with the posterior skin edge sewn in first. Sutures are then advanced anteriorly and if teeth are present, circum-dental sutures are employed. The lateral antebrachial cutaneous nerve of the forearm is anastamosed to the ipsilateral lingual nerve to allow for long term flap sensitization [11]. The forearm is closed with a layered closure of the proximal skin flaps and a split thickness skin graft over the flap skin site. Fig. 2 demonstrates the flap appearance and mobility 3 years after surgery.

Data collection

The prospective database was gleaned for patient demographics, tumor staging and histology, treatment details, survival details, as well as quality of life questionnaires and functional outcomes data. Diagrams of the site and extent of resection were made by the primary surgeon at the time of the operation. Data was confirmed by reviewing clinic charts and hospital records.

Outcomes

The primary outcome was the gastrostomy tube (GTube) rate at 12 months. Secondary outcomes included disease specific survival, surgical outcomes, additional swallowing and speech measures as well as quality of life.

Functional outcomes

Patients' speech and swallowing were evaluated pre-operatively and post-RT (6–12 months post-operatively). Naïve listeners' perceptual assessments of speech intelligibility were completed using the Computerized Assessment of Intelligibility of Dysarthric Speech (CAIDS; Pro-Ed, Austin, TX) [12]. Patients were instructed to read a standardized passage, which was then recorded and played to naïve listeners, who were neither a trained speech pathologist nor familiar with the patient. The listeners then interpreted the recording, which was scored for single word and sentence intelligibility. To confirm inter-rater reliability, the speech recordings were re-analyzed by a second naïve listener [12].

All patients were fed via a nasogastric tube post-operatively. Once their tracheostomy had been reversed (usually post-operative day 7–10) for 24 hrs, they underwent a swallowing evaluation by a speech pathologist. This consisted of a bed-side swallowing test or modified barium swallow to evaluate readiness for oral intake. Patients who could maintain $>$ 75% of their daily caloric intake with a nasogastric tube in place, had their feeding tube discontinued and were fed orally. Those patients, who failed the swallowing test, had a gastrostomy tube installed.

Swallowing was assessed in terms of *ability, safety and efficiency*. Swallowing *ability* was defined as the complete independence from a GTube to maintain daily caloric requirements. Patients were evaluated by a multidisciplinary team including a dietician and speech pathologist pre-operatively as well as 1, 6 and 12 months post-operatively for the need of a GTube. The use of a GTube at these time points was recorded prospectively by the speech pathologist.

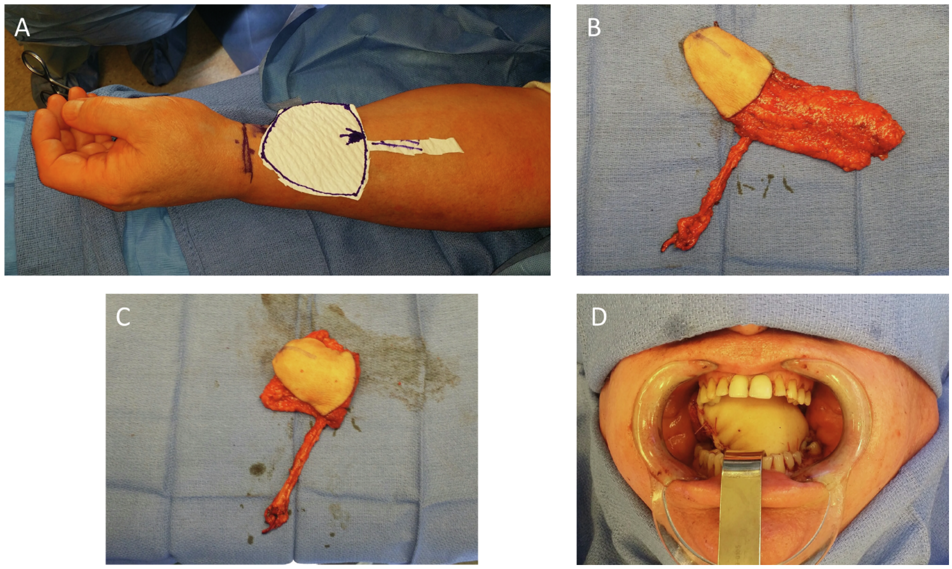

Fig. 1. (A) A template of the defect size and shape is made and transferred to the forearm, (B) the radial forearm free flap is harvested with the beavertail, (C) the beavertail is rolled under the flap with the vessels brought out laterally, (D) the flap is inset.

