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Head and Neck Oncology Reconstruction: A History

HISTORY AND MEMORY PAPER
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ABSTRACT

Reconstruction of surgical defects in the head and neck has evolved dramatically over the past 2 centuries. Surgical defects were frequently closed primarily or in a delayed fashion in the past, resulting in poor cosmetic and functional outcomes. Non-delayed pedicle flaps were introduced in the 1970s, allowing for large defects to be closed with better outcomes. The development of vascular anastomosis, aided by the introduction of the operating microscope, set the stage for the emergence of microsurgery and free tissue transfer. Today, free flaps are routinely performed to repair complex head and neck oncologic defects with great success, allowing for a more recent focus on improving surgical efficiency as well as functional and cosmetic outcomes. In this review, we seek to provide an overview of the history of head and neck cancer reconstruction, highlighting the clinical pioneers who advanced the field.

Keywords: History, head and neck, reconstruction, free flaps

Introduction

Cancer of the head and neck occurs in approximately 900 000 people yearly and causes more than 400 000 deaths annually worldwide.[1] In addition to this mortality, cancer of the head and neck is associated with significant morbidity, given that vital structures for speech, mastication, and swallowing may be affected. Moreover, the location of the cancer of the head and neck can result in a significant impact on the patient's appearance, causing psychological distress and hindering social interactions. While cancer of the head and neck itself can have a devastating effect on the patients' form and function, so can the treatments. Though surgical resection may require extensive and complex procedures, which may produce significant defects to remove the cancer, it remains the mainstay of therapy. As such, reconstruction of these surgical defects is an equally important aspect of head and neck surgery.

The "reconstructive ladder" has traditionally been described as going from the most minor to the most complex, such as healing by secondary intention, primary closure, skin grafting, bioengineered tissue, tissue expansion, local flaps, regional flaps, then free tissue transfer. In the modern era, free tissue transfer has become the primary technique used in the reconstruction of major defects. However, other reconstructive techniques remain important parts of the head and neck surgeon's arsenal.

With the rapid advances in reconstructive techniques, it is important to recall the surgical innovations and discoveries that led the field to where it is today. In this historical review, we seek to highlight the major developments pertaining to the reconstruction of head and neck defects and the surgical pioneers who established these methods.

The Fundamentals

Primary closure may be appropriate for small defects. If primary closure is not possible, a skin graft or other bioengineered tissue may be used to provide coverage for the area that cannot be closed primarily (Figure 1). Alternatively, tissue expanders have been used to increase the expansibility of surrounding tissue, allowing for primary closure. Moreover, in some cases, it

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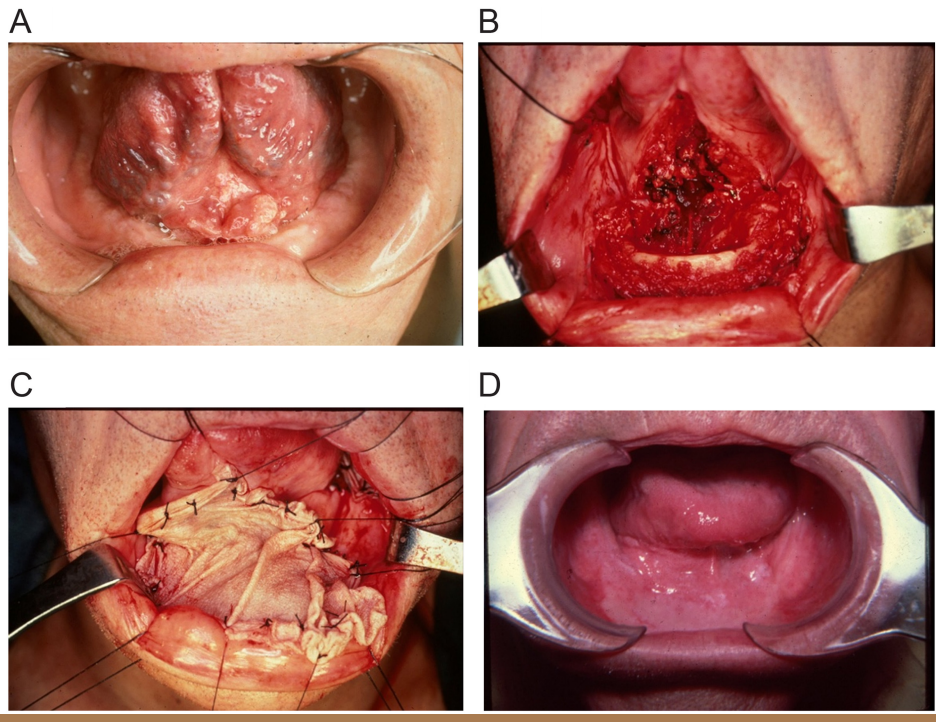

