

Prosthetics in Facial Reconstruction

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Abstract

Reconstruction of the head and neck can be a challenging undertaking owing to numerous considerations for successful rehabilitation. Although head and neck defects were once considered irretrievably morbid and associated with a poor quality of life, advances in surgical technique has immensely contributed to the well-being of these patients. However, all patients are not suitable surgical candidates and many have sought nonsurgical options for functional and cosmetic restoration. As such, the advent of prostheses has ameliorated those concerns and provided a viable alternative for select patient populations. Prosthetic reconstruction has evolved significantly over the past decade. Advances in biocompatible materials and imaging adjuncts have spurred further discovery and forward progress. A multidisciplinary approach to head and neck reconstruction focused on appropriate expectations and patient-centered goals is most successfully coordinated by a team of head and neck surgeons, maxillofacial surgeons, and prosthetic specialists. The aim of this article is to provide a comprehensive review of the current trends for prosthetic rehabilitation of head and neck defects, and further elaborate on the limitations and advancements in the field.

Keywords

- prosthetic
- facial reconstruction
- defect

Prostheses have become an integral part of head and neck restoration. With significant advancements over the past decade, postsurgical rehabilitation and quality-of-life measures have taken on paramount roles. Head and neck prostheses provide a synthetic replacement for ablative, congenital, or traumatic defects of the head and neck, and attempt to restore cosmetic appearance and functionality. The dual goals of craniofacial reconstruction, form and function, can often be harmoniously achieved. However, the challenging anatomy and physiology of the head and neck can prove daunting and time consuming to the most experienced surgeon. Therefore, a multidisciplinary

approach employing the ablative, reconstructive, and maxillofacial techniques for pre- and postsurgical planning is critical to a successful patient outcome. The purpose of this article is to review the current concepts surrounding prosthetic rehabilitation of head and neck defects, with emphasis on the advancements and limitations in the field of prosthetic reconstruction.

Methods

This review seeks to collate all full-text peer-reviewed publications concerning facial prosthetic rehabilitation of

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patients with head and neck cancer, posttraumatic, and congenital defects. The most current prosthetic biomaterials and their indications were also identified. A comprehensive search of studies published from January 1990 to July 2016 and listed in the PubMed/Medline and Cochrane Library databases was performed. Three authors independently reviewed the titles and abstracts of all citations identified by the literature search. Special attention was placed on auricular, orbital, midface, and nasal defects; prosthetic materials; retention mechanisms; and technique for placement. Articles were reviewed, and those appropriate to the central theme of this article were included in the study.

Presurgical Planning

The multidisciplinary approach to head and neck reconstruction is critical because treatment of these defects is complex.¹ In some cases, substitutions of biologic structures with prostheses are advantageous and may be superior to surgical reconstruction both in function and aesthetics.² Multiple factors must be taken into account when reconstructing a head and neck defect, including the size, location, age of the defect, and amount of adjacent supporting tissue around the defect. Overly large defects,^{3,4} and defects adjacent to mobile structures, may be more successful with surgical versus prosthetic approach to ensure fit and survival.⁵ The timing for reconstruction is critical in cases of trauma-induced defects and congenital malformations.⁶ Patients' age in congruence with their anticipated growth is also a factor in reconstructing an anatomical area that compliments their appearance. Prosthetics can be tailored to patients' age and facial features during different growth stages.⁴⁻⁶

Head and neck malignancy can ensue devastating aesthetic and functional consequences that patients require extensive preoperative counseling to tailor postoperative expectations.^{5,7,8} Reconstruction, when needed, is informed by disease features, including the presence or absence of metastases, extent of extirpation, and patient prognosis, among others.⁸ In patients in whom recurrence is more likely, prosthesis would be more favorable for long-term management and surveillance.⁵ Microvascular flap reconstruction affords the best reconstructive option if infection, osteonecrosis, or pathologic fractures are anticipated.⁹

Successful reconstruction in part relies on careful consideration of the patient's demographics, functional status, and pre-existing medical conditions. The psychological well-being of the patient should also be considered throughout the reconstructive process so that their goals and expectations are well communicated.^{10,11} The postsurgical hospital course in patients undergoing microvascular free flap surgery is extensive and may require revision surgeries and/or procedures which predisposes the patient to a variety of possible complications.¹² Hence, in each patient, a cost-benefit analysis of their wants, surgical needs, and expected outcomes must be weighed, and clinically prostheses may provide a better functional and cosmetic result in the face of attenuated survival.¹³⁻¹⁵ Therefore, elderly patients or those with significant comorbidities may benefit from prosthetic rehabilitation.¹⁶⁻¹⁸

