Oral Prosthetic Rehabilitation of Individuals with Head and Neck Cancer: A Review of Current Practice

Réadaptation par prothèse orale des personnes ayant un cancer de tête et cou : revue de la pratique courante

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ABSTRACT

This article describes the methods and procedures for assessment of speech and oral function in individuals with oral cancer who are managed with prosthodontic appliances. The article also describes methodologies for the prosthetic management of individuals with maxillary and mandibular defects secondary to oral cancer. Surgical, dental, speech, and psychosocial aspects of counseling throughout the management process from presurgery to immediate postsurgery obturation and through the interim and the definitive dental prosthesis stages are described. Techniques for speech assessment that focus on interaction between the various speech "valves" in the vocal tract are defined relative to their use in documenting outcome measures for communication success.

ABRÉGÉ

Ce mémoire décrit les méthodes et les procédures employées dans l'évaluation de la parole et de la fonction orale chez les personnes atteintes d'un cancer buccal et qui sont traitées au moyen de prothèses dentaires. Le mémoire décrit les méthodologies de traitement par prothèse de personnes présentant des défauts maxillaires et mandibulaires dus à un cancer buccal. On décrit, aux diverses étapes du traitement, les aspects chirurgicaux, dentaires, psychosociaux et de la parole du counseling au cours de l'ensemble du traitement, depuis le stade pré-chirurgical jusqu'à l'obturation post-chirurgicale, ainsi qu'aux étapes des prothèses intérimaires et définitives. On définit les techniques d'évaluation de la parole qui mettent l'accent sur l'interaction entre les diverses « valves » de parole du tractus aérien, relativement à leur utilisation dans la documentation de la mesure des résultats de communication.

KEY WORDS: oral cancer • prosthodontics • speech • outcome measures

A substantial number of individuals who have defects of the maxillofacial region secondary to surgical and/or radiotherapy management of carcinoma are seen each year in a dental oncology practice. It has been estimated that over 5% of all cancers occur in the oral-nasal-pharyngeal-laryngeal region, with 10 per 100,000 affecting primarily oral and oropharyngeal components of the oro-facial complex (Lauciello, Vergo, Schaaf, & Zimmerman, 1980; Parker, Tong, & Bolden, 1997; Silverman, 1998). Since the structures within the maxillofacial region are required for mastication, deglutition, and speaking, team management of posttreatment oral dental and speech function is a very important part of these individuals' total rehabilitation. While cancerous tumours of the oral cavity affect maxilla, mandible, tongue, and oropharynx, this article will focus primarily on prosthetic management of maxillofacial defects, with secondary emphasis given to mandibular defects that affect oral aspects of speech function.

Initial Considerations in Treatment Planning

Successful rehabilitation of individuals presenting with acquired oral defects typically requires a team approach in order to include the expertise of relevant health care professionals. In particular, a typical "maxillofacial rehabilitation unit" must have close working relationships between

the head and neck surgeon (ENT), oral surgeon (dental), radiation oncologist, chemotherapist, speech-language pathologist (SLP), anaplastologist, dietitian, and social worker or psychologist to fully benefit the individual. Each of these specialists may have more or less input to individual care at any one time, since there are several stages which the individual typically goes through during his or her treatment. Each stage still demands close cooperation between the particular professionals involved.

Following confirmed diagnosis, and before maxillofacial surgery, the head and neck surgeon, radiation oncologist, and prosthodontist should communicate about the location of the surgical site, the amount of ablation required, and the potential timing and sequencing of radiation treatment. Many of these preliminary planning decisions are made by the surgeon and oncologist at the local "tumour board rounds." In general, the initial stage of treatment for the individual undergoing maxillectomy, requires the head and neck surgeon to retain as much of the premaxillary area as possible, including tuberosity, and soft palate on the surgical side, while preserving the alveolar bone around the last tooth next to the defect. The surgeon should remove redundant tissue that might prevent extension of the prosthesis into the defect and place skin grafts around the area of the defect as needed. For those requiring mandibulectomy, attention to how much of the ramus and body of the mandible was taken, how much of the tongue was resected on the tumour side, and what soft tissues remain on the floor and buccal sulcus on the resected side are important features for the prosthodontist to know. As a second stage, the prosthodontist should have study models made available presurgery in order to plan for postoperative surgery modifications of the maxillorfacial prosthesis. As a third phase, it is the prosthodontist's role to fabricate the surgical splint that will be placed into the defect at the time of surgery, particulary following the maxillectomy. This placement is done by the surgeon and dental personnel in charge at the time of surgery. The maxillary splint may be a simple acrylic cover for the planned surgical site, or it may be a modification of an existing complete or partial upper denture. In mandibulectomy, a lower complete or partial denture may not be placed at the time of surgery, but may be considered once healing has occurred. Descriptions of each step in the dental-prosthodontic treatment plan for presurgical and postsurgical prosthodontic care for individuals with oral cancers may be found in the classical dental references (Adisman,1990; Beumer, Curtis, & Marunick, 1996).

Further to treatment planning, direct communication is needed between the oncologist and radiotherapist when radiation is needed, either in the presurgery planning or postsurgery stage when potential spread of the cancer is possible. Direct interaction between the head and neck surgeon and radiation oncologist maximize the treatment plan and simplify the direction taken by the prosthodontist for fabrications of the various stages of the prostheses. Preradiotherapy assessment and management of all natural dentition and supporting structures, and postradiation follow-up of dental structures must occur. Similar communication between the oncologist and radiology therapist is necessary when combined chemotherapy and radiation are employed for management of metastatic disease. The possible use of hyperbaric oxygen for management of radionecrosis of bone and cartilage is important as part of total dental care for the patient (Dempsey, Hynes, Smith, & Sproat, 1997; Marx, 1983). In the progression of treatment planning, a speech-language pathology consultation is an important part of the team approach since the individual undergoing maxillofacial surgery is often left with serious communication and swallowing problems. Assessment of overall intelligibility, articulation, voice, and resonance abilities is necessary before and after surgery.

Pre- and Postoperative Counseling

Patients who undergo maxillary or mandibular excision of an oral tumour will benefit from social and psychological counseling before, during, and after fitting of the oral dental obturator (Doyle, 1994; Kornblith et al., 1996). Kornblith et al. reported that the most significant predictor of the individual's adjustment and the perception of negative socio-economic impact of cancer on their lives was the 'satisfactory functioning' of the obturator (i.e., 'goodness of fit' for eating, swallowing, and speaking). Each session spent with the individual during the prosthodontic treatment phase is important in terms of dealing with feelings of satisfaction or lack thereof. It would seem that care-

ful scrutiny of the patient's feelings, perhaps employing some standardized inventories or scales of social and psychological adjustment (de Boer et al., 1995; Hassan & Weymuller, 1993; List et al., 1996), would be beneficial as a component of prosthetic management. In addition to counseling the patient, it is important to talk with the spouse, family, or caregivers concerning the various stages that will take place during prosthetic management (Doyle, 1994).