Figure 1. Images demonstrating (A) cancer of the floor of the mouth, (B) post-surgical ablative defect, (C) skin graft being placed to repair defect site, and (D) healed defect.

may be appropriate to allow a portion of the wound to heal by secondary intention. Next on the reconstructive ladder are local flaps. Local flap donor sites originate directly adjacent to the tissue defect, incorporating the donor site into the closure process. The 4 common types of local flaps may be classified into advancement, rotational, transposition, and interpolation flaps. Local skin flaps were commonly used in the 20th century and saw a rapid growth in their complexity and application, driven by pioneers of the field. By the end of the 20th century, most of the local flap techniques used today had been described.

Prior to the development of pedicled and free flaps, delayed reconstruction was a common technique, in which surgeons would wait for some healing by secondary intention following ablation before proceeding to second-stage surgery for attempted reconstruction. The "waltzed" tubed pedicled flap was one such multiple-staged regional flap. Popularized by Sir Harold Gillies, this random pattern flap is a reconstructive technique in which the skin and soft tissue from the chest or back are formed into a tubular pedicle and moved from the donor to the target site by periodically transferring one end and anchoring it closer to the target site, allowing for neovascularization of the flap to occur (Figure 2). It was not until the development of axial flaps that large areas of tissue could be reliably transferred in a single stage, due to the direct cutaneous blood supply from a named artery/vein pedicle. Following this, the use of operating microscopes and microvascular anastomosis allowed for the emergence of free tissue transfer, which has become the preferred reconstructive option in the modern era due to its reliability and versatility to repair a variety of defects in a single stage.

MAIN POINTS

- *Over the past two centuries, head and neck reconstructive techniques have evolved from primary closure and delayed reconstruction to advanced microvascular free flaps, significantly improving functional and aesthetic outcomes.*
- *The introduction of pedicled flaps and the subsequent development of microvascular free tissue transfer revolutionized head and neck reconstruction by enabling single-stage defect repair.*
- *The adoption of a two-surgeon approach and the integration of virtual surgical planning in modern free flap procedures have improved operative efficiency, reduced operative time, and enhanced patient outcomes.*
- *Achieving optimal functional and aesthetic results requires a multidisciplinary team approach, incorporating expertise from surgical, medical, and rehabilitative specialists.*

Pedicled Flaps

Commonly referred to as the first documented flap in history, a form of the pedicled paramedian/median forehead flap was described in the Hindu holy book, the Sushruta Samhita. In 700 BC, it was reportedly performed to repair defects for adulterers whose noses were amputated as punishment.[2] Reports of pedicled flaps were subsequently scattered throughout the early 20th century. The first pedicled tubed advancement flap was performed by Filatov in 1917.[3] However, it was not until 1963 that pedicled skin flaps became re-popularized, when McGregor reported on an oral cavity defect that was reconstructed using an axial pattern forehead flap based on the superficial temporal vessels.[4] This report was soon followed by Bakamjian and Littlewood, who in 1964 described the deltopectoral flap, a versatile flap that was often used in combination with local reconstruction and is still used today.[5] As described by McGregor and Morgan in the early 1970s, these axial flaps were

Figure 2. (A) The first stage of a "waltzed" tubular pedicle flap in which the skin is tubed and eventually moved in stages from the source to cover the cervical defect. (B) The final result after a waltzed flap reconstruction (separate patient).

distinct from random pattern flaps that were previously described, as they included a named artery/vein pedicle which allowed for large areas of tissue to be reliably transferred without delay due to its direct cutaneous blood supply.[6] Following this description, there was a rapid expansion of published pedicled myocutaneous flaps, including the temporalis, platysma, sternocleidomastoid, latissimus dorsi, pectoralis major, and trapezius.

