Chapter 6
Quality of Life Among Patients With Tongue Cancer: Primary Closure Versus Free Flap Reconstruction

Feras Al Halabi

Introduction

Oral cancers have the 7th and 13th highest incidence in the United States and Canada, respectively (Chong, 2005). Oral squamous cell carcinoma accounts for 24% of all head and neck cancers and often arises due to a combination of genetic alterations and continuous exposure to environmental agents such as tobacco and alcohol (Carvalho, Nishimoto, Califano, & Kowalski, 2004). Among European and North American populations, the tongue is the most common site for intraoral cancer, amounting to almost half of all oral cancers (Warnakulasuriya, 2009). It was estimated that in 2010, 10,990 new cases were diagnosed and 1990 patients had died of tongue cancer in the United States (Siegel, Naishadham, & Jemal, 2013). Typically, these aggressive lesions affect men aged 60–80 but can occur in the very young as well. Recently, tongue cancer has shown a fivefold increase in younger adults aged 20–44 years and a twofold increase in older adults (Shiboski, Schmidt, & Jordan, 2005). Tongue cancer is particularly dangerous because of a high risk of spreading to nearby lymph nodes and therefore has major implications for future well-being and quality of life among cancer survivors (Chong, 2005). More importantly, the tongue is one of the most difficult structures of the oral cavity to reconstruct because of its central role in articulation, deglutition, and airway protection (Engel, 2010).

F. Al Halabi (✉)
Faculty of Dentistry, McGill University, Montreal, QC, Canada
e-mail: feras.alhalabi@mail.mcgill.ca

T. R. Fitzpatrick (ed.), *Quality of Life Among Cancer Survivors*,
https://doi.org/10.1007/978-3-319-75223-5_6

Anatomy

The tongue lacks an internal skeletal structure, has a muscular architecture of three-dimensional orthogonal muscles, and maintains a constant volume as it deforms during function, allowing for highly complex and virtually infinite shapes to be achieved (Reichard, Stone, & Woo, 2012). The tongue is composed of two main muscle groups: the intrinsic and extrinsic muscles. The intrinsic muscles are all confined within the body of the tongue and are longitudinal with both superior and inferior components, transverse and vertical (Hamlet, Mathog, Patterson, & Fleming, 1990). These muscles serve mainly to deform the tongue for proper mastication, deglutition, and phonation. The four extrinsic muscles of the tongue, which originate outside of the tongue body, are the genioglossus, hyoglossus, styloglossus, and palatoglossus muscles. These muscles function to protrude, depress, and elevate the tongue, respectively (Hamlet et al., 1990). The finely coordinated contraction of the intrinsic and extrinsic muscles allows for the organ to carry out highly complex movements of speech, mastication, and swallowing (Hamlet et al., 1990; Suarez-Cunqueiro et al., 2008). Loss of integrity in any of these muscles severely impairs speech quality and swallowing (Suarez-Cunqueiro et al., 2008).

Tumors can involve the oral tongue, the base of tongue, or both; the anatomical point of separation is the circumvallate papillae. The site of most tongue cancers is the anterior two-thirds of the lateral border or the ventral surface (Chong, 2005). Adequate oncologic control of squamous cell carcinoma often necessitates aggressive surgical resection to ensure clear margins and minimize the risk of recurrence. Whereas 1 cm is generally considered adequate for most squamous cell carcinomas, for tongue cancer, it has been suggested that margins should be 1.5–2 cm given the high chance for local or regional recurrence (Chong, 2005). Glossectomy is often carried out as a therapeutic means to eradicate tongue malignancies (Spiro & Strong, 1974). The highly complex coordination of different muscles of the tongue produces the necessary precise movements for proper speech, mastication, and deglutition (Urken, 2003; Urken, Moscoso, Lawson, & Biller, 1994). How a patient adapts after the removal of tongue tissue might be dependent on the type of closure/reconstruction that is performed; however, there remains controversy regarding which of these specific procedures offers the patient the best functional outcomes. The importance of this question has led to the production of many articles that have clearly discussed the effect of oncologic ablative surgery for tongue squamous cell carcinoma and the significant comorbidity, specifically, due to the effects on speech and swallowing (Hara, Gellrich, Duker, Schön, Fakler, et al., 2003; Stelzle, Knipfer, Schuster, & Bocklet, 2013; Suarez-Cunqueiro et al., 2008; Urken et al., 1994). This in turn, plays a major role in the quality of life of patients post glossectomy (Hartl et al., 2009; Radford, Woods, & Lowe, 2004).

Quality of Life

The tongue is the key structure for pronunciation, sustenance, and communication. Patients suffering from tongue malignancies have significantly lower intelligibility scores than control patients, even before surgical intervention (Stelzle et al., 2013). Further impairment occurs after surgical rehabilitation and is closely related to tumor localization and the volume of resection which is guided by the tumor size (Borggreven et al., 2005; Matsui, Ohno, Yamashita, & Takahashi, 2007; Stelzle et al., 2013; Sun, Weng, Li, Wang, & Zhang, 2007). Loss of tongue mass and motor control, which occurs during glossectomy, creates challenges in reaching the palate and elevating the tongue tip during speech (Chuanjun, 2002; Reichard et al., 2012; Sun et al., 2007). Patients whose speech and swallowing are affected following treatment and surgery for tongue cancer may experience difficulties in communication as speaking may be affected together with health and nutrition issues resulting in increased isolation, possible depression, and loneliness. The surgical treatment of tongue cancer, with or without reconstruction and/or radiotherapy, leads to different levels of voice, speech, and deglutition disorders. Evaluating the quality of life related to these swallowing alterations is important to further our knowledge about the impact of such alterations from the patient's point of view (Costa Bandeira et al., 2008, p. 183). These authors studied the quality of life related to swallowing in patients treated for tongue cancer. Findings revealed that the aspects related to how to deal with deglutition problems, time taken for meal consumption, pleasure in eating, chewing problems, food sticking in the throat and mouth, choking, and the knowledge of feeding restrictions, which were evaluated by different domains of SWAL-QOL, were factors that contributed to a negative impact for patients with advanced-stage tumors who underwent radiotherapy (Costa Bandeira et al., 2008, p. 183).

Swallowing is an automatically regulated process until trauma occurs (Dodds, Logemann, & Stewart, 1990). After surgical intervention, patients show a significant decline in swallowing ability, with a level of dysfunction closely related to tumor stage, site, and extent of its excision within the oral cavity (Hsiao, Leu, & Lin, 2002; Logemann et al., 1993; Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004; O'Connell et al., 2008; Pauloski et al., 1993). Reconstructive treatments for oral cavity cancers involving the tongue are aimed at preserving the patient's ability to swallow and speak whenever possible (Engel, 2010). However, reconstruction following tongue cancer resection remains one of the most challenging problems in head and neck oncology (Engel, 2010). The principles of reconstruction traditionally follow a reconstructive ladder; small glossectomy defects may be closed by primary closure, healing by secondary intention, or with the use of skin grafts, while greater resections necessitate reconstructions with local, pedicled, or free flaps (Bokhari & Wang, 2007; Urken et al., 1994). The choice of reconstruction selected after tongue cancer resection plays a major role in the ultimate speech and swallowing abilities of the patient (Hsiao et al., 2002; Khariwala et al., 2007; Logemann et al., 1993; Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004; O'Connell et al., 2008; Pauloski et al., 1993, 2004; Su, 2003). Although, postoperative function is influenced by multiple factors, such as location, other structures in the area that are resected, and radiation, it is clear that restoration of mobility and bulk of the tongue is essential to achieving optimal outcomes (Hsiao et al., 2002; Hsiao, Leu, Chang, & Lee, 2003; Hsiao, Leu, & Lin, 2003). Quality of life during postoperative recovery will be greatly impacted by the success of the reconstruction surgery and the individual's ability to adjust and cope with the changes in speech and swallowing.

Techniques

Tongue reconstruction to restore its functionality after resection has been greatly advanced by the predictable use of microvascular free flap techniques (Khariwala et al., 2007). Although there is a clearer understanding on the technique to employ when dealing with the extremes of defects, there is a lack of consensus among clinicians as to the best method of reconstruction for a medium-sized defect (hemiglossectomy defect). There are advocates for both primary closure and flap reconstruction with differences in outcomes based on limited retrospective data (Bressmann, Ackloo, Heng, & Irish, 2007; Chuanjun, 2002; Hsiao et al., 2003; McConnel et al., 1998). There are numerous studies reporting on the use of a variety of free flaps to reconstruct partial or hemiglossectomy defects; however, there is not enough data comparing speech, swallow, and quality of life outcomes postsurgery (de Vicente, de Villalaín, Torre, & Peña, 2008; Matsui et al., 2007; Matsui, Shirota, Yamashita, & Ohno, 2009; Seikaly et al., 2003; Su, 2003; Sun et al., 2007). This review presents the available evidence for primary closure or free flap reconstruction for partial or hemiglossectomy defects. We also present the determinants and outcome measures used in the present literature to evaluate the functional outcome of speech and swallowing after surgical rehabilitation.