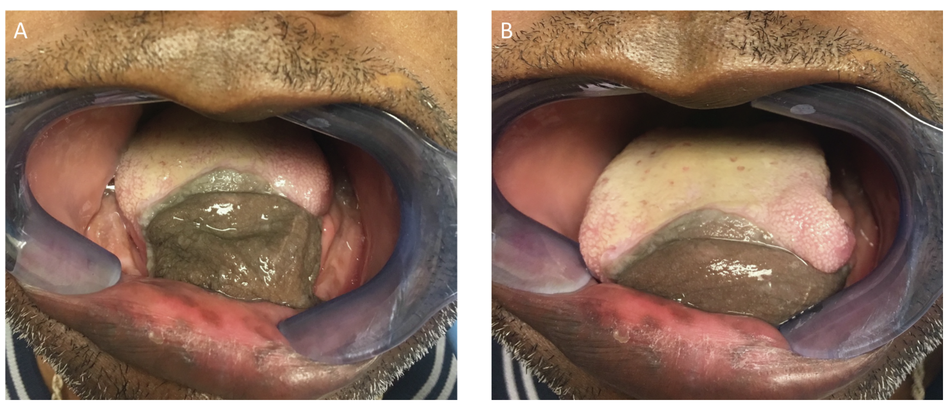

Fig. 2. A patient with a beavertail modified radial forearm free flap used to reconstruct a total oral tongue defect at 3 years after surgery. The patient maintains a total oral diet with a gastrostomy tube and has 100% sentence intelligibility. (A) tongue in resting position, (B) tongue protruding.

Swallowing safety and efficiency were evaluated via a modified barium swallowing procedure (i.e. videofluoroscopic swallowing study (VFSS)) completed in the presence of a radiologist within the diagnostic imaging department of the hospital (Misericordia Community Hospital; Edmonton, Alberta). Pudding mixed with barium paste (Esobar, barium sulfate cream, Therapex) in a 3:1 ratio was presented as a calibrated bolus on a teaspoon to the patients, who were asked to clear the material from the spoon and swallow it. Two trials of the swallow were made and a videofluoroscopic recording was saved to disc.

As per previous studies evaluating swallowing assessments, the clearest and most complete of the 2 VFSS was analyzed in frame-by-frame slow motion using the Digital Swallowing Workstation (Model 7200, KayPentax, Lincoln Park, NJ) [13–15]. Swallowing *safety* was determined using a previously described Penetration-Aspiration Scale [16]. This 8 level scale was simplified to a 2 point clinically applicable system: 0 = Level 1–5 (no penetration of the glottis) and 1 = Levels 6–8 (penetration of the glottis). This modification was made as patients receiving scores of 6–8 are deemed “unsafe” to swallow and are reliant on a GTube.

Swallowing *efficiency* was defined as the time it took the patient to complete 1 swallow (i.e. swallowing transit time). This was measured on the VFSS as the time from the start of the swallow to the time of the radio-opaque bolus to passing the cricopharyngeus muscle. To establish inter-rater reliability, 15% of the VFSS films were randomly chosen for re-analysis.

Quality of life

At the times of functional outcomes assessments (pre-operative and 6–12 months post-operative) patients were administered questions 31–60 of the EORTC H&N 35 [17]. This is a head and neck cancer specific self-administered quality of life questionnaire, which patients complete on their own without the help of a health care professional or questionnaire administrator. The minimal score is 30 and the maximal 120 with a higher score indicating a worse quality of life.

Survival data

Survival was defined as the interval from the date of surgery to the date of death or date of disease recurrence. This data was obtained from the Alberta Cancer Board patient registry which collects mortality data prospectively as it becomes available.

Surgical outcomes

Surgical outcomes included length of stay (LOS), return to the OR (ROR), and surgical complications.