Team Approach - Verbal Communication

In addition to the importance placed upon the need for a functional assessment of the individual's verbal communication, there is a need to assign values to the outcome measures made by speech-language pathologists and prosthodontists as they meet the needs of those with maxillofacial difficulties. This is crucial since the person with maxillofacial difficulties may require several components of health care management (surgery, radiotherapy, chemotherapy, dentistry, speech rehabilitation) and have potential financial limitations imposed by the health care system (Light, 1997).

In order to provide the rehabilitation team with information concerning oral communication and related factors (i.e., swallowing, cosmesis, quality of life), the speech-language pathologist's assessment employs perceptual, acoustical, and physiological measurement procedures related to overall communication ability. Speech evaluation includes estimating the "normalcy" of articulation, articulation of specific speech sounds, voice quality, oral and nasopharyngeal resonance, and/or the overall combination of these features (i.e., overall speech intelligibility).

Prior to assessment of each of the components related to speech production, it is important to determine the medical, psychological, social, and vocation/avocational characteristics of the individual. Case history information will lead to a more thorough understanding of the pretreatment aspects of the individual's quality of life (Doyle, 1994) and the areas which may need special attention in order to regain a more normal life postmanagement. In addition, a detailed description of the anatomical site of the oral cancer should be noted. An excellent graphic descriptor of the oral-pharyngeal area has been developed by Jacobson, Franssen, Fliss, Birt, and Gilbert (1995). This "resection template" demarcates anatomic subsites for possible surgical excision in the oral and oropharyngeal cavities. Colour coding and marking of 18 specific surgical areas allows for accurate detailing of site and extent of surgical excision for records and correlations with other physical and psychological factors which may influence functional outcomes for both the speech-language pathologist and prosthodontist.

Assessment of Oral-Motor and Communication Function

Systematic evaluation of the speech production mechanism involves assessment of speech production subsystems (i.e., respiratory, laryngeal, velopharyngeal, oral articulatory). These may be assessed individually with a variety of instrumental techniques, but are usually viewed in a holistic, interconnected and coordinated fashion, since speech is the result of a "coarticulated" overlapping of the movements and actions of a number of neuromuscular units. These elements provide the bases for production, and subsequently the perception of speech sounds by the listener (and the speaker). For example, information gained about articulatory precision in individuals with primarily hard palate defects (e.g., oral-nasal fistulae resulting from partial surgical ablation of a tumour site) must be tempered with concerns about the effective airflow and acoustic tone through a potentially incompetent velopharyngeal mechanism (posterior defect of the soft tissue due to tissue shrinkage from radiation). Such considerations must occur before a decision can be made about the primacy of "articulation problems" from anterior defects (the oral-nasal fistulae) as separate from the velopharyngeal component in distorting the quality of overall speech performance (Leeper, Sills, & Charles, 1993).

One approach to speech management of oral-pharyngeal defects is based upon a physiological model of a coordinated effort of each subsystem to optimize its contribution for efficient speech production (Netsell & Daniel, 1979). As suggested by these authors, the goal of a physiological, acoustical, and perceptual evaluation of an individual's speech production mechanism is to determine the type and extent of disorder to each "valve" in the subsystem. Such

an approach allows the speech-language pathologist to select and organize a management strategy based on knowledge about the capacity of each component of the system.

To produce speech, the functional subsystem components are, from the bottom-up: (a) the abdominal area, (b) diaphragm, (c) rib cage, (d) larynx, (e) velopharyngeal port mechanism (velum, posterior pharyngeal wall, lateral pharyngeal walls), (f) posterior portions of the tongue, (g) anterior portions of the tongue, (h) mandible, and (i) lips. Assessment of each component before and after prosthetic management is necessary in order to describe the efficiency of each valve in the system and to determine how each valve interacts with the others during speech production. With this subsystem in mind, an introduction to assessment procedures employed by SLPs when evaluating individuals with maxillofacial defects destined for prosthetic management is provided in the subsequent sections.

Respiratory Evaluation

Breath support for speech is assessed to determine if there is sufficient air transported from the lungs through the larynx to the oral articulators in order to provide reasonable speech loudness and acceptable phrase length. Some individuals will demonstrate respiratory irregularities or show reduced transglottal air pressure for phonation or impaired intraoral air pressure for certain consonant sounds (e.g., /p/) because of advanced age or chronic pulmonary obstruction or diseases (e.g., emphysema, asthma). Individuals who undergo oral prosthetic treatment and are postradiation or ablative surgery are "at-risk" for loss of control of air pressure from the laryngeal valve, and hence the lungs, and should be referred to a pulmonary function laboratory for standard spirometric evaluations (e.g., forced vital capacity [FVC], forced expiratory volume - one second [FEV1], flow-volume loops; e.g., Rolling Seals, Ohio Medical, model 100). These procedures are usually obtained using both a commercial computer and a software package to provide objective measures of respiratory function either with or without the prosthetic device in place (Leeper, Ahmad, Sills, & Gallie, 1989).

An indirect method to assess respiratory support for phonation and speech is via measurement of subglottal air pressure. Using electronic instrumentation (e.g., PERCI; Warren, 1979) subglottal (Ps) measures may be obtained from the pressure/flow traces produced by measuring the peak intra-oral air pressure output (as an estimate of alveolar air pressure) of repeated voiceless /p/ consonant and a vowel output (Holmes, Leeper, & Nicholson, 1994; Leeper & Graves, 1984; Wilson & Leeper, 1992). Individuals with excessive air escape through oral or velopharyngeal defects that do not allow separation of the oral-nasal cavities will often overdrive the laryngeal system with higher than normal alveolar pressures. Hence, they show increased respiratory drive which will deplete air volume rapidly for longer breath groups.

Phonatory Evaluation

As with the respiratory system, alterations in the oral-pharyngeal system can have "downstream" effects on how the vocal folds function for the production of the voice source. Thus, inabiliry to rapidly adjust the muscles that attach to the larynx from above may cause alterations in vocal frequency, intensity, and glottic closure, and thus add to an already perturbed speech signal with subsequent increases in "vocal roughness".

Initially, the phonatory system is evaluated perceptually to consider whether parameters of voice (pitch, loudness, vocal range, and quality) are within normal limits for the individual's gender, age, and physical condition. In addition, measurement of maximum phonation time (MPT) is typically used to relate respiratory vital capaciry (VC) and glottal efficiency (Boone & McFarlane, 1988).

Measures of laryngeal valving efficiency (laryngeal airway resistance; RLAW) are also typically assessed by recording intraoral air pressure as an estimate of subglottal pressure (transglottal pressure) and transglottal airflow and considering the ratio of the two as the aerodynamic equivalent of Ohm's Law for electrical voltage/current (see *Respiratory* section). Other instrumental acoustical measures that correlate well with a listener's perception of vocal quality are found in the assessment of average (habitual) pitch and range pitch (frequency measures) and pitch variability ("jitter"), average range of loudness (intensity measures) and loudness variability ("shimmer"), and a combination of pitch and loudness or signal-to-noise ratio (e.g., Interactive Voice Analysis System [IVANS], AVAAZ Innovations, 1999). These measures are non-invasive and may be obtained from acoustical recordings of sustained vowels or connected

speech employing gross maximal limits of voice production (Kent, Weismer, Kent, & Rosenbek, 1989). Often, these measures of vocal limits correlate well with physiological limitations of the laryngeal structures affected by the ablative surgery (including total or near total laryngectomy; Doyle, Leeper, Houghton-Jones, Heeneman, and Martin, 1996; Leeper et al.,1993) which detaches portions of the oral articulators (i.e., tongue, jaw, pharyngeal musculature) from supraglottal slings of the hyoid bone.