Functional Outcomes of Glossectomy, Reconstruction, and Quality of Life

Previous studies have concentrated their evaluations on speech and swallowing, factors which are most negatively affected by surgical ablation (Suarez-Cunqueiro et al., 2008). These are also the factors that patients usually identify as having a large effect on their quality of life (Dwivedi, Kazi, Agrawal, & Nutting, 2009; List et al., 2000). A number of determinants have been identified to affect the functional outcomes after glossectomy and surgical rehabilitation (Matsui et al., 2007, 2009; Reichard et al., 2012; Stelzle et al., 2013; Sun et al., 2007).

Speech: Determinants of Functional Outcome

Tumor site, sizes including volume of resection, mobility of the remaining native tongue, method of reconstruction, and postoperative radiotherapy have all been shown to determine postoperative articulation intelligibility after glossectomy. A number of studies have discussed the relationship between speech and tumor site or location (Matsui et al., 2007; McConnel et al., 1998; Pauloski et al., 2004; Pauloski, Logemann, & Rademaker, 1994; Seikaly et al., 2003; Stelzle et al., 2013; Sun et al., 2007). Most studies showed that independent of the method of reconstruction, patients who underwent resection of the anterior portion of the oral tongue had significantly lower intelligibility scores than those who had resection of the middle or posterior third of the oral tongue (Matsui et al., 2007; Sun et al., 2007). Matsui et al. analyzed the intelligibility of 126 patients classified into 3 groups based on the site of tongue resection. Although the type of flap used had no effect on the functional outcome, they concluded that low speech intelligibility scores were recorded when the flap directly contributed to pronunciation in the anterior, lateral, and combined anterolateral resection groups (Matsui et al., 2009). Similarly, Sun et al. showed that patients with preservation of the tongue tip and floor of the mouth showed significantly less decline in intelligibility than those with resection of these sites (Sun et al., 2007). On the other hand, resection of the tongue base did not significantly affect articulation. They concluded that the attempt to preserve the anterior third of the tongue, specifically the tip, and floor of the mouth as much as possible has positive results on speech outcome (Sun et al., 2007).

It is well established that the greater the extent of tongue resection, the poorer the functional outcome (Colangelo, Logemann, & Rademaker, 2000; Matsui et al., 2007; Pauloski et al., 1998; Pauloski et al., 2004; Rieger, 2007; Stelzle et al., 2013; Sun et al., 2007). Patients with advanced primary tumors did significantly worse than patients with smaller tumors in the assessments before and after treatment, concerning communicative suitability, intelligibility, articulation, and consonant errors (Borggreven et al., 2005). Sun et al. showed that patients with T3 tumors had significantly greater decline in intelligibility than the T1 group (Sun et al., 2007). Similarly, Stelzle et al. showed that speech intelligibility in patients with T1 tumors was significantly higher than in patients with larger T2 or T4 tumors. At 12 months postoperatively, the volume of resection was closely related to the functional outcome independently of tumor stage (Stelzle et al., 2013). Hence, patients with larger tongue resection volumes consistently had lower intelligibility scores (Pauloski et al., 1998). Most studies used tumor stage as a mean of identifying tumor size (Colangelo et al., 2000; Matsui et al., 2007; Pauloski et al., 1998, 2004; Rieger, 2007; Stelzle et al., 2013; Sun et al., 2007). Although tumor stage has not explicitly been shown to affect functional outcome, tumor size presents a reliable determinant of speech outcomes. Current research has yet to provide evidence on the percentage of tongue resection or tumor stage that indicates free flap reconstruction to produce a better functional outcome.

Various studies have compared speech outcomes in patients based on the method of reconstruction (Chuanjun, 2002; de Vicente et al., 2008; Hsiao et al., 2002; Matsui et al., 2007; McConnel et al., 1998; Nicoletti et al., 2004; Sun et al., 2007; Thankappan et al., 2011). Conflicting results have been reported on the postoperative motion of the tongue with different techniques for closure selected, whether primary closure or flap reconstruction. Hsiao et al. and Chuanjun et al. found poorer intelligibility and articulation when comparing a radial forearm free flap (RFFF) reconstruction of hemiglossectomy to primary closure (Chuanjun, 2002; Hsiao et al., 2002). Others studying the difference between free flaps found no significant difference in speech outcomes between RFFF and reconstruction with adjacent tongue dorsal flap (Sun et al., 2007), anterolateral thigh flap (ALTF) (de Vicente et al., 2008), rectus abdominis myocutaneous flap (RAMCF), or pectoralis major musculocutaneous flap (PMF) (Matsui et al., 2007). Some data has suggested that a more thin pliable flap such as the RFFF reconstruction resulted in higher intelligibility in certain articulatory sites and modes compared to RAMCF reconstruction of lateral oral tongue defects (Matsui et al., 2009).

Regardless of the method of reconstruction used, it is commonly agreed that mixed modality treatment involving postoperative radiotherapy is associated with poor speech outcomes (Matsui et al., 2007; Nicoletti, Soutar, Jackson, Wrench, Robertson, & Robertson, 2004; Pauloski et al., 1994; Shin, Koh, Kim, Jeong, & Ahn, 2012; Suarez-Cunqueiro et al., 2008; Thankappan et al., 2011; Zuydam, Lowe, Brown, Vaughan, & Rogers, 2005). Shin et al. found that postoperative radiotherapy negatively influenced speech and swallowing in patients with partial glossectomy and RFFF reconstruction (Shin et al., 2012). Patients who were treated by surgery and postoperative radiotherapy had significantly worse speech repetition rates than those treated by surgery only (Shin et al., 2012). Other retrospective studies found that patients who had postoperative radiotherapy had restricted diet and tongue mobility and poorer subjective and objective speech outcomes (Matsui et al., 2007; Thankappan et al., 2011). Although there was no difference in tongue mobility, radiotherapy may have induced more tongue shrinkage than expected preoperatively and thus resulted in a decrease in coordinated tongue movement (Shin et al., 2012; Thankappan et al., 2011). Yun et al. reported that unexpected volume loss of reconstructed tongue tissue can lead to a decreased ability to swallow or speak intelligibly (Yun et al., 2010).

Speech: Assessment Methods

When assessing speech, most studies used perceptual, acoustic, and subjective methods. In perceptual evaluation, recorded speech from the patient under standardized conditions is presented to one or many blinded listeners. The listeners then transcribe the patients' speech for different functional parameters and rate it. The most commonly assessed speech parameters include speech intelligibility, communicative understandability, speech acceptability, articulation, reading time, type of speech errors, and diadochokinetic rate (de Vicente et al., 2008; Hsiao et al., 2002; Hsiao, Leu, & Lin, 2003; Loewen, Boliek, Harris, & Seikaly, 2010; Matsui et al., 2009; Rieger, Zalmanowitz, & Wolfaardt, 2006; Shin et al., 2012; Sun et al., 2007; Thankappan et al., 2011; Uwiera, Seikaly, Rieger, Chau, & Harris, 2004; Yun et al., 2010).

Speech intelligibility is the most common evaluated parameter and includes intelligibility of consonants, vowels, and syllables, as well as words, sentences, and conversations (Bressmann, Sader, Whitehill, & Samman, 2004; Loewen et al., 2010; Matsui et al., 2007; Stelzle et al., 2013; Uwiera et al., 2004). A number of studies graded intelligibility on a scale of 1–7 based on the number of errors the patient produces (de Vicente et al., 2008; Hsiao et al., 2002; Hsiao, Leu, & Lin, 2003; Rieger, 2007; Uwiera et al., 2004). The intelligibility scale they used relied on the number of errors the patient produces, while the articulation scale measured the patient's extent of dysarthria or mispronunciation (Hsiao et al., 2002; Hsiao, Leu, & Lin, 2003). Articulation is usually evaluated by the intelligibility test, because speech is a social tool whose most significant measurement should be how well it is understood (Michi, 2003). Analysis on the basis of articulatory mode and site can determine the sources of speech disorders, regardless of the language in which the test is carried out (Michiwaki, Schmelzeisen, Hacki, & Michi, 1992). The manner by which the tongue interacts with other structures in the oral cavity determines the articulatory mode. The articulatory mode of glossal sounds is composed of seven groups including plosives, fricatives, affricatives, grids, nasals, vowels, and semi-vowels. Evaluating errors in speech based on articulatory site and mode allows an evaluator to draw conclusions on the effect of reconstruction on speech based on the site and size of resection. In addition, analysis of tongue mobility and effect of volume of resection on speech is carried out by understanding deficits in articulation based on articulatory site and mode.