The latissimus dorsi flap, based on the thoracodorsal artery and vein, was first described by Italian surgeon Tansini for breast reconstruction in 1896,[7] but was not popularized until 1978 when it was used by Quillen for reconstruction of a mandibulectomy defect.[8] The first pectoralis major flap, based on the pectoral branch of the thoracoacromial artery, was reported by Hueston and McConchte in 1968 as a part of the deltopectoral flap,[9] and was eventually used in the head and neck by Ariyan in 1979.[10] The pectoralis major flap is a versatile flap that can be used for a variety of defects (Figure 3). The sternocleidomastoid flap, which is supplied by sternocleidomastoid branches of the occipital, superior thyroid, and suprascapular arteries, was first described by Owens in 1955.[11] Other flaps less commonly used included the platysma flap, first described by Gersuny in 1887, and variants of the trapezius flap described in 1979.[12,13] Many of these flaps still remain important in head and neck reconstruction today. The pectoralis major myocutaneous flap is not uncommonly used to repair total laryngectomy defects, while the sternocleidomastoid flap may be used to protect the great vessels after neck dissection when adjuvant radiation is indicated.

Prior to the popularity of pedicled flaps, the reconstruction of bone defects relied on non-vascularized cortical bone grafts, typically harvested from distant locations and held in place by titanium plates. The most common donor sites included the tibia, iliac crest, and rib.[14,15] With the increased popularity of pedicled flaps, surgeons began experimenting with integrating bone into the pedicled flap. For example, the serratus anterior could be combined with the rib, or the pectoralis major with the rib, clavicle, or sternum. However, the vascular supply of the harvested bone was often poor, resulting in these osseous pedicled flaps never being widely adopted. It was not until free flaps became prominent that reconstruction with bone could be reliably performed.

Free Flaps

In 1912, Alexis Carrel won the Nobel Prize for his work showing that blood vessel anastomosis could be achieved through meticulous suturing.[16] This revolutionary work laid the groundwork for vessel anastomoses across all fields of surgery. Initially, Carrel's findings were applied to macrovascular anastomoses, primarily in limb and organ transplants during the 1930s-1950s.[17,18] In 1960, Buncke reported success in anastomosing vessels 1 mm in size, coining the term "microsurgery" for the first time.[19] The modern operating microscope was developed by Carl Zeiss in the 1950s.[20] This microscope was predated by the first monocular operating microscope built by otolaryngologist Carl-Olof Siggesson Nylén in 1921 and the first binocular microscope built by Gunnar Holmgren in 1922.[20] These developments set the stage for microsurgery and free tissue transfer as we know it today. However, the first few microvascular free flaps were performed without the aid of operating microscopes. Seidenberg is credited with the first published free tissue transfer in 1959, when he transferred a jejunal flap into an esophageal defect.[21] In the 1970s, the transverse abdominal flap was described, later becoming a frequently used flap for various types of reconstruction before falling out of favor due to unacceptable morbidity. These sequelae were