Table 1
Patient variables.

Variable	Number
n	17
Mean age, y (range)	62.5 (48–80)
Sex	
Male	10
Female	7
T-Stage	
T2	1
T3	11
T4	5
AJCC Stage	
III	7
IV	10

Abbreviations: y, years; AJCC, American Joint Committee on Cancer.

Analysis

Disease-free survival rates were determined using Kaplan-Meier survival analysis. Categorical data was compared with chi-squared analysis. Continuous variables were compared with an independent sample *t*-test. Statistical significance was defined as a $p < 0.05$. An alpha of 0.05 was used throughout the study. Comparisons were made between each post-operative time frame and the pre-operative time. All statistical analyses were performed by a statistician using *SPSS* version 23 (SPSS Inc, Chicago, IL).

Results

17 consecutive patients met criteria and were included. All patients had biopsy proven squamous cell carcinoma (SCC) of the tongue and were treated with primary surgical resection and beavertail radial forearm free-flap reconstruction followed by RT or Chemo-RT. Table 1 describes the patient and disease characteristics. All final pathology resection margins were negative.

Functional outcomes

GTube requirements for patients in each group at 4 time periods are shown in Table 2. No patients were lost to follow-up. In patients able to swallow 1-month post-surgery the best level of solid intake achieved was: a diced dysphagia diet in 54%, a minced diet in 23%, a pureed diet in 15% and a regular full solid diet in 8%. By 12 months post-operatively, all patients were GTube free and able to tolerate a regular full solid diet.

Patients who were willing to complete swallowing studies demonstrated swallowing transit times as per Table 3. The change in score from pre-op to post-op was not statistically significant ($p = 0.32$). All patients who could perform the VFSS did not aspirate and had aspiration scores of 0. No patient was given a palatal drop prosthesis.

Table 2
GTube requirements at peri-operative time periods.

Time period	n (%)
Pre-op	
GTube rate (%)	2 (12)
1 mo post-op	
GTube rate (%)	6 (35)
6 mos post-op	
GTube rate (%)	3 (17)
12 mos post-op	
GTube rate (%)	0 (0)

Abbreviations: Pre-op, pre-operative; mo(s), month (s); post-op, post-operative; GTube, gastrostomy tube.

Table 3
Peri-operative swallowing transit times.

Time period	
Pre-op	
Number tested	13
Transit time, sec	1.32 (0.75) (52, 34–69)
Post-op	
n	12
Transit time, sec	1.61 (0.86) (55.5, 46–77)
Change in score	
Number tested	8
Transit time, sec	0.36 (1.0) (0.26, 0.87–1.79)

Abbreviations: Pre-op, pre-operative; sec, seconds; post-op, post-operative.
Note: Data are given as mean (SD) (median, range).
Note: Change in transit time = post-op time - pre-op time.

Table 4
Peri-operative speech intelligibility.

Speech measure	
Pre-op	
Number tested	14
Single word intelligibility, %	81.5 (25.1) (93, 10–100)
Sentence intelligibility, %	85.5 (24.4) (97, 10–100)
Post-op	
Number tested	12
Single word intelligibility, %	62.3 (25.1) (61, 23–98)
Sentence intelligibility, %	75.0 (21.6) (81, 33–99)
Change in intelligibility	
Number tested	9
Single word intelligibility, %	−27.2 (28.8) (−29, −71–20)
Sentence intelligibility, %	−12.4 (38.9) (−21, −67–78)

Abbreviations: Pre-op, pre-operative; post-op, post-operative.
Note: Data are given as mean (SD) (median, range).
Note: Change in intelligibility = post-op score - pre-op score.

All patients were able to phonate and their speech was interpreted as shown in Table 4. The changes in single word and sentence intelligibility from pre-op to post-op were not statistically significant ($p > 0.05$). Missing data was due to patients refusing to participate in the test due to time constraints.

10(59%) patients attended the prescribed speech and swallowing rehabilitation sessions for the first post-operative year. This included at least a monthly visit for the first 6 months and every 2 months thereafter. All patients who underwent functional testing were attendees of the rehabilitation program.