Measurement of diadochokinetic (DDK) rate is a test used by speech-language pathologists (SLP) to assess, diagnose, and treat speech malfunctions (Gadesmann & Miller, 2008). It is also known as the Fletcher Time-by-Count Test of Diadochokinetic Syllable Rate. DDK rate measures how quickly a person can accurately repeat a series of rapid, alternating phonetic sounds. These sounds, called tokens, are designed to test different parts of the mouth, tongue, and soft palate in the back of the throat. The tokens contain one, two, or three syllables. There are established DDK rate norms for each year of age through childhood and for adults with various underlying conditions. The patient's ability to repeat a word or syllable a number of times infers information about the lucidity and mobility of the tongue after glossectomy and reconstruction. Hsiao et al. used repetition rate as an objective evaluation of speech when comparing different methods of reconstruction after glossectomy and in a functional outcome analysis of glossectomy patients reconstructed with RFFF (Hsiao et al., 2002; Hsiao, Leu, & Lin, 2003). By relating repetition rate to the type of reconstruction used, they made observations about how the surgical rehabilitation method alters tongue movement and mobility.

A number of studies have used *ultrasound imaging* combined with perceptual evaluation to analyze the biomechanical nature of tongue movement during speech

(Bressmann et al., 2005; Rastadmehr, Bressmann, Smyth, & Irish, 2008). Rastadmehr et al. instructed patients to read the first four sentences of a passage with a variety of phonemes to mimic everyday conversational speech (Rastadmehr et al., 2008). Ultrasound imaging of the tongue was conducted during the passage recital, and information about tongue velocity and movement was recorded. Reading time as a quantitative perceptual measure was recorded and was related to tongue velocity and mobility (Rastadmehr et al., 2008). Other studies used clinical tongue mobility testing to relate speech deficits to lack of lucidity or mobility of the tongue (Matsui et al., 2007; Shin et al., 2012; Thankappan et al., 2011; Yun et al., 2010). Matsui et al. measured tongue mobility in relation to intelligibility and subjective speech evaluation (Matsui et al., 2007).

Acoustic evaluation includes the analysis of characteristics of vowel and diphthong sounds, i.e., duration, first and second formants and fundamental frequency, and sibilant sounds, i.e., spectral moments and frication duration, from speech samples (Laaksonen, 2010; Laaksonen, Rieger, Harris, & Seikaly, 2010). Acoustic characteristics correspond to the function of different tongue movements for diphthongs and position vowels, helping to determine the reasons for reduction in intelligibility of speech. Formants are the resonant harmonics in the speech spectrum and are described as being the characteristic partials of individual's speech (Atal & Hanaver, 1971). Formant frequencies objectively measure approximation between various portions of the oral cavity and the oropharynx. Although there are infinite numbers of formants, only the first three are of clinical use (de Carvalho-Teles, Sennes, & Gielow, 2008). First formant frequency (F1) is related to the vertical displacement of the tongue and F2 with the horizontal displacement of tongue, while F3 is related to the size of the oral and oropharyngeal cavity (de Carvalho-Teles et al., 2008). Information about the effects of size, site, and method of reconstruction on speech may be acquired by evaluating changes in these frequencies before and after resection and surgical rehabilitation and over time (Laaksonen, 2010; Laaksonen et al., 2010).

It has been shown that the larger the acoustic area, the greater the articulatory space, enabling a more precise articulation and a better intelligibility of speech (Laaksonen, 2010). Laaksonen et al. were able to define whether RFFF reconstruction of hemiglossectomy defects reduces the ability of patients to produce vowel sounds as indicated by vowel space area. The same group reported on the effect of resection and reconstruction with an RFFF on the acoustics of sibilants by measuring certain spectral and temporal characteristics. They were able to reflect on functional changes in the ability to articulate (Laaksonen et al., 2010). Sibilants require detailed somatosensory feedback (tactile and proprioceptive) and precise muscular movements, being some of the most challenging sounds to produce (Reichard et al., 2012). This in turn allows the evaluator to understand how different reconstruction methods alter tongue movement and ability to articulate.

Subjective assessment usually includes self-reported questionnaires about speech function. Subjective patient information evaluates speech outcome from the patient's perspective and allows the evaluator to measure the patient's satisfaction with final outcome. More importantly, subjective data infers information about the quality of speech and the patient's overall quality of life based on the speech deficits present.

Swallowing: Determinants of Functional Outcome

The tumor site, size, and extent of its excision, as well as the method of reconstruction, determine the adverse effects of surgery on swallowing (Hsiao et al., 2002; Logemann et al., 1993; Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004; O'Connell et al., 2008; Pauloski et al., 1993). In addition, the use of multimodal therapy including postoperative radiotherapy has been shown to affect swallowing outcomes (Shin et al., 2012; Thankappan et al., 2011). Studies on swallowing impairment are common and dependent on tumor site and size (Hara, Gellrich, Duker, Schön, Nilius, et al. 2003; Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004; Pauloski et al., 2004; Su, 2003; Thoné, Karengera, Siciliano, & Reychler, 2003). Borggreven et al. found a significant positive correlation between large tongue tumors or extensive resections and increased morbidity from dysphagia (Borggreven et al., 2007). Patients with smaller resections showed better swallowing outcomes, while patients with base of tongue resections showed worse outcomes with regard to tumor site (Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004). Furthermore, patients with resection of the oral tongue and floor of the mouth experienced problems in the oral phase, while patients after resection of the base of tongue encountered swallowing dysfunction in the pharyngeal phase (Hara et al., 2003; Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004; Pauloski et al., 2004). Hara et al. showed that regardless of the type of free flap used, the larger the resection, the greater was the impairment of the tongue movement due to scar formation. They also showed that patients who underwent the most anterior (lingual tip) had greater decreases in global tongue mobility than those who underwent lateral and posterior resections. Accordingly, resection of the anterior tongue and floor of the mouth had more impairment in swallowing than patients with resection of the lateral tongue or base of tongue (Hara et al., 2003).

Similar to speech outcome, the effect of the type of reconstruction on swallowing is not clear (Hsiao et al., 2002; Khariwala et al., 2007; Logemann et al., 1993; Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004; O'Connell et al., 2008; Pauloski et al., 1993; Su, 2003). Hsiao et al. reported better swallowing in patients with RFFF reconstruction in terms of larger bolus volume and better ingestion rate compared to those with primary closure following hemiglossectomy of oral tongue (Hsiao et al., 2002). The same group used videofluoroscopy (VFS) studies to compare swallowing function of patients after hemiglossectomy and reconstruction with primary closure or RFFF. They found nearly normal patterns of swallowing in patients reconstructed with RFFF. These patients were able to make good tongue-palate contact, facilitating the sealing of the posterior pharyngeal sphincter and preventing premature spilling of the bolus (Hsiao, Leu, Chang, & Lee, 2003). Sue et al. showed no significant difference in swallowing outcome between patients who underwent hemiglossectomy and reconstruction with RFFF or PMF (Su, 2003). Similarly, there was no significant difference in swallowing outcome between RFFF and ALTF reconstruction in patients after subtotal glossectomy of the oral tongue (de Vicente et al., 2008). Hence, the type of reconstruction that allows for better swallowing outcomes remains elusive. It is evident that further research is required to fully understand the method of reconstruction required to surgically treat specific tongue tumors based on size and site.

With regard to multimodal therapy, including the use of postoperative radiotherapy, significantly higher proportion of patients who had adjuvant treatments had restricted tongue mobility and diet (Thankappan et al., 2011). On subjective examination, Shin et al. found that postoperative radiotherapy was related to poorer swallowing function after partial glossectomy and RFFF (Shin et al., 2012). In addition, radiotherapy may induce late complications such as subcutaneous fibrosis, mucosal edema, trismus, and salivary gland atrophy (Bokhari & Wang, 2007; Kazi et al., 2008; Pauloski et al., 1994).

Swallowing: Assessment Methods

Various methods are used to evaluate swallowing function and impairment, including objective radiological and clinical assesments, as well as, targeted patient questionnaires on swallowing deficits. Objective evaluations include the use of videofluoroscopic and modified barium swallowing (VFS/MBS) studies (Brown, 2010; O'Connell et al., 2008; Rieger, 2007; Seikaly, 2008; Uwiera et al., 2004). VFS studies are currently the preferred objective assessment methods in most institutions because it permits the visualization of bolus flow in relation to structural movement throughout the upper aerodigestive tract in real-time (Argon et al., 2004; Pauloski et al., 1994; Shaw et al., 2004). Further, clinicians are able to observe the effects of various bolus volumes, bolus textures, and compensatory strategies on swallowing physiology. Hence, VFS studies help to determine how tumor site and method of reconstruction affect tongue movement and swallowing (Hsiao, Leu, Chang, & Lee, 2003).