Resonatory Evaluation

Posterior anatomical defects that impinge on the velopharyngeal area may cause major problems in the intelligibility of individuals with orofacial deficits. Defects that do not allow for closure of the velum against the posterior pharyngeal wall during the production of most of the speech sounds of our languages cause the listener to perceive speech to be "hypernasal." The physical concomitant of such a deficit results in a "damping" of acoustic resonance through the divided oral/nasal passages, a "muffled" (i.e., less intense oral output), and reduced articulatory efficiency. Conversely, a lack of normal nasal resonance (on /m/, /n/, and /ng/) may cause the listener to perceive speech as being "hyponasal" (Sandor, Leeper, & Carmichael, 1997).

The least intrusive assessment approach is via listener judgments of psychophysical scaling of "resonance balance" (hyper/hyponasality) during speech production. Such judgments form the basis of pre- and postprosthetic management speech changes and relate to the efficacy of the therapeutic approach.

Another less intrusive assessment tool, the Nasometer, employs measures of the ratio of acoustic nasal sound energy divided by the oral plus nasal sound energy (called nasalance) during selected oral and nasal sound speech production (Kay Elemetrics, Pine Brook, NJ). Nasalance values from individuals undergoing prosthetic management may be compared to normative values already available in the research literature (Seaver, Dalston, Leeper, & Adams, 1991).

Using commercially available (e.g., PERCI; Warren, 1979) pressure transducers, pneumotachographs, and computer acquisition hardware and software, measures of air pressure and airflow through the nose and mouth are collected during selected speech sound production (Leeper & Sills, 1986). The resultant pressure-flow signals associated with the production of these speech elements are applied to a formula designed to estimate opening (orifice area-size; Warren & DuBois, 1964). Orifice area values above 20 sq mm are generally considered problematic for VP incompetence, while values less than 20 sq mm on nasal sounds (e.g., /m/) may relate to perception of speech as lacking appropriate nasal tone (i.e., "hyponasal"; Warren, 1996). In addition, the same instrumentation may be used to describe the nasal airway resistance (Rnaw; resistance = differential pressure divided by nasal air flow; Rnaw = DP/Vn) during rest breathing. Measures of the nasal airway resistance to the flow of air through that system have been found useful for describing alterations in the oro-pharyngeal airway before and following surgical or prosthetic management (Warren, Trier, & Bevin, 1974; Leeper, Janzen, Sills, Seewald, & Ahmad, 1994).

A more intrusive instrument for evaluation of the velopharyngeal port is the flexible fiberoptic nasendoscope (e.g., Olympus, model ENF-P2, Olympus Corporation, Carson Medical, Hamilton, ON; D'Antonio, Marsh, Province, Muntz, & Phillips, 1989). This device allows for direct optical viewing and videorecording of the velopharyngeal mechanism from above (transnasal view) to describe the anterior-posterior palate velum and posterior pharyngeal wall and medialization of the lateral pharyngeal walls during speech and swallowing. The visual images available are synchronized with sound input from a microphone to document the size, shape, colour, and movement of the VP mechanism during speech prior to and following prosthetic management and are available on videotape for group perceptual judgments (Golding-Kushner, 1990).

The most invasive procedure available to describe the VP port mechanism is through the use of videofluoroscopy (Skolnick & Cohn, 1989); this information is obtained using standard X-ray equipment found in the radiology department of most hospitals. The videofluoroscopic view of the velopharyngeal system is typically viewed separately by the dental oncology team (oral surgeon, prosthodontist, speech-language pathologist) with the same speech elements in a three-dimensional format (i.e., frontal, lateral, basal).

The frontal view is useful for describing the height and movement of the lateral pharyngeal walls during speech and swallowing, the lateral view is useful for detailing the lift, placement, and degree of closure of the velum (and/or its remnants) upon the posterior pharyngeal wall, while the basal view allows for a view of the three dimensional closure pattern of the VP system during speech and swallowing prior to and following prosthetic management.

Oral Articulatory Evaluation

The assessment of the articulatory aspects of speech is accomplished by employing perceptual and instrumental techniques. As with perceptual judgments of resonance balance, articulation is rated (either with formal inventories; i.e., Templin-Darley Tests of Articulation) or informal assessments (e.g., judgments of right/wrong for speech sound production) by judges following production of a series of syllables or words that contain all phonetic elements of speech. In addition, judgments of articulatory precision, speed and consistency of production, and stimulability for correct production of a sound are examined. As a more global description of articulation performance, a rating of proficiency on a seven point, equal-appearing interval scale may be used to describe a combination of the parameters noted above. Finer details concerning specific aspects of the features of consonant production may be conducted using one of several types of intelligibility tests initially designed for neurogenic dysarthrias of speech, but directly applicable to "peripheral" dysarthrias in persons who have had ablative surgery and subsequent prosthetic management (Kent et al., 1989; Yorkston, Beukelman, & Traynor, 1984). In addition, acoustic analyses (formant frequency and amplitude, spectral moments) of the production of certain vowels and consonants, alone or in combination in words or phrases, have been used (Duncan, Leeper, & Gratton, 1999; Gillis & Leonard, 1983; Leonard & Gillis, 1982, Tobey & Lincks, 1989) to document acoustic consequences of production of speech elements in relationship to perceptual quality of speech.

Another portion of the assessment involves the aeromechanical evaluation of oral port (tongue-hard palate valving) size (constriction; using a hydrodynamic equation of Warren & DuBois, 1964) as described by Leeper and Sills (1986). The difference in technique from assessing the velopharyngeal port is that a mask covers the mouth, rather than the nose. Differential pressure sensors are then placed in front of and behind the articulatory constriction (e.g., the tongue dorsum for /s/) for data collection on articulatory precision with individuals prior to and following placement of an oral dental appliance. The effects of partial, subtotal, or total removal of the tongue and/or portions of the anterior maxilla or mandible on speech are devastating. With limited or nonexistant tongue mobility in the anterior oral cavity, eating, swallowing, and speech are problematic (Gillis & Leonard, 1983; Leonard & Gillis, 1982; Leonard & Gillis, 1990; Wheeler, Logemann, & Rosen, 1980). The oral articulation assessment procedures noted above are also useful for describing changes in the speech of these individuals following prosthetic management as well.