Imaging Modalities and Prosthesis Design

Reconstruction of head and neck defects has improved immensely over the years due to advancements in three-dimensional (3D) printing technologies. These digital imaging modalities allow a surgeon to preoperatively visualize the patient's defect and create customizable patient-tailored prosthetics. Further advancements in the computer-aided design/computer-aided manufacturing (CAD/CAM) technology allow for creating and manufacturing patient-specific custom prostheses.¹⁹⁻²¹ Imaging modalities such as computed tomography (CT) and magnetic imaging resonance (MRI) can be converted to a rapid prototyping model that can be printed in wax or acrylic.^{22,23} These models can be further modified, or duplicated with other prosthetic materials.

Materials

Throughout history, materials such as silver, leather, porcelain, paper-mache, gelatin, latex, and acrylic were employed in prosthetic reconstruction.^{24,25} Development of an ideal facial prosthetic relies on factors such as durability, flexibility, weight, color matching, longevity, biocompatibility, texture, hygiene, and thermal conductivity.²⁶ Modern materials used for head and neck prostheses are divided into methacrylates, polyurethane elastomers, and silicone elastomers. These clinically inert materials easily absorb pigmentation and can be designed to match the color and texture of the surrounding structures for the most natural result.^{24,27,28} Silicone has become the most widely used materials in facial prosthetics. The soft and flexible texture of a silicone elastomer retains body temperature without distortion and can be stretched until transparent to blend with the adjacent skin. However, facial prosthetics are not without their disadvantages. On average, a facial prosthetic is remade or reconditioned every 2 years.¹⁸ Environmental influences, ultraviolet light, and discoloration play important roles in the degradation of a prosthesis, which puts a considerable burden on patients.^{17,18,26}

Retention Systems

The success of a prosthesis and overall patient compliance relies heavily on its retention system. Anchorage relies on a range of patient-specific factors, including anatomic, mechanical, chemical, and surgical considerations.²⁷⁻³⁰ Facial prostheses were often mechanically anchored to spectacles or secured via anatomical undercuts early in the 20th century.¹⁸ Complications with these retention systems and advancements in prosthetic anchoring, including adhesives, have since largely replaced these older practices. While easier to use, medical adhesives often lose their bone strength as the adhesive naturally weakens, requiring re-application every 4 to 8 hours, or sooner if compromised by humidity and/or perspiration. Patients with active lifestyles are poor candidates for an adhesive-based prosthesis, as they easily dislodge with frequent movement.^{28,31,32} These early methods of adhesion often resulted in skin irritation, allergic

reactions, and difficulty in positioning the prosthetic.^{28,33,34} Compliance and satisfaction with daily-applied prosthetic adhesive is reduced relative to surgical methods of prosthetic anchorage.³⁵

Implant-retained facial prosthetics has vastly improved anchorage and become a reliable practice of retention. Osseointegration gained popularity in the 1950s when Swedish physician Per-Ingvar Brånemark discovered that titanium was biocompatible with bone.³⁶ For a successful rigid fixation of an alloplastic material to bone, two processes play a vital role in osseointegration: osteointegration and osteoconduction.³⁷ Implants introduced into the bone within or adjacent to the defect triggers osteoinduction. The stimulation of preosteoblasts in the formation of new bone is speculated to be the most important factor in ensuring prosthesis survival. Once the implants are placed, osteoconduction begins a cycle of remodeling and bone formation.³⁷⁻³⁹ When the bone is finally healed, it bonds with the implant. Abutments or attachments to the bone-anchored implant exit the skin and allow for external prosthesis attachment.²⁴ Osseointegration is a simple surgical procedure that is generally well tolerated, and holds a low risk of long-term complications.^{29,30} Bone-anchored implant mechanisms have revolutionized craniofacial prosthetic rehabilitation, as they are comfortable to wear and easy to clean and self-align in an anatomically correct position.³⁴ While bone anchoring is an excellent modality in many respects, it is by no means a panacea. Implant-retained prostheses have a greater risk of failure in irradiated bone, and may portend an increased risk of microbial infections.^{18,40} Individual assessment among patients is therefore critical when planning their prosthetic rehabilitation.