A number of studies used a variety of quantitative swallowing and tongue mobility measures to evaluate VFS studies (Brown, 2010; O'Connell et al., 2008; Rieger et al., 2006; Uwiera et al., 2004). Brown et al. reported on swallowing impairment in patients with resection of the anterior two-thirds of the tongue and reconstruction with RFFF (Brown, 2010). They were able to make standardized conclusions on how RFFF reconstruction of anterior tongue resections affected the oral and pharyngeal phase of swallowing. In addition, this study evaluated swallowing function postoperatively for 12 months and used VFS studies to show changes in swallowing impairment (Brown, 2010).

Clinical evaluations rely on functional tests or grading systems to rate the method, time required, and type of food intake (de Vicente et al., 2008; Hsiao et al., 2002; Hsiao, Leu, & Lin, 2003; Su, 2003; Thankappan et al., 2011; Yun et al., 2010). Hsiao et al. used functional tests that enabled them to determine the swallowing outcomes of patients with hemiglossectomy defects reconstructed with RFFF, in addition to comparing the swallowing outcomes between primary closure and RFFF reconstruction (Hsiao et al., 2002; Hsiao, Leu, & Lin, 2003). The same group used information on dietary habits relative to the results of the functional tests to further understand how RFFF reconstruction affected swallow outcomes (Hsiao, Leu, & Lin, 2003). When comparing lateral arm free flap (LAFF) reconstruction to RFFF of tongue defects, Thankappan et al. based swallowing functional outcome on dietary characteristics: unrestricted, soft, and liquid. Patients with less diet restrictions and more regular diet had better swallowing outcomes (Thankappan et al., 2011). A number of studies (de Vicente et al., 2008; Su, 2003) used a 1–7 scale to evaluate swallowing objectively as previously described by Teichgraeber in 1985 (Teichgraeber, Bowman, & Goepfert, 1985). Su et al. clinically evaluated swallowing outcomes of patients with reconstruction with either RFFF or PMF where the average swallow rating was related to the extent of resection and the type of flap used to reconstruct glossectomy defects (Su, 2003). Similarly, RFFF and ALTF reconstructions of hemiglossectomy defects were compared to objectively identify changes in functional outcomes of swallowing (de Vicente et al., 2008).

Subjective assessment by means of questionnaires has been used to determine swallow outcomes. Su et al. used a questionnaire on the consistency of the diet to analyze the effect of the flap type used on the swallowing outcomes. Liquid consistency diets were related to lower swallowing outcomes and patients with larger resections, such as in patients with total glossectomy, while patients with hemiglossectomy had better swallowing outcomes and were able to eat semisolid or regular diets (Su, 2003). Kazi et al. used the M.D. Anderson Dysphagia Inventory (MDADI) which is a validated questionnaire designed to assess swallowing dysfunction based on global, emotional, functional, and physical scores (Kazi et al., 2008). Similarly Shin et al. used the MDADI as a subjective means of evaluating swallow outcomes after hemiglossectomy and reconstruction with RFFF (Shin et al., 2012). Patient-reported scales or questionnaires are helpful in assessing how patients view the outcome of their swallowing as a result of treatment and how changes in swallowing affected their quality of life (Kazi et al., 2008).

Evidence for Primary Closure

When considering the method of reconstruction of glossectomy defects, the main goal is to optimize speech and swallow outcomes. There is evidence in the literature that surgical resection of less than half of the tongue typically results in minimal and temporary dysfunction in speech and swallow (Michiwaki et al., 1992; Pauloski et al., 1998). Furthermore, there is evidence to support that small defects remaining after ablative surgery may be closed primarily without significant functional deficiency (Bressmann et al., 2005;Chuanjun, 2002 ; Hsiao et al., 2002 ; McConnel et al., 1998). This no doubt will affect the patient's everyday quality of life. McConnel et al. reported on a multi-institutional prospective study evaluating speech and swallow outcomes after oral and base of tongue glossectomy, based on the method of reconstruction: primary closure, distal myocutaneous flaps, and microvascular free flaps (McConnel et al., 1998). This evaluation included VFS studies for swallow function, speech intelligibility, and sentence articulation testing. Patients who had primary closure were more efficient at swallowing liquids and had less pharyngeal residue, a longer oral transit time with paste, and higher conversational intelligibility than patients who underwent reconstruction with a distal flap. Compared with patients who underwent reconstruction with a free flap, those who had primary closure had more efficient swallowing of liquids, less pharyngeal residue, and shorter pharyngeal delay times with paste (McConnel et al., 1998). These results indicate that the bulk of a muscle skin flap may be considered as a factor interfering with function in oral cavity and oropharyngeal reconstruction. They showed that a flap could be acting as an adynamic segment that impairs the driving force of the remaining tongue, thereby reducing the swallowing efficiency. This flap may also reduce the fine control of the tongue for speech (McConnel et al., 1998). They concluded that with relatively small resections of the oral tongue (30%) and tongue base (60%), there is no significant improvement in speech and swallowing efficiency between patients having flaps and patients with primary closure (McConnel et al., 1998).

Chuanjun et al. evaluated articulation intelligibility in patients with minor glossectomy or hemiglossectomy of T1 and T2 tongue cancer tumors reconstructed with either primary closure or vascularized flaps (Chuanjun, 2002). The articulation intelligibility was better in patients who were not receiving grafts compared to those with grafts. For patients who underwent primary closure, the intelligibility of articulation was significantly higher in blade portion, mid portion, and rear portion glossal sounds (Chuanjun, 2002). These results imply that the scar formation of the reconstructive flaps reduced the flexibility and mobility of the residual and, in turn, intensified articulatory impairment in patients who underwent reconstructive surgery. In addition, the remaining hemitongue reconstructed using RFFF without innervated muscle cannot produce voluntary movements. However, hemiglossectomy without reconstruction leaves a half-intact tongue, which may be more flexible in speaking movements than a reconstructed tongue. The residual hemitongue can compensate for the missing tongue to a great extent, as the articulation intelligibility scores indicate. The reconstruction with flaps, which interferes with the flexibility and mobility of the tongue, contributed to articulatory impairment. Therefore, if speech is the outcome of interest, reconstruction may be unnecessary for hemiglossectomy or partial glossectomy within the hemitongue (Chuanjun, 2002).

Hsiao et al. compared the postoperative speech and swallowing functions of patients who underwent RFFF reconstruction or primary closure after hemiglossectomy of T1–T3 tumors of the tongue (Hsiao et al., 2002). Speech quality, including intelligibility and articulation, was better in patients with primary closure. However, the bolus volume and ingestion rate in deglutition were better in those with flap reconstruction. Patients who underwent primary closure of the defect retained a small but freely movable tongue. The excellent mobility allowed for good speech, but the tongue displacement and volume loss resulted in less effective transport of food into the hypopharynx. This indicates that the volume and mobility of the reconstructed tongue determine the functional results of deglutition and speech in a hemiglossectomized patient. The flap increases bulk, thus improving pharyngeal clearance by maintaining the tongue-to-mouth roof contact that is necessary in the swallowing process, however hinders articulation by restricting the mobility of the remaining portion of the normal tongue (Hsiao et al., 2002).

For partial glossectomy defects without involvement of the tip, floor of the mouth, or base of tongue, free flap reconstruction does not appear to improve post-operative function over primary closure (Chuanjun, 2002). Three-dimensional echography shows a certain degree of lingual asymmetry, as a result of primary closure, can be compensated for quite successfully (Bressmann et al., 2007). The adynamic nature of the free flap may interfere with mobility and symmetry of the remaining tongue, thus accentuating the speech impairment (Bressmann et al., 2007). While the decision to use flap reconstruction in a case is obviously at the surgeon's discretion based on the extent of resection and the nature of the defect to be repaired, it is important to consider the use of primary closure where possible, especially if it is likely to improve functional outcomes (Chuanjun, 2002; McConnel et al., 1998; Zuydam et al., 2005).

Evidence for Free Flap Reconstruction

Microvascular free flap reconstruction represents a major advance in head and neck surgery (Hidalgo & Pusic, 2002; Urken, 2003). To date, the reliability of microvascular head and neck reconstruction is well established, and some authors have reported free flap success percentages over 95%, following careful patient selection (Dassonville et al., 2008; Urken, 2003). Because of better outcome in terms of function, cosmesis, and consequently a better quality of life, many have advocated the use of free vascularized flaps, such as RFFF, to reconstruct soft tissue defects in the oral cavity and oropharynx (Borggreven et al., 2007; Bozec et al., 2007; Chien, Su, Hwang, & Chuang, 2006; Hara et al., 2003; Khariwala et al., 2007; Seikaly et al., 2003). Surgical resection of less than half of the tongue typically results in minimal and only temporary deficits in speech and swallowing. Small defects after ablative surgery usually close primarily without significant functional deficiency (Chuanjun, 2002; Hsiao et al., 2002; McConnel et al., 1998). However, larger surgical defects leave patients with significant functional morbidity (Yu & Robb, 2005). Therefore, it is evident that flap reconstruction usually is required if more than half of the tongue is resected (Hsiao, Leu, Chang, & Lee, 2003).