Swallowing Assessment

Many individuals with oral cancer demonstrate masticatory and swallowing difficulties, as well as speech problems following oral-maxillofacial surgery (Haribhakti, Kavarana, & Tibrewala, 1993; Pauloski et al., 1994; Shimodaira, Yoshida, Yusa, & Kanazawa, 1998; Wedel, Yontchev, Carlsson, & Ow, 1994). Few investigations (Wheeler et al., 1980; Robbins, Bowman, & Jacob, 1987), however, have evaluated the swallowing behaviour of individuals with oral cancer before and after fitting of an oral dental obturator. Wheeler et al. (1980) reported that the oral prosthesis aided in swallowing, but that compromises had to be made when fabricating the appliance to permit optimal tongue manipulation of liquids and food, while also meeting the demands for articulation of speech sounds. Physical and functional assessment of long-term follow-up of these obturators and subsequent modification of these dental appliances for swallowing requires further research.

Assessment of swallowing in individuals with surgical resections for oral cancer and who are fitted with a dental obturator should follow standards of practice outlined by Logemann (1983). In general, these procedures would include videofluroscopic assessment focusing on anterior lip activity, posterior pharyngeal wall action, soft palate func-

tion, and the action at the bifurcation of the esophagus and laryngeal airway inferiorly. Multiple swallows of a portion of a teaspoon of barium liquid paste and a quarter of a cookie with barium paste applied to it for contrast should be videorecorded. Video review and physical timing of (a) oral transit time, (b) pharyngeal transit time, (c) pharyngeal delay time, (d) duration of laryngeal closure, and (e) duration of cricopharyngeal opening, may serve as data for estimating oropharyngeal swallowing efficiency. Manipulation of the amount of residue of the bolus left in the oral and pharyngeal areas, in conjunction with transit times, is used to compute the oropharyngeal swallow efficiency (OPSE), defined as the percept of the bolus swallowed divided by the total transit time in seconds (Logemann, 1988; Pauloski et al., 1993). This relates to judgments by clinicians of the amount of bolus swallowed, the residue, and the actual time involved in the act. Combining physical and perceptual measures is useful for comparisons of individuals with a variety of oral deficits (i.e., maxillary and mandibular cancers, partial and total glossectomies, and radiation or chemotherapy induced oro-pharyngeal dysfunction). Assessment of swallowing behaviour of individuals into stratified subgroups, perhaps employing a graphic descriptor (e.g., Jacobson et al., 1995) of the entire upper and lower oral cavity by anatomical subsite would be most useful for tracking changes in function over time for each type of defect and each type of obturator or dental appliance.

No matter which "valves" are found defective following initial treatment procedures, it is imperative that the team work to provide the patient with the most complete and functional prosthesis that can accomplish as many tasks as possible (i.e., eating, swallowing, speech). It is also very important that the individual understand the methods for developing the most satisfactory oral verbal communication to aid in the overall intelligibility of speech.

Current Suggestions for Outcome Measures for Speech and Prosthodontics

Measurement of outcomes following surgical resection, radiotherapy, and dental obturation of oral defects secondary to oral cancer is necessaty for the continuing management of individuals with oral cancer. It is also important for the refinement of protocols and research into the effectiveness of these protocols for various clinical groups. As noted earlier, describing the effectiveness of certain management programs is now essential in terms of the cost of treatment, the number of individuals needing management, the effect on long term lifestyle and everyday functioning, and as a way of studying the effectiveness of each treatment plan. One model for evaluating outcomes is described in a document called "Disability in America: Toward a National Agenda For Prevention" (Pope & Tarlov, 1991). In this document, four levels of assessment are recommended.

1. Pathology, the cellular or tissue level of the disease, would include the presence of oral-pharyngeal cancer, the site and size of the surgery, remaining anatomical areas, infection, and soft tissue irritation as a result of prosthodontic management.

2. Impairment is the impact of the disease on each of several subsystems serving speech and/or swallowing (i.e., respiratory, laryngeal velopharyngeal, articulatory).

3. Function limitations refer to the individual's ability to perform certain daily tasks such as talking, eating, swallowing.

4. Disability relates to the psycho-social level of the dis ease/disorder and includes how the individual interacts with friends, family, and society in general and how his and/or her presence is accepted or discriminated against at home, work, or at leisure.

Mahanna, Beukelman, Marshall, Gaebler, and Sullivan (1998) have reported their protocol for serving the four areas outlined above. To evaluate each area of the assessment protocol the authors used the following items:

1. Pathology/tissue Level - visual description and palpation of soft tissue irritation via prosthetics, and presence or absence of infection of the surgical site.

2. Impairment Level - evaluation of speech performance including perceptual scaling of the amount of hyperhyponasality, and aerodynamic studies of appropriate separation of the oral/nasal-pharyngeal components of speech.

3. Functional Limitations - including computerized measures of speech intelligibility and rate of speech.

4. Disability - assessed via a Modified Communication Effectiveness Index (Lomas et al., 1989), a self-adminis-

tered visual analog scale to rate the patient's ability to communicate effectively before and following prosthodontic management of the oral defect. The investigators suggest that this approach to documenting outcomes at several levels of physical, psychological, and social-societal is important for evaluating the effectiveness of obturator prosthetic treatments for individuals with oral cancers.

A similar approach has been suggested by Light (1997) who surveyed SLPs and members of other disciplines in the rehabilitation teams that treat individuals with oral cancers. Light suggested eight categories of functional assessment for evaluation of individuals with oral cancer who need maxillofacial prosthodontics. The categories included: (a) total body function including an oral motor component; (b) oral motor functional mechanisms; (c) speech intelligibility or articulation tests; (d) nasal emission tests; (e) swallowing assessment, including oral preparatory and transit phase times; (f) muscle movement, including nonspeech oral motor maneuvers; (g) presence of drooling assessment; and (h) self-assessment of function status and improvement.

It should be noted that no matter which assessment tools are used pre- or postoperatively, it is important that some reliable and valid method of assessment be made across the four levels of outcome assessment. Both perceptual and physical measures should be made at the time of each obturator fitting (i.e., surgical splint, interim, definitive) and changes in physical and psycho-social outcomes of the patient noted. Modification of any protocol should occur when any one of the assessment tools fail to meet strict guidelines for validity and reliability of test instruments. Such modifications help the clinician meet the requirements of reduced cost to the health care system, improved strategies for training individuals how to care for their prosthesis, and documenting the effectiveness of prosthodontic care.

Presurgical Dental Assessment and Management

Since the oral-maxillofacial surgery must be performed as soon as possible, certain compromises in dental management may have to occur. At a minimum level, dental management should include the following: a) oral prophylaxis, b) taking diagnostic impressions and casts, c) mounting casts on an articulator for tooth and jaw relationship records, d) management of acute infections of the oral cavity, e) extraction of teeth that may compromise the surgical area and, f) restoration of teeth that need to be retained to support the forthcoming oral appliance.