Several mechanisms exist to couple the osseointegrated implant with the external prosthesis. These include bar-clip attachments, ball attachments, and magnetic retention.⁴¹ Bar-clip retention for facial prostheses is most widely used, and provides the strongest bond. However, adequate surface area to sustain the load is required to support the attachment.⁴² Magnetic retention has strong attractive forces in small and inconspicuous sizes that are ideal for craniofacial deficits.^{42,43} Nasal and orbital prostheses, for example, are almost exclusively retained by magnets.^{24,41} Bone-anchored prostheses typically last between 3 and 5 years compared with 1 and 3 years for an adhesive-retained prosthesis before replacement as natural wear is needed.⁴⁴

Auricular Prostheses

Auricular defects are commonly associated with congenital malformations, ablative tumor surgery, or trauma. The size and extent of the deformity determine whether the defect can be treated with surgical reconstruction or prosthesis.⁴⁵ The best approach to surgically restore the auricle is dependent on patient preference, surgeon experience and comfort, and available tissue.⁴⁶ Larger defects are harder to reconstruct surgically and depend on multiple factors to make the reconstruction a success. The adjacent skin and subcutaneous tissue, which are frequently damaged by trauma or

radiation therapy, must be intact with a rich blood supply to support an autologous graft.⁴⁶⁻⁴⁸ Auricular reconstruction presents a challenge to even the most accomplished surgeon. Multiple surgeries are required for graft harvesting, tissue expansion, and cosmetic revision, increasing the morbidity and risk for complications. Bleeding, infection, and hematoma are more frequent in comparison to an auricular prosthesis at the implant and graft site.⁴⁹ Moreover, overall patient satisfaction is frequently lower due to inconsistent aesthetic outcomes.⁵⁰⁻⁵²

Variations and inconsistencies in surgical practice paved the way for prosthetic reconstruction. In these cases, preservation of the tragus aids in prosthesis alignment and defect concealment.⁵³ Retention of an auricular prosthesis is achieved via chemical adhesives or more commonly with osseointegrated implants. Osseointegration for retention of auricular implants is favorable due to the high success rate in temporal bone anchoring, even in irradiated patients.⁵⁴⁻⁵⁶ Implants are placed in two to three locations to lend greater infrastructure support.⁵⁷ The implants are placed 20 mm from the external ear canal to correspond with the 1-, 3-, and 5-o'clock positions along the antihelix of the left ear and 7-, 9-, and 11-o'clock positions for the right ear.^{5,58} Placement as such allows for a sufficiently high space for the abutment to support the prosthesis in correct anatomical position.²⁴ The bone must be well vascularized and thick enough (>2.5 mm) to support the load of the prosthesis.^{25,45,59} It is important to consider that portions of the normal anatomy, such as the tragus, can be kept intact to hide the transition from skin to prosthesis. Preoperative CT imaging is always needed for presurgical planning to review the integrity of the temporal bone and map out adequate sites for implants.⁵⁹

An auricular prosthesis can be easily implemented, and provides significant functional and aesthetic benefits. Sound amplification and acoustic gain are markedly attenuated in the deformed ear. Auricular prostheses provide a clinically relevant acoustic gain at certain head positions and frequencies that aid speech recognition in noise.⁵⁶ **→Figs. 1 to 4** show a patient following auriclectomy successfully restored using an auricular prosthesis.



Fig. 1 Patient following auriclectomy with placement of bone anchored posts to hold prosthesis.



Fig. 2 Anterior view of auricular prosthesis.



Fig. 4 Previously shown patient in ►Fig. 1 with placement of auricular prosthesis.

Nasal Prostheses

Nasal lesions may require a partial or total resection, and are commonly reconstructed with the use of regional flaps. The paramedian forehead flap is the most cosmetically favorable because of the similar skin color and texture to the nasal region.^{60,61} Nonetheless, color match is not always optimal, and revision surgeries come with increased morbidity and mortality.^{62,63} Moreover, patients undergoing postoperative radiation have delayed wound healing and an increased risk of flap failure.^{64–66} In some cases, prosthesis may be the best alternative to match and restore the defect with a nose similar in color, thickness, and texture to the surrounding anatomy.^{64,66}