In patients who undergo hemiglossectomy and reconstruction with free flap transfer, the remaining oropharyngeal tissue is relatively large, and the majority of patients recover speech and eating functions, and this allows them to live a normal life. Hsiao et al. studied the swallowing function of patients with T2–T3 tumors in the anterior two-thirds of the lateral tongue and who underwent hemiglossectomy with either primary closure of the defect or RFFF reconstruction (Hsiao, Leu, Chang, & Lee, 2003). With flap reconstruction, patients easily could lift the tongue and make good contact with the entire palate. They were able to seal the posterior pharyngeal sphincter by elevation of the reconstructed tongue, approximating it to the soft palate, so that premature spilling of the bolus rarely happened. Their swallowing pattern was nearly normal. They suggested that although the reconstructed flap is nonfunctional, it provides bulk and helps the remaining tongue to complete the swallow. The authors concluded that it is better to reconstruct with a RFFF when more than half of the tongue is resected to restore tongue volume and swallowing efficiency (Hsiao, Leu, Chang, & Lee, 2003). Similarly, other studies have shown that primary closure of partial or hemiglossectomy defects provides better tongue mobility to allow for better speech (Bressmann et al., 2007; Chuanjun, 2002; Hsiao et al., 2002; McConnel et al., 1998). It is evident that swallowing outcomes are better when more volume is added to the remaining small mobile tongue (Hsiao, Leu, Chang, & Lee, 2003).

The same group evaluated speech and swallow outcomes of patients after hemiglossectomy of the anteriolateral tongue and reconstruction with RFFF (Hsiao, Leu, & Lin, 2003). The majority of patients scored between 3 (difficult to understand) and 5 (intelligible speech with noticeable errors), with 50% of patients scoring 5 and over half of the patients had distorted articulation which was acceptable or improved with multiple repetitions (Hsiao, Leu, & Lin, 2003). In addition, swallowing function among these patients did not differ significantly from that of controls based on measures of bolus volume, duration of deglutition, and ingestion rate (Hsiao, Leu, & Lin, 2003). The RFFF reconstruction technique they used provided bulk necessary for good deglutition, although improvements would be required to further enhance speech (Hsiao, Leu, & Lin, 2003). Thankappan et al. reported on the functional outcomes of patients who underwent partial glossectomy for T1–T3 tumors of the lateral border of the tongue and reconstruction with LAFF (Thankappan et al., 2011). In their study, speech was normal or nearly normal in all patients, and tongue movement was not grossly restricted in the majority of patients. Furthermore, most of the patients were able to consume an unrestricted diet, while a minority were restricted to soft foods (Thankappan et al., 2011). They concluded that LAFF is an excellent flap option for the reconstruction of partial glossectomy defects without involvement of the floor of the mouth (Thankappan et al., 2011).

Uwiera et al. prospectively evaluated the functional outcomes of patients who underwent hemiglossectomy of T2–T3 of tongue tumors and RFFF reconstruction (Uwiera et al., 2004). Their patients were evaluated preoperatively and postoperatively, at 1 and 6 months after surgery. There was no significant difference across any of the evaluation times for sentence intelligibility (Uwiera et al., 2004). With respect to swallowing, analysis revealed fewer instances of laryngeal penetration with liquids postoperatively, no incidence of penetration for either pudding or cookie bolus, and no incidence of aspiration at any of the evaluation times (Uwiera et al., 2004). In addition, there were no significant differences in any of the oral preparatory swallowing parameters (bolus hold, bolus form, mastication, lip closure) or the oral phase swallowing parameters (bolus control, prolonged transit time, oral stasis) across treatment times. They concluded that RFFF provides functional speech which can consistently achieve preoperative levels and the necessary structure to restore the ability of the patient to consume a fairly *normal diet* (Uwiera et al., 2004). Similarly, Brown et al. showed that there was significant decline in swallowing of liquid at 1 month after hemiglossectomy of the anterior two-thirds of the tongue and RFFF reconstruction. This was shown to be due to premature laryngeal penetrations and a higher number of swallowing attempts to clear the bolus; however, all VFS parameters returned to preoperative levels after 1 year (Brown, 2010).

Although there is decline in speech and swallowing outcomes in the postoperative phase, patients with flap reconstruction of partial or hemiglossectomy defects recover and reach preoperative outcomes with time (Brown, 2010; Uwiera et al., 2004). The use of free flaps is a reliable and efficient method of reconstruction, especially when tongue bulk is required (Brown, 2010; Hsiao, Leu, Chang, & Lee, 2003; Hsiao, Leu, & Lin, 2003; Seikaly, 2008; Uwiera et al., 2004). However, the use of free flaps has been most highlighted for larger defects which are not amendable to primary closure (Seikaly, 2008; Urken et al., 1994; Yu & Robb, 2005). For partial and hemiglossectomy defects after resection of T1–T2 tumors, further evidence is required to establish functional outcome benefits of free flaps as compared to primary closure, specifically, with regard to speech and swallow outcomes, as well as overall morbidity caused by the use of free flaps.

Functional Reconstruction

Successful tongue reconstruction involves more than satisfactory wound healing and flap survival (Urken et al., 1994). Mobility and volume of the oral tongue are essential for speech and swallowing (Urken et al., 1994). Hence, the goal of functional reconstruction after partial or hemiglossectomy is to maximize mobility of the residual tongue and to maintain its shape and volume within the oral cavity by primary closure or by introducing free flaps (Brown, 2010; de Vicente et al., 2008;Urken et al., 1994 ; Urken & Biller, 1994 ; Uwiera et al., 2004).

The quality of speech after hemiglossectomy is more a function of tongue mobility than volume (Hsiao et al., 2002). It has been noted that preservation of the tip of the tongue and the floor of the mouth, excision of cancer located laterally, and smaller excision have better speech outcomes (Matsui et al., 2007; Sun et al., 2007). This can be ascribed to greater mobility of the residual tongue and a greater ability to articulate (Matsui et al., 2007). Furthermore, as compared to RFFF reconstruction, patients after primary closure of hemiglossectomy defects show better speech outcomes (Chuanjun, 2002; Hsiao et al., 2002). This has been attributed to the fact that the freely movable residual tongue maintains good mobility and allows for better speech (Bressmann et al., 2007; Chuanjun, 2002; Hsiao et al., 2002). Hence, primary closure of partial or hemiglossectomy defects remains a very simple yet effective technique to optimize speech outcomes by maintaining greater mobility of the residual tongue.

Anterior resection including floor of the mouth significantly reduces the mobility of the whole tongue and limits tip elevation to touch the alveolar ridge or palate, in turn, intensifying the speech and swallow dysfunction (Matsui et al., 2007; Rieger, 2007; Sun et al., 2007). The use of a bilobed design of RFFF to separately reconstruct the oral tongue and the floor of the mouth has also been advocated to improve the functional outcomes (Urken et al., 1994; Urken & Biller, 1994; Uwiera et al., 2004). Speech outcomes in patients with partial or hemiglossectomy defects reconstructed with RFFF regain preoperative levels after 1 year and remain acceptable (Brown, 2010; Uwiera et al., 2004). In addition, as compared to patients who had primary closure, patients who had RFFF reconstruction of hemiglossectomy defects had a tongue-palate contact that is required to complete a swallow and showed nearly normal swallowing pattern (Hsiao, Leu, Chang, & Lee, 2003; Hsiao, Leu, & Lin, 2003). Although the flap is nonfunctional, it adds the required bulk for the residual tongue to complete an efficient swallow (Brown, 2010; Hsiao, Leu, Chang, & Lee, 2003). Hence, the use of a thin and pliable free flap, such as RFFF, ALTF, and LAFF, can facilitate good recovery of intelligibility, articulation, and swallowing by providing volume required to fill the oral cavity (Matsui et al., 2009; Sun et al., 2007; Thankappan et al., 2011; Uwiera et al., 2004).