Within this time period, it is also important for the maxillofacial team to meet with the patient and discuss the various stages of the procedure, including but not limited to cosmesis, potential surgical site extent, placement and timing of orodental appliance therapy, mastication and swallowing behaviours, speech difficulties related to maxillary, mandibular, and lingual function, and overall speech intelligibility. Reduction in the person's anxiety about such procedures and their effect on quality of life issues may be dealt with by the team and/or by referral to a clinical psychologist and/or social worker. It is important to remind the individual of the time frame from start to completion of the surgical and rehabilitation processes and what might be expected at each stage of management.

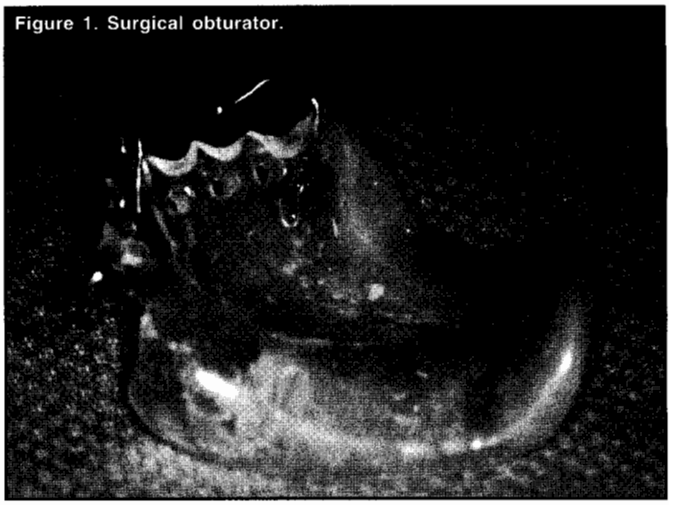


Figure 1. Surgical obturator.

Prosthetic Management of the Acquired Maxillary Defect

A large number of maxillary deficits compromise the function of the oral cavity by causing food and fluid leakage into the nasal cavity, impaired masticatory function, swallowing difficulties, hypernasality, nasal air emission, and loss of articulatory precision leading to reduced overall speech intelligibility.

Restoration of the ablated tissue by prosthetic appliance obturation can minimize these problems. For patients with maxillectomies, there is usually a three-stage management procedure recommended: a) placement of a 'surgical obturator' at the time of surgery, to be retained in place for from 10 to 21 days (or until first level of wound healing occurs; b) placement of an interim or "provisional" obturator, or until the healing of the defect is complete. (i.e., three to six months; and c) placement of a "definitive" obturator after wound healing is confirmed (six to 12 months; Desjardins, 1977, 1978).

The Surgical Splint (Obturator)

The prosthodontist and surgeon traditionally consult on the site and extent of tissue to be removed during surgery. From the altered cast model provided by the prosthodontist, the surgeon outlines the hard and soft tissue areas to be ablated. The maxillary cast is then trimmed along these outlines in concert with the surgeon's plans and, as a method of maintaining the alveolar ridge crest height, the cast is removed where the teeth will be removed so as to provide a hard palate surface that is smoothly contoured. The prosthodontist then develops a surgical splint to cover as much of the defect as possible with a prosthesis. Typically, the splint (see Figure 1) is made of clear acrylic resin and is retained within the oral cavity with 18 gauge wire clasps embedded within the acrylic. Along the edges of the splint, small holes may be bored at interproximal areas to allow for wire ligatures around the remaining teeth in the palatal arch. If the individual has few remaining teeth and/or if retention of the splint is in question, bilateral wire hooks may be embedded to secure the splint to wires passed through the zygomatic area of the maxilla. The wires may be passed through the remaining maxillary area to secure the prosthesis. In other cases, anterior attachments with wires from the labial frenum to the nasal spine may be used.

After a period of 7 to 10 days, the surgical splint with attached wires may be removed. Once the wire ligatures have been removed, the appliance will have to be refitted to take into account shrinkage of the wound site tissues and the potential loss of tissue bulk in the area. Modification of the acrylic area surrounding the defect may also be necessary. Further relining with the tissue conditioner will help keep the appliance in place while further healing takes place (Anderson, Awde, Leeper, & Sills, 1992; Desjardins, 1977).

For the edentulous individual who has his/her own dentures, this prosthesis may be modified to act as the surgical

Figure 2. Interim obturator.

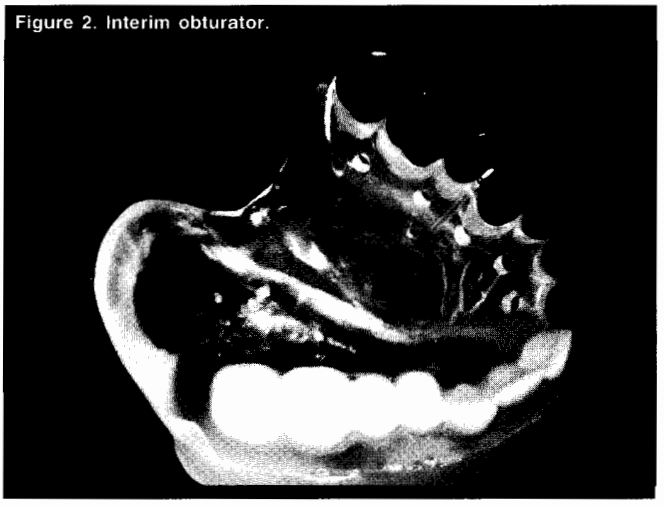


Figure 3a. Definitive obturator: defect area.

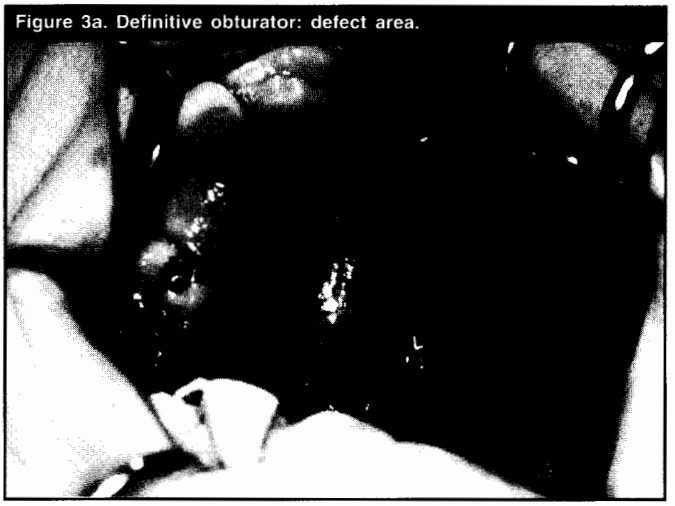


Figure 3b. Definitive obturator: appliance.