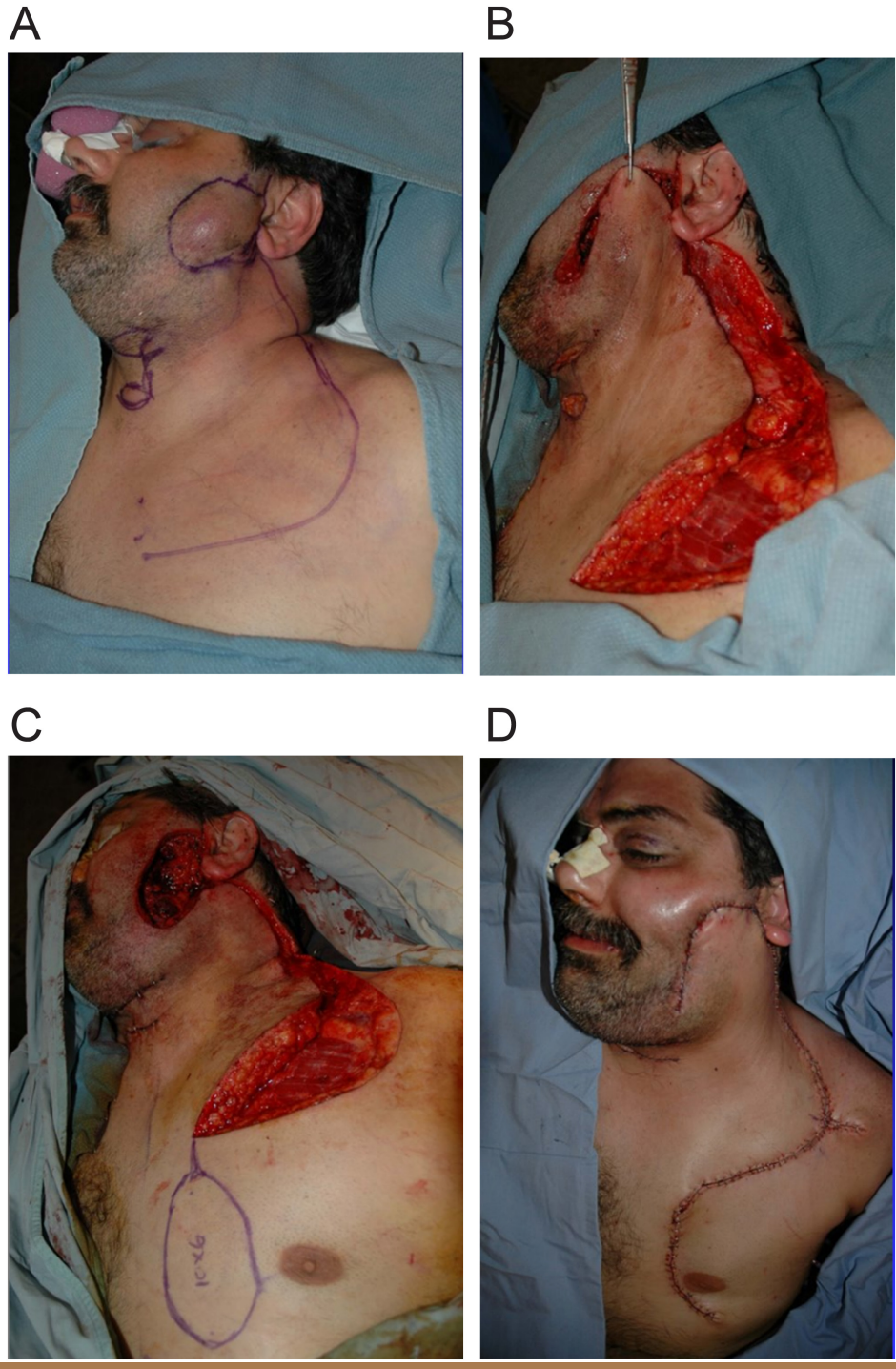

Figure 3. Extensive reconstruction for a cancer of the parotid gland demonstrating (A) preoperative markings, (B) cervicofacial advancement flap, followed by a (C) pectoralis major myocutaneous flap beneath the skin to add bulk, resulting in (D) well-approximated closure.

eventually mitigated through the development of the deep inferior epigastric perforator flap in 1999.[22] Although most routinely used for breast reconstruction, it was first applied to head and neck surgery by Beausang in 2003 and is still used today when subcutaneous volume needs to be maximized.[23] The first osseous free tissue transfer was performed by Taylor in 1975.[24] The fibula free flap was eventually popularized by Hidalgo after reporting on its successful usage in reconstruction of the mandible in 1989.[25]

The early 1980s was a period of substantial innovation in microvascular reconstruction. The radial forearm free flap was first described in China in 1981 by Yang for the reconstruction of burn wounds,[26] before being introduced as a reliable option for intraoral reconstruction by Soutar in 1983.[27] Based on the radial artery, this dynamic flap can also successfully incorporate muscle, tendon (palmaris longus), nerve (lateral antebrachial cutaneous), or bone (radius). In 1982, the free scapular flap, based on the circumflex scapular artery, was

introduced by Gilbert and Teot.[28] This was applied to mandibular reconstruction by incorporating the lateral scapula, although, nowadays, the scapular tip is currently more commonly used.[29] That same year, the lateral arm flap, based on the posterior radial collateral artery, was first described by Song et al.[30] This flap has multiple applications in head and neck reconstruction based on modifications to facilitate various fasciocutaneous thicknesses and pedicle lengths as well as options for simultaneous nerve, muscle, or bone harvest (Figure 4).[31] One of the most versatile and commonly used flaps, the anterolateral thigh free flap, based on septocutaneous or musculocutaneous perforators from the descending branch of the lateral femoral circumflex artery, was first described by Song in China in 1984 before being applied to the head and neck region by Koshima in 1993.[32,33] Many other flaps remain available to the head and neck surgeon, including the anteromedial thigh, profunda artery perforator, iliac crest, and ulnar forearm free flaps.