The complexity of the tongue structure limits the possibilities for functional reconstruction (Engel, 2010). In fact, the ideal method for reconstruction of partial or hemiglossectomy defects remains elusive. Functional reconstruction is aimed at optimizing speech and swallow outcomes. There is evidence for both primary closure and free flap reconstruction in the treatment of partial or hemiglossectomy defects, based on the mobility and volume of the reconstructed residual tongue (de Vicente et al., 2008; Hsiao et al., 2002; Hsiao, Leu, Chang, & Lee, 2003; Hsiao, Leu, & Lin, 2003; Seikaly, 2008; Uwiera et al., 2004). When deciding for the best method of reconstruction, it is important to consider other factors. Older patients and patients with associated comorbid conditions are known to have poor functions as compared to their younger counterparts who have better healing and regeneration potential (Matsui et al., 2007; Nicoletti, Soutar, Jackson, Wrench, & Robertson, 2004). In addition, donor-site morbidity associated with the use of free flaps presents a significant disadvantage to this method of reconstruction (de Vicente et al., 2008; Huang, Chen, Huang, Mardini, & Feng, 2004). When taken together, primary closure presents an ideal treatment due to its technical simplicity and lack of donor-site morbidity. However, free flap reconstruction is often better in providing overall swallow outcomes (Hara et al., 2003; Uwiera et al., 2004). For this reason both primary closure and free flap reconstruction should be considered and employed for the surgical rehabilitation of partial and hemiglossectomy defects.

Conclusions

Patients who have tongue cancer and have experienced the effects of complicated treatment methods such as that which has been described above may suffer from problems of communication, nutrition, work-related difficulties, and maintaining relationships at home and with friends, along with issues of isolation, loneliness, possible depression, and fear of recurrence. However, overall functional speech and swallowing outcomes of partial or hemiglossectomy and reconstruction are influenced by multiple factors including tumor size, site, method of reconstruction, and the use of postoperative radiotherapy. Although there is significant decline in speech and swallow measures postoperatively, the majority of patients recover to preoperative levels. Speech and swallow outcomes are directly associated with the volume and degree of mobility remaining after surgical interventions. Surgical rehabilitation whether by primary closure or free flaps for the immediate reconstruction of the tongue after tumor resection should aim at the maintenance of the mobility of the residual tongue and restoration of tongue bulk, in order to optimize the recovery of speech and swallowing functions. Primary closure of partial and hemiglossectomy defects is beneficial in maintaining higher mobility of the residual tongue to optimize speech. On the other hand, free flap reconstruction allows for volume and bulk modifications to the residual tongue required to optimize swallowing. Hence, when contemplating the method of reconstruction, both primary closure and free flap reconstruction of partial or hemiglossectomy defects should be considered.

Presently, the literature shows a wide variation in the level of evidence, methodological design, and reporting of results. There is a lack of standardized classification of tongue defects and functional evaluation methods. Moreover, there is little evidence comparing the functional outcomes of patients with partial and hemiglossectomy defects reconstructed with primary closure or free flaps. For patients who present with T1–T2 tumors, further evidence is required to determine the best method of reconstruction that takes into account speech, swallowing, and overall patient quality of life and morbidity, including donor-site morbidity. Future research in this field should employ standardized and reliable evaluation methods of speech and swallowing outcomes to further explore these factors by using multiple modalities in well-designed cohort and longitudinal studies. In addition, future investigations should further examine the psychological effects of the various surgical treatments and interventions on the quality of life among tongue cancer patients by conducting a qualitative inquiry using a large sample of patients. Nevertheless, oncology professionals and dental clinicians and researchers working with these patients should gain valuable information and insight from the review that was presented in this chapter. Further understanding of these issues will ultimately reflect on quality of care and more comprehensive services to this population of cancer survivors.

References

Argon, M., Secil, Y., Duygun, U., Aydogdu, I., Kocacelebi, K., Ozkilic, H., & Ertekin, C. (2004). The value of scintigraphy in the evaluation of oropharyngeal dysphagia. *European Journal of Nuclear Medicine and Molecular Imaging*, *31*(1), 94–98. https://doi.org/10.1007/s00259-003-1276-0

Atal, B. S., & Hanaver, S. L. (1971). Speech analysis and synthesis by linear prediction of the speech wave. *The Journal of the Acoustical Society of America*, *50*(2), 637–655.

Bokhari, W. A., & Wang, S. J. (2007). Tongue reconstruction: Recent advances. *Current Opinion in Otolaryngology & Head and Neck Surgery*, *15*(4), 202–207. https://doi.org/10.1097/MOO.0b013e3281fbd406

Borggreven, P. A., Verdonck-de Leeuw, I., Langendijk, J. A., Doornaert, P., Koster, M. N., de Bree, R., & Leemans, C. R. (2005). Speech outcome after surgical treatment for oral and oropharyngeal cancer: a longitudinal assessment of patients reconstructed by a microvascular flap. *Head & neck*, *27*(9), 785–793.

Borggreven, P. A., Leeuw, I. V. D., Rinkel, R. N., Langendijk, J. A., Roos, J. C., David, E. F., ... & Leemans, C. R. (2007). Swallowing after major surgery of the oral cavity or oropharynx: a prospective and longitudinal assessment of patients treated by microvascular soft tissue reconstruction. *Head & neck, 29*(7), 638–647.

Bozec, A., Poissonnet, G., Converset, S., Lattes, L., Chamorey, E., Vallicionni, J., … Dassonville, O. (2007). Oropharyngeal reconstruction with radial forearm free flap: Functional results. *Revue De Laryngologie – Otologie – Rhinologie*, *128*(1–2), 19–26.

Bressmann, T., Ackloo, E., Heng, C.-L., & Irish, J. C. (2007). Quantitative three-dimensional ultrasound imaging of partially resected tongues. *Head & Neck Surgery*, *136*, 799–805.

Bressmann, T., Sader, R., Whitehill, T. L., & Samman, N. (2004). Consonant intelligibility and tongue motility in patients with partial glossectomy. *Journal of Oral and Maxillofacial Surgery*, *62*(3), 298–303. https://doi.org/10.1016/j.joms.2003.04.017

Bressmann, T., Thind, P., Uy, C., Bollig, C., Gilbert, R. W., & Irish, J. C. (2005). Quantitative three-dimensional ultrasound analysis of tongue protrusion, grooving and symmetry: Data from 12 normal speakers and a partial glossectomy. *Clinical Linguistics & Phonetics*, *19*(6–7), 573–588. https://doi.org/10.1080/02699200500113947

Brown, L. (2010). A longitudinal study of functional outcomes after surgical resection and microvascular reconstruction for oral cancer: Tongue mobility and swallowing function. *Yjoms*, *68*(11), 2690–2700. https://doi.org/10.1016/j.joms.2010.05.004

Carvalho, A. L., Nishimoto, I. N., Califano, J. A., & Kowalski, L. P. (2004). Trends in incidence and prognosis for head and neck cancer in the United States: A site-specific analysis of the SEER database. *International Journal of Cancer*, *114*(5), 806–816. https://doi.org/10.1002/ijc.20740

Chien, C. Y., Su, C. Y., Hwang, C. F., & Chuang, H. C. (2006). Ablation of advanced tongue or base of tongue cancer and reconstruction with free flap: Functional outcomes. *European Journal of Surgical Oncology*, *32*, 353–357.

Chong, V. (2005). Oral cavity cancer. *Cancer Imaging : the Official Publication of the International Cancer Imaging Society*, *5 Spec No A*, S49–52. https://doi.org/10.1102/1470-7330.2005.0029

Chuanjun, C. (2002). Speech after partial glossectomy: A comparison between reconstruction and nonreconstruction patients. *Journal of Oral and Maxillofacial Surgery*, *60*(4), 404–407. https://doi.org/10.1053/joms.2002.31228

Colangelo, L. A., Logemann, J. A., & Rademaker, A. W. (2000). Tumor size and pretreatment speech and swallowing in patients with resectable tumors. *Otolaryngology–Head and Neck Surgery : Official Journal of American Academy of Otolaryngology-Head and Neck Surgery*, *122*(5), 653–661.

Costa Bandeira, A. K., Azevedo, E. H., Vartanian, J. G., Nishimoto, I. N., Kowalski, L. P., & Carrara-de Angelis, E. (2008). Quality of life related to swallowing after tongue cancer treatment. *Dysphagia*, *23*(2), 183–192. Epub 2007 Nov 13. PMID: 17999111. https://doi.org/10.1007/s00455-007-9124-1

Dassonville, O., Poissonnet, G., Chamorey, E., Vallicioni, J., Demard, F., Santini, J., … Bozec, A. (2008). Head and neck reconstruction with free flaps: A report on 213 cases. *European Archives of Oto-Rhino-Laryngology*, *265*(1), 85–95. https://doi.org/10.1007/s00405-007-0410-1

de Carvalho-Teles, V., Sennes, L. U., & Gielow, I. (2008). Speech evaluation after palatal augmentation in patients undergoing glossectomy. *Archives of Otolaryngology–Head & Neck Surgery*, *134*(10), 1066–1070. https://doi.org/10.1001/archotol.134.10.1066

de Vicente, J. C., de Villalaín, L., Torre, A., & Peña, I. (2008). Microvascular free tissue transfer for tongue reconstruction after hemiglossectomy: A functional assessment of radial forearm versus anterolateral thigh flap. *Journal of Oral and Maxillofacial Surgery : Official Journal of the American Association of Oral and Maxillofacial Surgeons*, *66*(11), 2270–2275. https://doi.org/10.1016/j.joms.2008.01.018

Dodds, W. J., Logemann, J. A., & Stewart, E. T. (1990). Radiologic assessment of abnormal oral and pharyngeal phases of swallowing. *AJR. American Journal of Roentgenology*, *154*(5), 965–974. https://doi.org/10.2214/ajr.154.5.2108570

Dwivedi, R. C., Kazi, R. A., Agrawal, N., & Nutting, C. M. (2009). Evaluation of speech outcomes following treatment of oral and oropharyngeal cancers. *Cancer Treatment Reviews*, *35*(5), 417–424.