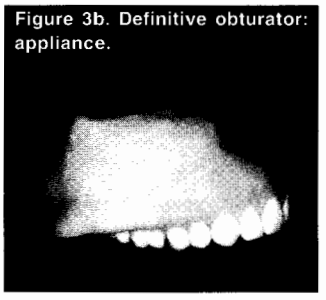
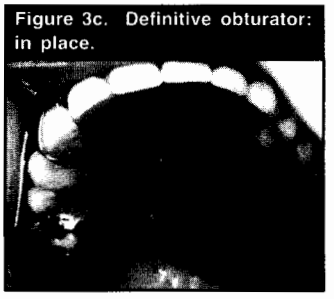


Figure 3c. Definitive obturator: in place.



obturator. Needless to say, a new complete denture will be needed in the definitive stage of obturation. When using the 'old' denture as a surgical obturator, the labial or buccal flange (side ridge) may have to be reduced to accommodate the surgical site. Similarly, the posterior portion or soft palate region may have to be extended with a modified acrylic base to obturate the new surgical site. Within the surgical suite, the obturator may have to be modified, reduced, and/or relined (with tissue conditioner) to maximize the fit, and thus, to optimize the function of the appliance (Beumer, Zlotolow, & Sharma, 1998).

The functional usefulness of the surgical obturator should be obvious. That is, it allows careful packing (dressing) of the wound site, keeps food and other debris from getting into the wound, allows eating, drinking, and swallowing without a nasogastric tube in place, and improves the quality of life by allowing immediate oral communication with the family or caregivers, surgeon, and prosthodontist.

The Interim Obturator

Depending on the length of time and complications of wound healing, the surgical splint may be relined, and/or modified to allow sufficient fit of the appliance for speech and deglutory function. However, as modifications are made, the appliance may become more bulky and less hygienic, hence less pleasing to the person. When this occurs, it is desirable to replace the surgical obturator with an "interim" obturator (see Figure 2).

When such an appliance is necessary, the prosthodontist must make new impressions of the defect and entire maxillary region, both anterior and posterior areas. Packing of the defect allows a more definitive description of the features of the maxillary, palatal, and pharyngeal areas, depending on the site and extent of the defect. From the new cast models taken, a simple design of the interim appliance is possible. The design typically follows the basic principles of removable partial dentures and may include placement of missing teeth in the visible areas of the anterior oral cavity. Again, acrylic resin applications of a 'partial' denture technique may be followed. Since this version of the appliance will not be the final one, wire clasps will be added to the malleable resin as it is fixated in the model. These clasps will be adjusted for an accurate fit and comfort. Pressure on the oral mucosa must be located with pressure indicator paste and then relieved. Reinstruction concerning insertion and removal of the new interim appliance should occur. In addition, office visits are to be scheduled regularly to correct minor tissue irritations and to readjust clasp arms for comfortable fit. Dental care of existing teeth must also continue during this interim appliance period (Desjardins, 1978).

The Definitive Obturator

The decision to begin design of the "definitive" obturator appliance (see Figures 3a, b, and c) should begin after a majority of the wound healing has taken place, all radiotherapy has been completed and adjustment to this course of treatment accepted, and the advice of the surgeon that no active pathology exists. The definitive obturator may be either designed as a typical partial denture or as a complete denture. As with the interim appliance, impressions are again made, artificial stone cast models are constructed, and these models, fabricated in wax, are placed on an articulator device to determine simulated jaw motion with the appliance in place. Artificial teeth may be added to the partial denture or a full set of artificial teeth to the wax base for full denture construction. These models are placed in the mouth to check esthetics, occlusal relationships, and closure of the defect. After the full contour wax obturator is acceptable to both prosthodontist and individual, the model is placed in a heavy metal flask, the wax is boiled

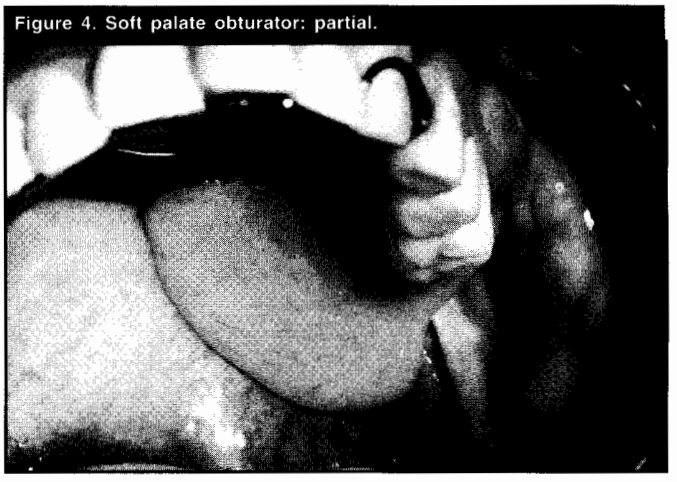


Figure 4. Soft palate obturator: partial.

away, and permanent acrylic resin is substituted. In many cases, a metal framework (e.g., chromium cobalt) is adhered to the wax and then to the acrylic. Cast metal clasps are attached to this framework and are related to the remaining teeth in the maxillary segment.

In cases where the person is edentulous, complete upper (CUD) and lower (CLD) dentures may be fabricated as well. The approach for making these appliances is similar to those for the normal denture wearer, except for the areas where the defect is present in the maxillary or near and/or on the soft palate area. Here, special techniques are used to decrease the weight of the obturator in the defect area by making the obturator "hollow." The "box type" obturator fills the defect area within the maxillary defect, but has a smooth "lid" attached to it on the oral side. The air-filled obturator segment fulfils the need for obturation while keeping the weight of the area at a minimum (Anderson et al., 1992; Desjardins, 1978).

Defect Management for the Partially Edentulous Individual

The typical protocol of treatment for this type of individual is developed with a careful assessment of the condition of the remaining teeth and tissues in and around the defect area. Specific radiographs and a survey analysis from the diagnostic casts of the maxillary and mandibular arch segments are necessary to find optimum location for attachments of the denture components. Obviously, it is necessary to complete all restorative and periodontal procedures before proceeding. The person must have a good oral hygiene program underway and must understand the features of the appliance and his/her role in maintaining it for maximum usefulness.

As with application of a partial denture for any person, the maxillofacial treatment must have an appliance with similar basic features, including support, bracing, and retentive components. The basic components of the appliance, namely the framework and the case area, are made in several steps. The framework is designed by the prosthodontist and fabricated in chromium cobalt alloy metal and contains the supportive, bracing, and retentive elements in its design. The base area of the appliance is made with acrylic resin and covers the edentulous/defect area and provides a base for attachment of artificial teeth. With additional defects in the posterior area (soft palate), the partial denture may need a "tailpiece" or section to cover (obturate and/or lift) the defect in the soft tissue (see Figure 4).

For either the anterior (maxillary) or posterior (soft palate) defect areas, it is essential to get effective seals in each region to eliminate as much food and fluid leakage as possible into the nasal passages and to normalize resonance balance during speech.

Again, internal bulky portions of the obturator may be made hollow to reduce weight. In addition, lining and relining of the obturator-defect area with a soft malleable material will be necessary from time to time to keep a viable seal. The same relining material may be used along the junction of the buccal and maxillary region where deep undercut areas (ablation of alveolar or palatal ridge) from the surgery may cause the seal (suction) of the denture against the palatal area to become loosened (Anderson et al., 1992; Desjardins, 1978).