Quality of life

Quality of life scores are summarized in Table 5. Missing questionnaires were due to patients refusing to complete the questionnaires. Scores did not change significantly from the pre-operative state ($p = 0.78$).

Survival

The 1, 2 and 5-year disease specific survival rates were: 71%, 65%, and 53%. The cause of death was recurrent or metastatic disease in all cases. 1 patient had local recurrence at 1.2 years post-operatively, but was still alive after salvage surgery at the time of data collection. 1 other patient developed a locoregional recurrence 6 months after surgery and died from this.

Table 5
Peri-operative EORTC H&N 35 scores.

Time period	
Pre-op	
Number tested	15
Score	35.3 (12) (52, 34–69)
Post-op	
Number tested	15
Score	35.0 (13.4) (55.5, 46–77)
Mean change in score	
Number tested	8
Change	7.4 (7)(12, 0–19)

Abbreviations: Pre-op, pre-operative; post-op, post-operative.
Note: Data are given as mean (SD) (median, range).
Note: Change in score = post-op score - pre-op score.

Surgical outcomes

The mean length of stay was 19.1 days (range: 14–50). 1 patient had a return to the OR for flap compromise on POD 2. The vein was revised and the flap survived with no further complications. There were no total flap failures. 2 patients had partial flap loss which healed by secondary intention. There were no hematomas or seromas. 3 neck infections were treated with antibiotics and resolved uneventfully. Flap donor sites experienced a widened scar in each patient. All skin grafts healed well by 3 months and there were no wrist contractures. No other flap donor site complications were encountered.

Discussion

Reconstructing a fully functional anterior tongue is a major challenge. It is not possible to create an independently mobile tip of the tongue as in the original state; thus, the surgeon creatively designs a mound of tissue that provides sustained bulk and can be mobilized by the base of tongue and mandible [1–3,18].

The *total oral tongue* (total anterior glossectomy) defect has often been grouped with total glossectomy; few descriptions of the defect and its reconstruction have been described [19–21]. The most detailed descriptions of anterior tongue reconstruction have included pentagonal shapes and modifications or rectangles [20]. None of those studies emphasized the use of bulky tissue to create a sustained mound of tissue. The technique described herein employees an independent fibrofatty tail that is used to tailor bulk, support the floor of mouth and shape the anterior tongue.

By 12 months post-op all patients were able to maintain total oral nutrition with a full solids diet without a GTube. All patients exhibited a safe swallow without aspiration. However, swallowing efficiency decreased with mean swallowing transit time increasing by 0.4 s. While this is only a fraction of a second per swallow, it adds up. Considering all swallows per meal, meal times will be prolonged. This is certainly the case in total glossectomy, where in many patients, meals are so prolonged that patients prefer to use a GTube for convenience [5]. In the current series, this was not the case and patients were able to enjoy full oral diets. This is not only a testament to the success of their reconstruction but also to their rigorous speech and swallowing rehabilitation [5]. By maintaining the BOT, patients had a mobile piece of tongue to aid in swallowing, which has been shown to be a critical structure for swallowing recovery after head and neck surgery [3,11,22]. Due to the paucity of literature on total oral tongue defects, there are no studies to compare these result to.

Pre-operatively all patients demonstrated impaired single word and sentence intelligibility, with good congruence between both measures. This is likely due to neuromuscular adaptation to the growing tumor. Post-surgery and RT all scores decreased. This was particularly evident for word intelligibility, which dropped on the order of 20–30%. However, perhaps of more clinical importance, are the mean sentence intelligibility scores, which allow the listener to incorporate contextual clues to fill in gaps. These scores only dropped by 12% indicating that despite significant resection, patients could maintain good intelligibility. There was a wide range of speech scores in patients; this is likely accounted for by some patients being able to attend speech therapy classes regularly and some being less motivated than others. Previous studies support that patient motivation and compliance with speech rehabilitation will influence long term intelligibility [5,23].

While other studies have shown that extensive glossectomy patients fail to achieve acceptable speech, this is not supported here. A possible explanation could be enrollment of patients in a regular speech and swallowing rehabilitation program at the University of Alberta. However, it can be somewhat difficult to directly compare results as functional outcome testing is yet to be standardized [27].