Engel, H. (2010). A strategic approach for tongue reconstruction to achieve predictable and improved functional and aesthetic outcomes. *Plastic and Reconstructive Surgery*, *126*(6), 1967–1977. https://doi.org/10.1097/PRS.0b013e3181f44742

Gadesmann, M., & Miller, N. (2008). Reliability of speech diadochokinetic test measurement. *International Journal of Language & Communication Disorders*, *43*(1), 41–54. https://doi.org/10.1080/13682820701234444

Hamlet, S. L., Mathog, R. H., Patterson, R. L., & Fleming, S. M. (1990). Tongue mobility in speech after partial glossectomy. *Head & Neck*, *12*(3), 210–217. https://doi.org/10.1002/hed.2880120304

Hara, I., Gellrich, N. C., Duker, J., Schön, R., Fakler, O., Smelzeisen, R., … Satoru, O. (2003). Swallowing and speech function after intraoral soft tissue reconstruction with lateral upper arm free flap and radial forearm free flap. *British Journal of Oral & Maxillofacial Surgery*, *41*(3), 161–169. https://doi.org/10.1016/S0266-4356(03)00068-8

Hara, I., Gellrich, N. C., Duker, J., Schön, R., Nilius, M., Fakler, O., … Honda, T. (2003). Evaluation of swallowing function after intraoral soft tissue reconstruction with microvascular free flaps. *International Journal of Oral and Maxillofacial Surgery*, *32*(6), 593–599. https://doi.org/10.1054/ijom.2002.0436

Hartl, D. M., Dauchy, S., Escande, C., Bretagne, E., Janot, F., & Kolb, F. (2009). Quality of life after free-flap tongue reconstruction. *The Journal of Laryngology & Otology*, *123*(05), 550–554. https://doi.org/10.1017/S0022215108003629

Hidalgo, D. A., & Pusic, A. L. (2002). Free-flap mandibular reconstruction: A 10-year follow-up study. *Plastic and Reconstructive Surgery*, *110*(2), 438–449. discussion 450–1.

Hsiao, H.-T., Leu, Y.-S., Chang, S.-H., & Lee, J.-T. (2003). Swallowing function in patients who underwent hemiglossectomy: Comparison of primary closure and free radial forearm flap reconstruction with videofluoroscopy. *Annals of Plastic Surgery*, *50*(5), 450–455. https://doi.org/10.1097/01.SAP.0000044147.09310.E8

Hsiao, H.-T., Leu, Y.-S., & Lin, C.-C. (2002). Primary closure versus radial forearm flap reconstruction after hemiglossectomy: Functional assessment of swallowing and speech. *Annals of Plastic Surgery*, *49*(6), 612–616. https://doi.org/10.1097/01.SAP.0000024760.06545.E7

Hsiao, H.-T., Leu, Y.-S., & Lin, C.-C. (2003). Tongue reconstruction with free radial forearm flap after hemiglossectomy: A functional assessment. *Journal of Reconstructive Microsurgery*, *19*(3), 137–142. https://doi.org/10.1055/s-2003-39824

Huang, C.-H., Chen, H.-C., Huang, Y.-L., Mardini, S., & Feng, G.-M. (2004). Comparison of the radial forearm flap and the thinned anterolateral thigh cutaneous flap for reconstruction of tongue defects: An evaluation of donor-site morbidity. *Plastic and Reconstructive Surgery*, *114*(7), 1704–1710. https://doi.org/10.1097/01.PRS.0000142476.36975.07

Kazi, R., Prasad, V., Venkitaraman, R., Nutting, C. M., Clarke, P., Rhys-Evans, P., & Harrington, K. J. (2008). Questionnaire analysis of swallowing-related outcomes following glossectomy. *ORL; Journal for Oto-Rhino-Laryngology and Its Related Specialties*, *70*(3), 151–155. https://doi.org/10.1159/000124287

Khariwala, S. S., Vivek, P. P., Lorenz, R. R., Esclamado, R. M., Wood, B., Strome, M., & Alam, D. S. (2007). Swallowing outcomes after microvascular head and neck reconstruction: A prospective review of 191 cases. *The Laryngoscope*, *117*(8), 1359–1363. https://doi.org/10.1097/MLG.0b013e3180621109

Laaksonen, J.-P. (2010). Speech after radial forearm free flap reconstruction of the tongue: A longitudinal acoustic study of vowel and diphthong sounds. *Clinical Linguistics & Phonetics*, *24*(1), 41–54. https://doi.org/10.3109/02699200903340758

Laaksonen, J.-P., Rieger, J., Harris, J., & Seikaly, H. (2010). A longitudinal acoustic study of the effects of the radial forearm free flap reconstruction on sibilants produced by tongue cancer patients. *Clinical Linguistics & Phonetics*, *25*(4), 253–264. https://doi.org/10.3109/02699206.2010.525681

List, M. A., Stracks, J., Colangelo, L., Butler, P., Ganzenko, N., Lundy, D., … Vokes, E. E. (2000). How do head and neck cancer patients prioritize treatment outcomes before initiating treatment? *Journal of Clinical Oncology*, *18*(4), 877–884.

Loewen, I. J., Boliek, C. A., Harris, J., & Seikaly, H. (2010). Oral sensation and function: A comparison of patients with innervated radial forearm free flap reconstruction to healthy matched controls. *Head & Neck*, *32*, 85–95. Loewen – 2009 – Wiley Online Library.

Logemann, J. A., Pauloski, B. R., Rademaker, A. W., McConnel, F. M., Heiser, M. A., Cardinale, S., … Johnson, J. (1993). Speech and swallow function after tonsil/base of tongue resection with primary closure. *Journal of Speech and Hearing Research*, *36*(5), 918–926.

Matsui, Y., Ohno, K., Yamashita, Y., & Takahashi, K. (2007). Factors influencing postoperative speech function of tongue cancer patients following reconstruction with fasciocutaneous/myocutaneous flaps—A multicenter study. *International Journal of Oral and Maxillofacial Surgery*, *36*(7), 601–609. https://doi.org/10.1016/j.ijom.2007.01.014

Matsui, Y., Shirota, T., Yamashita, Y., & Ohno, K. (2009). Analyses of speech intelligibility in patients after glossectomy and reconstruction with fasciocutaneous/myocutaneous flaps. *International Journal of Oral and Maxillofacial Surgery*, *38*(4), 339–345.

McConnel, F. M., Pauloski, B. R., Logemann, J. A., Rademaker, A. W., Colangelo, L., Shedd, D., … Johnson, J. (1998). Functional results of primary closure vs flaps in oropharyngeal reconstruction: A prospective study of speech and swallowing. *Archives of Otolaryngology–Head & Neck Surgery*, *124*(6), 625–630.

Michi, K. (2003). Functional evaluation of cancer surgery in oral and maxillofacial region: Speech function. *International Journal of Clinical Oncology*, *8*(1), 1–17. https://doi.org/10.1007/s101470300000

Michiwaki, Y., Schmelzeisen, R., Hacki, T., & Michi, K. (1992). Articulatory function in glossectomized patients with immediate reconstruction using a free jejunum flap. *Journal of Cranio-Maxillo-Facial Surgery : Official Publication of the European Association for Cranio-Maxillo-Facial Surgery*, *20*(5), 203–210.

Nicoletti, G., Soutar, D. S., Jackson, M. S., Wrench, A. A., & Robertson, G. (2004). Chewing and swallowing after surgical treatment for oral cancer: Functional evaluation in 196 selected cases. *Plastic and Reconstructive Surgery*, *114*(2), 329–338.