Modern Times

Over the last half-century, the field of head and neck surgery has seen a rapid development of reconstructive techniques. Today, free flaps are a reliable and versatile option for major head and neck reconstruction, with free flap success rates consistently being reported >95%. New techniques continue to develop, with much of the emphasis now placed on efficiency and functional outcomes.

The modern free flap consists of a 2-surgeon approach, with 1 surgeon focusing on the ablation while the other simultaneously begins the reconstructive portion. This 2-team approach leads to improved operative efficiency, decreased operating time, and improved outcomes, which is beneficial to both the surgeon and patient. Virtual surgical planning is another novel method that can improve surgical efficiency. The technique of virtual surgical planning consists of the preoperative use of computer-aided design and computer-aided manufacturing techniques to design 3D stereolithographic models and osteotomy guides fitted specifically to the predicted surgical bone defect and donor site, respectively (Figure 5). Virtual surgical planning has the potential to reduce intraoperative time and complications; however, the additional time and effort required outside of the operating room makes this a matter of debate.

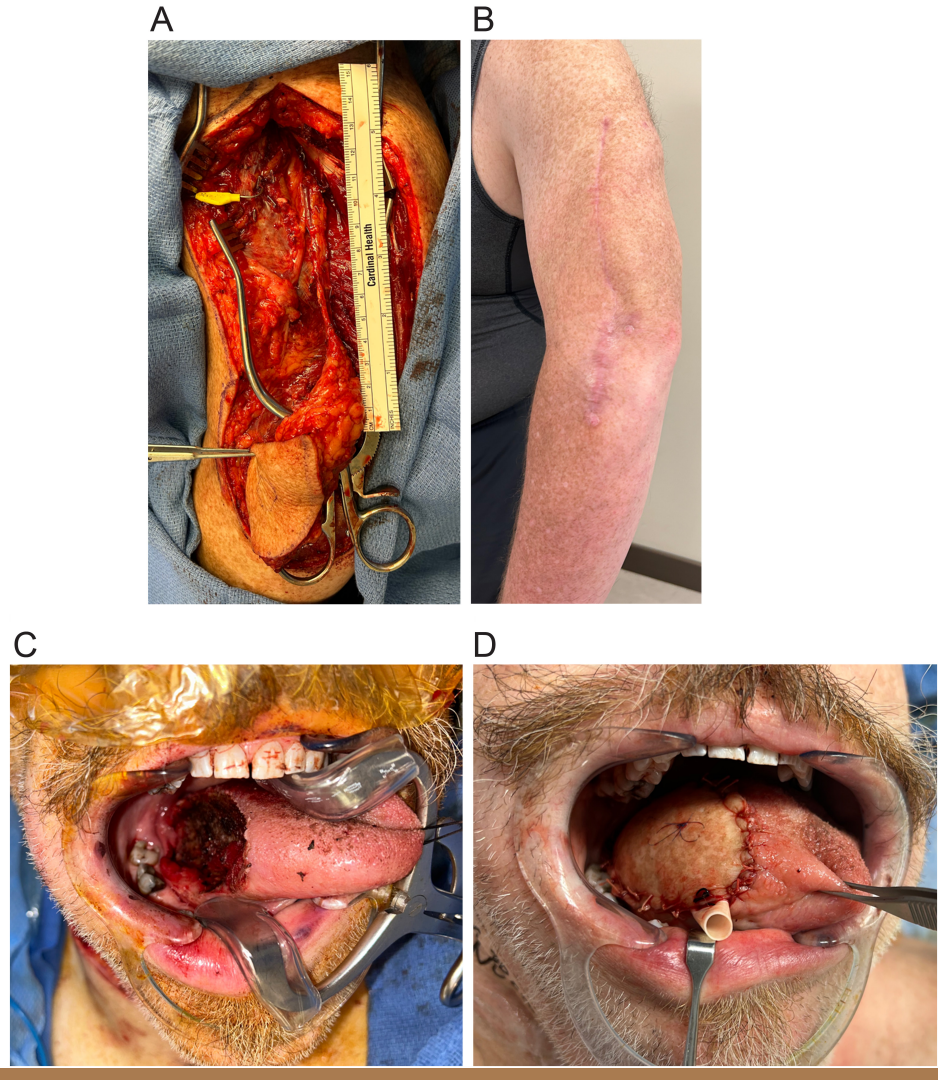

Figure 4. Lateral arm free flap used to reconstruct a partial glossectomy defect. (A) dissected flap demonstrating the vascular pedicle, (B) ablation defect, (C) flap inset, and (D) healed donor site scar.