It should be noted that although differences in speech scores were not statistically significant, the drop in single word intelligibility of 27% could be argued to be clinically relevant. Fortunately, most spoken language is interpreted in sentences, and thus, it is argued that the drop of sentence intelligibility of only 12% showed acceptable maintenance in spoken communication.

Previous studies have suggested that the site and extent of glossectomy will determine speech articulation and intelligibility [25,26]. As expected, larger resections lead to poorer intelligibility scores. This is particularly true for single word intelligibility, where the listener does not have contextual clues to help interpret the pathological speech. Moreover, it is the site of the resection that will ultimately determine how understandable a patient is. Anterior tongue resections, especially those involving the tip, will create challenging rehabilitation for patients. The reason is that the tongue tip, versus the lips, is primarily responsible for forming consonant sounds. In languages dependent on consonants, such as Polish or Chinese, this can severely impact speech outcomes [26,24]. Conversely, middle or posterior resections limited to the base of tongue, will produce nearly normal speech [21,22,26]. This is because the tongue base, unlike the anterior tongue, has less mobility, and thus, naturally plays less of a role in articulation. As such, it is critical that a functional reconstruction be performed in total oral glossectomy as shown here [8,9].

Mean quality of life scores remained high and stable from the pre-operative state. This is despite a decline in speech and swallowing function over time. Few studies exist that have used validated QOL measures in extensive glossectomy patients. In one of the more objective studies, Ruhl et al. have shown data similar to this study, showing that even total glossectomy patients can achieve good quality of life [8]. This could be due to a balance in cancer treatment-related improvements and deteriorations. For example: while cancer-related pain improved, swallowing function declined. Furthermore, family and social factors could account for a stabilized quality of life. Other studies have shown that patients who are motivated, have emotional support from their families, attend regular follow-up visits with their physicians and attend rehabilitation sessions with speech language pathologists have the highest quality of life and often the best functional outcomes [24]. Perhaps, pre-operative counseling including preparing the patient and their family for the challenges ahead played a role in maintaining quality of life in total glossectomy patients.

The 1, 2, and 3 year disease specific survival rates were comparable or better to similarly staged patients of other studies [25,26]; All patients were treated with aggressive surgery and RT and survived long term to have functional outcomes measured.

Surgical outcomes were excellent with high flap viability, minimal complications and comparable quality metrics compared to previous studies [27]. The LOS was on the longer end of the spectrum. This is because patients were kept in the hospital to receive daily speech and swallowing therapy until they could swallow at least 50% of their daily caloric intake. Because most patients lived > 1 h from the hospital, keeping them in-house allowed for vigorous early rehabilitation. This helps maximize function before RT. The only difference in standard RFFF outcomes was a widened scar in the proximal forearm; this is due to the extensive thinning of the skin flaps to harvest the beavertail.

The weaknesses of this study are inherently due to a small sample size and selection bias. While all patients could be included in the survival analysis, only those who were alive and willing to perform swallowing function tests could be included. In addition, not all patients who could swallow and speak agreed to perform the tests, and all patients who performed the tests attended rehabilitation sessions. Thus, there is a likely a selection bias in that patient who did well functionally, were more likely to undergo functional testing. Lastly, patients with poorer outcomes are more likely to drop out of a longitudinal study; thus, leading to an overestimate of favorable outcomes.

Unfortunately, there was no measure of flap atrophy. However, given the favoranble functional outcomes, it is likely that a significant amount of bulk was retained as this is a known prognostic factor for retaining function [26].

Conclusion

The BTRFFF reconstruction of the total oral tongue defects leads to excellent functional outcomes with a meaningful quality of life in the long term.

Submission declaration and verification

This manuscript is not under consideration for publication elsewhere. All authors and responsible authorities in the authors' institution approve the publication of this manuscript. If accepted, this manuscript will not be published elsewhere in any language, including electronically, without the written consent of the copyright holder.

Ethics approval

Prior to commencement of this study, ethics approval was obtained from the University of Alberta Health Research Ethics Board.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose related to this manuscript.

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