Nicoletti, G., Soutar, D. S., Jackson, M. S., Wrench, A. A., Robertson, G., & Robertson, C. (2004). Objective assessment of speech after surgical treatment for oral cancer: Experience from 196 selected cases. *Plastic and Reconstructive Surgery*, *113*(1), 114–125. https://doi.org/10.1097/01.PRS.0000095937.45812.84

O'Connell, D. A., Rieger, J., Harris, J. R., Dziegielewski, P., Zalmanowitz, J., Sytsanko, A., … Seikaly, H. (2008). Swallowing function in patients with base of tongue cancers treated with primary surgery and reconstructed with a modified radial forearm free flap. *Archives of Otolaryngology--Head & Neck Surgery*, *134*(8), 857–864. https://doi.org/10.1001/archotol.134.8.857

Pauloski, B. R., Logemann, J. A., Colangelo, L. A., Rademaker, A. W., McConnel, F. M. S., Heiser, M. A., … Esclamado, R. (1998). Surgical variables affecting speech in treated patients with oral and oropharyngeal cancer. *The Laryngoscope*, *108*(6), 908–916. https://doi.org/10.1097/00005537-199806000-00022

Pauloski, B. R., Logemann, J. A., & Rademaker, A. W. (1994). Speech and swallowing function after oral and oropharyngeal resections: One-year follow-up. *Head & Neck*, *16*(4), 313–322. Pauloski – 2006 – Wiley Online Library.

Pauloski, B. R., Logemann, J. A., Rademaker, A. W., McConnel, F. M., Heiser, M. A., Cardinale, S., … Baker, T. (1993). Speech and swallowing function after anterior tongue and floor of mouth resection with distal flap reconstruction. *Journal of Speech and Hearing Research*, *36*(2), 267–276.

Pauloski, B. R., Rademaker, A. W., Logemann, J. A., McConnel, F. M. S., Heiser, M. A., Cardinale, S., … Beery, Q. (2004). Surgical variables affecting swallowing in patients treated for oral/oropharyngeal cancer. *Head & Neck*, *26*(7), 625–636. https://doi.org/10.1002/hed.20013

Radford, K., Woods, H., & Lowe, D. (2004). A UK multi-centre pilot study of speech and swallowing outcomes following head and neck cancer. *Clinical Otolaryngology & Allied Sciences*, *29*(4), 376–381. Radford – 2004 – Wiley Online Library.

Rastadmehr, O., Bressmann, T., Smyth, R., & Irish, J. C. (2008). Increased midsagittal tongue velocity as indication of articulatory compensation in patients with lateral partial glossectomies. *Head & Neck*, *30*(6), 718–726. https://doi.org/10.1002/hed.20772

Reichard, R., Stone, M., & Woo, J. (2012). Motion of apical and laminal/s/in normal and post-glossectomy speakers. *Journal of the Acoustical Society of America*, *131*, 3346–3350.

Rieger, J. M. (2007). Functional outcomes after surgical reconstruction of the base of tongue using the radial forearm free flap in patients with oropharyngeal carcinoma. *Head & Neck*, *29*(11), 1024–1032. https://doi.org/10.1002/hed.20623

Rieger, J. M., Zalmanowitz, J. G., & Wolfaardt, J. F. (2006). Functional outcomes after organ preservation treatment in head and neck cancer: A critical review of the literature. *International Journal of Oral and Maxillofacial Surgery*, *35*, 581–587.

Seikaly, H. (2008). Beavertail modification of the radial forearm free flap in base of tongue reconstruction: Technique and functional outcomes. *Head & Neck*, *31*(2), 213–219. https://doi.org/10.1002/hed.20953

Seikaly, H., Rieger, J., Wolfaardt, J., Moysa, G., Harris, J., & Jha, N. (2003). Functional outcomes after primary oropharyngeal cancer resection and reconstruction with the radial forearm free flap. *The Laryngoscope*, *113*(5), 897–904. https://doi.org/10.1097/00005537-200305000-00023

Shaw, D. W., Williams, R. B. H., Cook, I. J., Wallace, K. L., Weltman, M. D., Collins, P. J., … Simula, M. E. (2004). Oropharyngeal scintigraphy: A reliable technique for the quantitative evaluation of oral-pharyngeal swallowing. *Dysphagia*, *19*(1), 36–42. https://doi.org/10.1007/s00455-003-0033-7

Shiboski, C. H., Schmidt, B. L., & Jordan, R. C. K. (2005). Tongue and tonsil carcinoma. *Cancer*, *103*(9), 1843–1849. https://doi.org/10.1002/cncr.20998

Shin, Y. S., Koh, Y. W., Kim, S. H., Jeong, J. H., & Ahn, S. (2012). Radiotherapy deteriorates post-operative functional outcome after partial glossectomy with free flap reconstruction. *Journal of Oral and Maxillofacial Surgery*, *70*, 216–220.

Siegel, R., Naishadham, D., & Jemal, A. (2013). Cancer statistics, 2013. *CA: A Cancer Journal for Clinicians*, *63*(1), 11–30. https://doi.org/10.3322/caac.21166

Spiro, R. H., & Strong, E. W. (1974). Surgical treatment of cancer of the tongue. *The Surgical Clinics of North America*, *54*(4), 759–765.

Stelzle, F., Knipfer, C., Schuster, M., & Bocklet, T. (2013). Factors influencing relative speech intelligibility in patients with oral squamous cell carcinoma: A prospective study using automatic, computer-based speech analysis. *Journal of Oral and Maxillofacial Surgery*, *42*, 1377–1384.

Su, W. (2003). Functional comparison after reconstruction with a radial forearm free flap or a pectoralis major flap for cancer of the tongue. *Otolaryngology – Head and Neck Surgery*, *128*(3), 412–418. https://doi.org/10.1067/mhn.2003.38

Suarez-Cunqueiro, M.-M., Schramm, A., Schoen, R., Seoane-Lestón, J., Otero-Cepeda, X.-L., Bormann, K.-H., … Gellrich, N. C. (2008). Speech and swallowing impairment after treatment for oral and oropharyngeal cancer. *Archives of Otolaryngology–Head & Neck Surgery*, *134*(12), 1299–1304. https://doi.org/10.1001/archotol.134.12.1299

Sun, J., Weng, Y., Li, J., Wang, G., & Zhang, Z. (2007). Analysis of determinants on speech function after glossectomy. *Journal of Oral Maxillofacial Surgery*, *65*(10), 1944–1950. https://doi.org/10.1016/j.joms.2006.11.017

Teichgraeber, J., Bowman, J., & Goepfert, H. (1985). New test series for the functional evaluation of oral cavity cancer. *Head & Neck Surgery*, *8*(1), 9–20.

Thankappan, K., Kuriakose, M. A., Chatni, S. S., Sharan, R., Trivedi, N. P., Vijayaraghavan, S., … Iyer, S. (2011). Lateral arm free flap for oral tongue reconstruction. *Annals of Plastic Surgery*, *66*(3), 261–266. https://doi.org/10.1097/SAP.0b013e3181d50e9e

Thoné, M., Karengera, D., Siciliano, S., & Reychler, H. (2003). Reconstruction of the mobile tongue malignant tumor excision: Quality-of-life assessment in 19 patients. *Revue de Stomatologie et de Chirurgie Maxillo-Faciale*, *104*(1), 19–24.

Urken, M. L. (2003). Advances in head and neck reconstruction. *The Laryngoscope*, *113*(9), 1473–1476. https://doi.org/10.1097/00005537-200309000-00008

Urken, M. L., & Biller, H. F. (1994). A new bilobed design for the sensate radial forearm flap to preserve tongue mobility following significant glossectomy. *Archives of Otolaryngology–Head & Neck Surgery*, *120*(1), 26–31. https://doi.org/10.1001/archotol.1994.01880250022002

Urken, M. L., Moscoso, J. F., Lawson, W., & Biller, H. F. (1994). A systematic approach to functional reconstruction of the oral cavity following partial and total glossectomy. *Archives of Otolaryngology–Head & Neck Surgery*, *120*(6), 589–601. https://doi.org/10.1001/archotol.1994.01880300007002

Uwiera, T., Seikaly, H., Rieger, J., Chau, J., & Harris, J. (2004). Functional outcomes after hemiglossectomy and reconstruction with a bilobed radial forearm free flap. *Journal of Otolaryngology*, *33*(6), 356–359.

Warnakulasuriya, S. (2009). Global epidemiology of oral and oropharyngeal cancer. *Oral Oncology*, *45*(4–5), 309–316. https://doi.org/10.1016/j.oraloncology.2008.06.002

Yu, P., & Robb, G. L. (2005). Reconstruction for total and near-total glossectomy defects. *Clinics in Plastic Surgery*, *32*(3), 411–419. https://doi.org/10.1016/j.cps.2005.02.005

Yun, I. S., Lee, D. W., Lee, W. J., Lew, D. H., Choi, E. C., & Rah, D. K. (2010). Correlation of neotongue volume changes with functional outcomes after long-term follow-up of total glossectomy. *Journal of Craniofacial Surgery*, *21*(1), 111–116. https://doi.org/10.1097/SCS.0b013e3181c46692

Zuydam, A. C., Lowe, D., Brown, J. S., Vaughan, E. D., & Rogers, S. N. (2005). Predictors of speech and swallowing function following primary surgery for oral and oropharyngeal cancer. *Clinical Otolaryngology*, *30*(5), 428–437. https://doi.org/10.1111/j.1365-2273.2005.01061.x