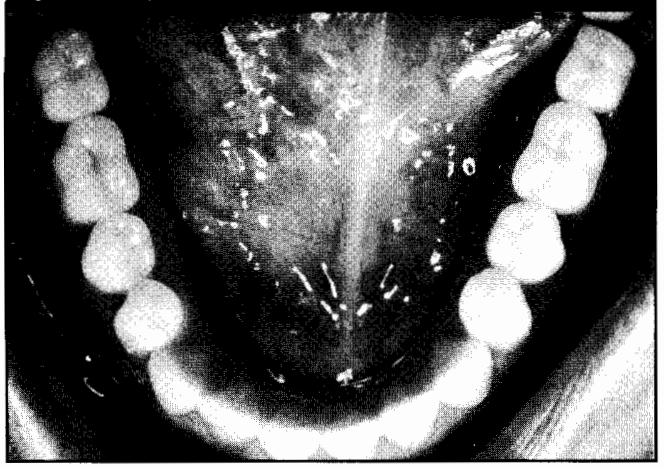
Defect Management for the Edentulous Individual

A major challenge for any prosthodontist is the fabrication of an appliance for the edentulous individual who has had a partial or total maxillectomy. The major problems are many, with size and shape of the defect primary, but with secondary features of absence of supporting teeth, lack of sufficient seal (suction) to hold the denture in place, and the potential movement of the appliance around the oral cavity. Ideally, the prosthodontist hopes to have the maxillary obturator contact the superior-lateral, posterior-lateral walls of the defect area, the medial area of the resected area, the skin graft-mucosal junction around the buccal, or the pharyngeal area of the defect. Developing a healthy understanding of the limitations of this appliance during swallowing and speech, and difficulties in developing a good path of insertion and removal, are paramount and appointments for adjustments and follow-up care are typically necessary to increase the chances for a successful outcome.

Defect Management for Mandibular Defects

Not unlike persons needing CLD, individuals with cancer who require oral surgery to remove portions of the mandible present a particular challenge for prosthodontists.

Figure 5. Complete lower denture "Mandible".



Typically, smaller cancerous lesions may be excised and will not affect the continuity of the mandible. Larger lesions may need surgery to the mandible, tongue, and floor of the mouth, with onlay flaps of tissue from a nearby donor. Anterior or lateral surgical excision of portions of the bone will necessitate stabilization of the remaining segments of the mandible with donor bone or surgical steel splints at the time of initial surgery, or after a period of tumour-free living. Loss of the posterior portions of the mandible (condyle) will necessitate implants of artificial condylar elements and body of the mandible in order to regain symmetry and function of the lever action for mastication and speech (Anderson et al., 1992).

The Partially Edentulous Mandibular Individual

Following surgery, some teams recommend fixation of the arch segments with ligature wires for 5 to 10 weeks to provide successful wound healing. Other approaches suggest no interarch fixation and beginning the individual on a program of physical therapy exercises shortly after wound healing to reduce tissue fixation in the temporomandibular joint region by progressively opening the mouth wider, and closing with slight resistance and moving the mandible away from the surgically resected side at about three weeks postsurgery.

When there is some dentition remaining on the resected side and on the opposite side, a small partial denture with a flange is attached to the remaining mandibular teeth. This flange or guide aids in directing the mandible to a position of maximum interdigitation with the opposing teeth in the maxillary arch. Typically, the flange or guide is fabricated of acrylic resin and may be modified over time to continue to aid the occlusal demands of the jaw closing mechanism. If the mandible is so surgically altered that it does not guide well with a simple flange splint, a more extensive guide ramp is fabricated of acrylic and is used to force the jaws together for stability. Such appliances are typically described as interim appliances for classification and funding.

The definitive mandibular appliance, as with others, must have retentive and bracing elements to attach to the remaining teeth in the mandible. The location and final design of these components must be such that they do not place undue lateral or torque forces on the remaining teeth within the mandible during chewing or swallowing. In most cases, the prosthodontist makes sure that centric occlusion for tooth contact occurs primarily on the surgical side, hence eliminating extraneous tooth contacts on the non-resected side of the jaw. Obviously, biting and chewing should occur on the nonresected side.

Defect Management for the Completely Edentulous Mandibular Individual

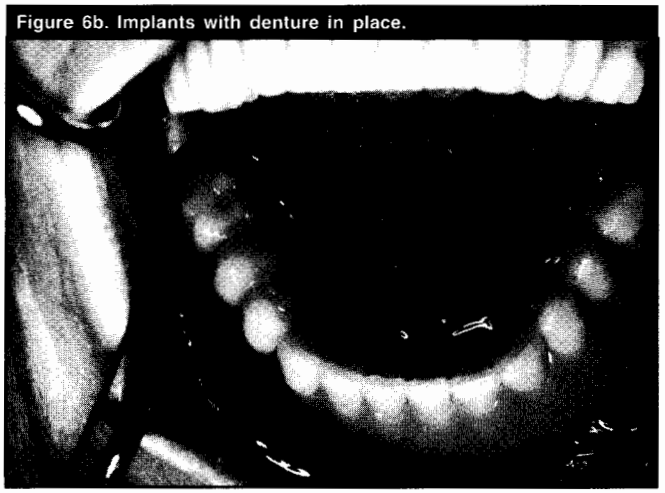
The anatomical and functional limitations for a CLD in individuals who are edentulous are very confounding. In addition, loss of tissue in the floor of the mouth, buccal areas, lip area, and lingual surgery also complicates the situation for placement of lower dentures (See Figure 5).

The greater the loss of tissue in the mandible and surrounding areas, the more problematic the denture bearing area. Thus, the more the mandible has been surgically altered, the more the mandible will deviate to the surgical side and the more the mandibular teeth may be in poor occlusal relationships to the maxillary segments on the resected side. Such a relationship will impinge on mastication and tongue function for speech, and therefore appliance stability, on the resected side. Other features of treatment, such as radiotherapy and chemotherapy, can affect the oral tissues and result in major tissue irritation, dryness, and possible ulceration that makes use of denture in this area guarded (Anderson et al., 1992).

Those individuals with mandibular resection may be

Figure 6a. Implants and bar attachment.

Figure 6b. Implants with denture in place.



treated with rather simple, uncomplicated denture designs with appropriate modifications of the mandibular area. Close adaptation of the denture base to the remnants of the mandibular ridge, extension of the lingual flanges to the limit of tissue tolerance, and precise contouring of the flanges to fit with the buccinator muscle are necessary. In cases where the tongue is sutured to the resected side of the jaw, it may be possible to use the deep sulcus on that side to fit a flange in that area for better stability.

Because the mandible cannot close in a symmetrical, repeatable fashion on the resected side, a flat occlusal format is used to counteract this motion. A maxillary occlusal ramp made of acrylic resin may be placed lingually to the maxillary posterior teeth on the surgical side to guide tooth contact and improve stability of the appliance. Another option is to place a second row of maxillary teeth lingually to the unresected side to allow for a broader curve and better occlusal table to minimize mandibular denture dislodgement (Anderson et al.,1992).