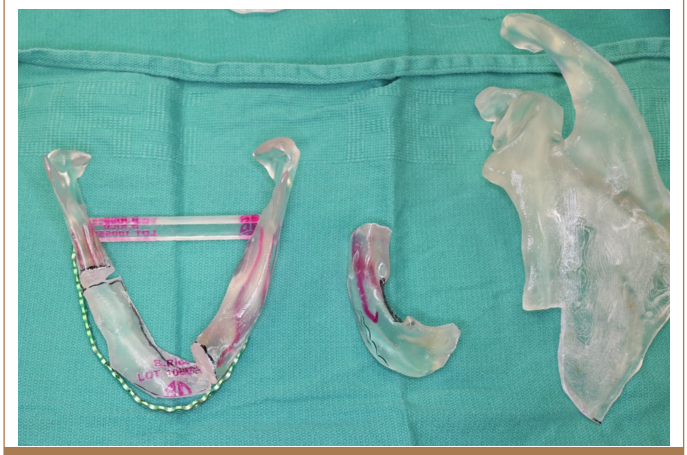

Figure 5. Preoperative virtual surgical planning using 3D printed models of a scapular flap used to reconstruct a mandibular defect.

In most cases, a single flap provides adequate tissue coverage. For certain large defects, however, multiple separate flaps may be required. Alternatively, compound or "chimeric" flaps may be used. Compound flaps include various tissue types of separate vascular pedicles that naturally converge into a single vascular pedicle, allowing for a high degree of freedom while maintaining the need for a single pedicle anastomosis. When multiple chimeric or compound flaps are combined based on a single vascular pedicle, this is often referred to as a "mega-flap." One such example is the latissimus dorsi-parascapular osteomusculocutaneous free flap.[34] The advantages of these compound flaps over multiple individual flaps are a decrease in operative harvest time and the number of anastomoses. However, the disadvantages of compound flaps include the variation of perforators, risk for pedicle torsion, and the occasional need for secondary venous drainage.

One area of emerging reconstructive research is the transplantation of allogenic and alloplastic grafts. The most significant advances have occurred with total laryngeal transplantation. To date, 12 cases of total laryngeal transplantation have been reported. In 2024, the first laryngeal transplant was performed in the setting of active cancer, in which a patient with laryngeal chondrosarcoma received a transplant including the larynx, pharynx, esophagus, trachea, thyroid and parathyroid glands, neurovascular structures, and skin.

With the advances in modern head and neck cancer treatments, including chemotherapy, radiation, and immunotherapy, patients are living longer after surgery. While exciting, the same treatments that prolong survival leave many patients with severe functional and cosmetic defects. As such, multidisciplinary collaboration is essential to optimize outcomes. Radiation and medical oncology will remain integral parts of head and neck cancer treatment, and reducing radiation dosage remains an active area of research to minimize morbidity. Speech-language pathologists can work with patients throughout treatment to improve speech and swallowing outcomes. Head and neck cancer patients experience rates of depression and anxiety substantially above the general population, so early collaboration with psychiatrists is important in managing comorbid psychiatric issues. Collaboration with facial plastic and reconstructive surgeons can optimize both functional and cosmetic outcomes following oncologic surgery.

Conclusion

Reconstruction of head and neck oncologic defects has evolved significantly, driven by surgical pioneers throughout the years. Though local and pedicled flaps remain important, the success of free tissue transfer has widely supplanted these techniques as the preferred reconstructive approach for large and small defects alike. New reconstructive tools continue to emerge, including virtual surgical planning and allogenic transplantation. As the number of head and neck cancer survivors increases, the integration of a multidisciplinary team is essential in minimizing post-treatment morbidity.

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