Defect Management with Implant Supported Prostheses

Given the cautions noted earlier concerning instability of dental appliances for oral cancer defect management, it is important to note that osseointegrated dental implants have become a major technique for providing oral function in persons with appliance retention problems. A brief description of these appliances and their application to oncological management of orofacial defects follows.

Osseointegrated dental implants (see Figures 6a, b) are made of titanium or a titanium alloy. They are formed as a hollow cylinder of various lengths or a cylindrical screw of various lengths. Typically, they are placed in the maxillary or mandibular bone in two surgical stages. The first stage is to raise a skin flap over the implant site. The bone site is drilled, sized for the particular implant to be used, and tapped to receive the implant screw device. The implant is then screwed into place and the hollow centre core is closed with a cover screw device. The skin flap is replaced and left to heal for three to four months. After the healing period, the second stage consists of uncovering the implant fixture and replacing the cover screw with an abutment extension which penetrates the overlying mucosa. After this area heals, the prosthesis is fabricated onto these abutments.

After preliminary impressions are made, a custom impression tray is constructed to carry the final impression material to the implant site. This final impression is made using special impression material to record the position of the abutments and the surrounding tissue as accurately as possible. From the resulting master stone cast, a metal superstructure is made which will be used to retain the prosthesis. The final prosthesis will then be attached to the superstructure directly, or as a removable or clip-on device. If it is rigidly attached, it will act as natural teeth and be cared for similarly to normal dentition. With a removable device, it will have to be cared for like any other removable partial denture device (Anderson et al., 1992; Beumer et al., 1998; Leeper et al., 1993).

Radiotherapy, Chemotherapy, and Surgery - An

Integrated Approach to Prosthetic Care

Methods of Management

Surgical resection and radiation therapy are the typical methods of management for many oral concerns and typically occur before placement of a dental prosthesis. Selection of one or both is determined by myriad factors relating to the tumour and the individual's general health characteristics. Surgical considerations include local excision of the malignancies of the maxilla or mandible with or without soft tissue (lip, tongue) or lymph node removal. Reconstructive surgery has improved over the past 20 years, primarily by demonstrating better function and appearance. Newer techniques using vascularized soft and hard tissue (bone) which are transferred from the body to the neck and oral region are now common.

Radiation therapy may be delivered to the oral lesion in the form of external beams of X-ray or gamma rays, external beams of heavy particles (electrons), or internally implanted X-ray or gamma rays. Newer approaches use neutrons or heavily-charged particles to deposit energy in a dense pattern around the cancer site. Another approach employs radiosensitizers for increasing the cell kill of hypoxic tumours. A third method is to use radioprotective compounds that selectively decrease the injury to normal tissues surrounding the cancer cells. In addition, hyperthermia or increasing temperature to 42-45 degrees may increase heat to the local area and aid in reducing the amount of radiotherapy needed to kill the cancer cells.

Cytotoxic chemotherapy may also be used to kill cancerous tumours of the oral cavity. These may be used alone or in combination with radiation and/or surgery for recurrent or metastatic disease (Singer, Phillips, Kramer, & Fu, 1998) either prior to or adjunctive to prosthetic management of oral cancer.

Methods of Promoting Healing: Hyperbaric Oxygen

Radiotherapy, oral surgery, and chemotherapy intervention may cause irreversible damage to the oral cavity tissues and, hence, to active management of the oral cancer defect via prosthetics. Radiotherapy damage is characterized by decreased blood flow to tissue within and around the oral cavity, including bone, cartilage, and the blood vessels in that region. The impact is a compromise in collagen synthesis and cell production leading to a disruption of normal cell rejuvenation and, thus, nonhealing. This leads to osteoradionecrosis (ORN) which is defined by a pathological fracture, exposed bone, biopsy proven necrosis, fistula, and/or unrelenting pain in the general area. The incidence of ORN has been reported to be between 3 and 14% (Blalogh & Sutherland, 1983). Most conservative approaches to this problem fail because they do not consider the underlying pathophysiology of irradiated tissue, that is, the underlying hypoxic, hypovascular, hypocellular condition.

One method of overcoming the effects of ORN is the use of hyperbaric oxygen (HBO) therapy. The traditional HBO protocol as originally described by Marx (1983) has specific individuals awaiting surgery being exposed to 30 HBO "dives" in an oxygen chamber. Wound care is maintained with saline rinses and, typically, antibiotics are continued. If wound healing shows clinical improvement after 20 dives, the surgical procedure is performed and an additional 10 dives are recommended to achieve full wound healing. If the postsurgery wound healing is unsuccessful, the individual may receive further surgical resection of the wound site and bony underpinnings and 10 more dives occur. If further surgery is not required, the person may enter oral prosthodontic rehabilitation about one month after the fixation is released. Flexibility in the number of dives and potential surgery should occur depending on the protocol of the institution and the wound healing of the patient. The HBO protocol used with head and neck cancer patients has been shown to be cost effective (Dempsey et al., 1997), and to demonstrate greater pain reduction and increased sleep while requiring fewer narcotics for pain relief. Once the ORN has been treated appropriately, continuation of prosthetic management can occur.

Extra-Oral Implant Devices

A full discussion of this topic is too extensive in the present context. However, it should be noted that osseointegrated implants are possible throughout the craniofacial area. Given the possibility that portions of the face, lip, nose, cheek, eye, and ear are involved and must be sacrificed surgically for life purposes, implants that aid in fix-

ating prostheses to these areas are important considerations (Anderson et al.,1992; Beumer et al., 1998). Planning for these extra-oral devices commits the team of ENT, maxillofacial, or plastic surgeons, as well as the prosthodontist and anaplastologist, to be involved in the planning of each step. That is, if the individual is to have a maxillary prosthesis, as well as an extra-oral nose and eye prosthesis made, it will be important for each professional to know which component should be placed first, second, and third in the treatment plan. At each stage of treatment, the person, and perhaps family members, should be counseled by a psychologist and/or social worker concerning emotional issues. Speech pathology assessment and treatment should focus on eating, swallowing and speech function with each stage of prosthodontic management.

Summary and Conclusions

This review has provided information on the prosthodontic and speech management of individuals with orofacial cancer. It describes current methods of assessment and management from a transdisciplinary approach, from presurgical planning to follow-up care of the prosthesis and communication skills of the individual undergoing treatment. This procedures includes discussion of methods of speech assessment of the respiratory, laryngeal, velophatyngeal, and oral articulatory systems. In addition, the review includes descriptions of a various prosthodontic oral appliances employed to "normalize" the maxillofacial region following surgery or radiotherapy/chemotherapy procedures. Prosthetic management for dentulous and edentulous individuals with maxillary and mandibular defects are also discussed. An integrated rehabilitation team approach to individuals with orofacial defects secondary to cancer demands a team of professionals expert at each stage of surgical, dental, speech, and psychosocial care who are sensitive to the personal desires of the person they serve.

Acknowledgements

The authors would like to thank Drs. P. S. Sills, G. D. Soskin, and P. C. Doyle for their assistance and feedback on earlier versions of this paper.

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