Before determining the appropriate method of reconstruction, careful attention to the retention mechanism used for a nasal prosthesis must be acknowledged. Adhesives have a short life span and often fail because of the constant air exchange, humidification, and moisture in the nasal cavity.⁶⁷ Mechanical retention may be sufficient if the appropriate surgical undercuts are made to position the im-

plant, and enough surface area is available to achieve appropriate anchorage.⁶⁸ Osseointegration has significantly improved nasal implant retention because of its tenacity and resilience in the face of dynamic environmental conditions. This technique, however, is dependent on the quantity and quality of the available bone stock.^{67–69} Osseointegrated implants are traditionally placed in the floor of the nasal cavity or glabella. Limitations in the amount of bony support can compromise the stability of an implant, or cause dislodgement with functional movements such as mastication.⁶⁹ Scott et al looked into the placement of zygomatic implants to support a nasal prosthesis in patients who had undergone rhinectomy. In comparison to nasal implantation, using the zygoma provides a region with greater length and bone stock for successful osseointegration.⁷⁰ Second, the length of the zygomatic implant is often not in the field of radiation therapy, thus improving implant success.^{71,72} It is again important to consider that portions of the normal anatomy may need to be removed, such as the ala, anterior septum, and columella to allow the prosthesis to fit properly without requiring a large construct. Care must also be taken to ensure that the upper lip or melolabial crease is not disturbed to prevent stark contrast between native tissue and the prosthesis. While nasal prostheses share some disadvantages, overall they provide a cosmetically advantageous result that can be achieved with a low morbidity surgical procedure. ►Figs. 5 to 7 show a patient following rhinectomy successfully restored using a nasal prosthesis.



Fig. 3 Posterior view of auricular prosthesis showing mounting holes to fit onto osseous posts.

Maxillary and Midface Prostheses

Reconstruction of midface and maxillary defects is a complex undertaking. The maxilla is essential for mastication, phonation, malar projection, and deglutition. The maxilla provides structural support between the skull base and occlusal plane, and supports facial structures involved in expressive movements.⁷³ Reconstruction of maxillary defects must accomplish closure of the oral cavity, support of orbital contents and maxillary buttresses, restoration of dentition and

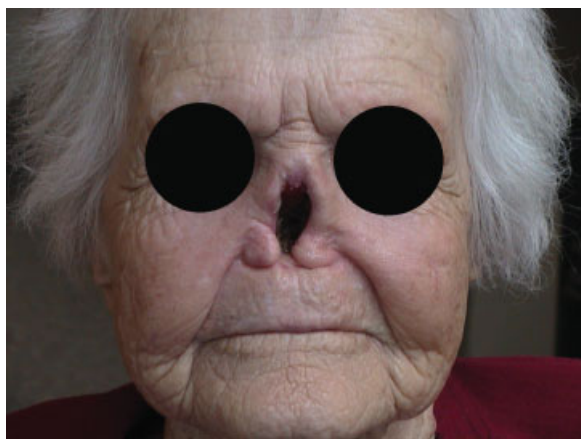


Fig. 5 Patient with nasal defect following rhinectomy (eyes have been removed from image).



Fig. 6 Nasal prosthesis to be used for reconstruction.



Fig. 7 Previously shown patient in ▶ Fig. 5 with placement of nasal prosthesis (eyes have been removed from image).

functionality, and restitution of midface contour and symmetry. Traditionally, maxillectomy defects were reconstructed with prosthetic obturation, with the primary goal of separating the oral cavity from the sinonasal cavity.^{74,75} Obturator stability is directly dependent on the amount of tissue available for support, and extensive hard palate resections compromise the airtight fit of the obturator with remnant structures.^{75–77} This instability leads to leak from the nasal cavity and sinuses, increasing irritation and wear on the oral cavity.^{77–81}

Maxillary and midface defects have spanned the reconstructive ladder from prosthetic rehabilitation to microvascular free flap. The size and location of the defect largely dictate the most appropriate reconstruction. Brown et al developed a modern classification system for maxillary defects in 2000,⁸² dividing defects into four vertical and three horizontal classes with associated surgical and prosthodontic approaches and reconstructive strategies. Smaller defects without alveolar involvement are most amenable to obturator rehabilitation and can be reconstructed using a local advancement or microvascular free flap. Prosthesis for smaller defects is well tolerated but maintenance is the greatest factor that drives patient preference between single and multiple surgery reconstructions.⁷⁵

Midface defects typically require three to four implants for adequate support.²⁹ The zygomatic buttress, supraorbital rim, vomer, and horizontal part of the hard palate are stable recipient sites.⁵³ The amount of remnant palate and/or the adjacent abutment tooth is critical to utilize for stability and retention of the prosthesis.⁸³ The integrity of the canine and molar teeth is also critical for strong prosthesis retention. Forces that influence the fit of a prosthesis need to be considered and include downward gravitational forces, upward occlusive forces, and rotational forces involved with functional speech, swallow, and mastication.^{81,84}

Large maxillary defects may not be amenable to prosthetic rehabilitation due to the absence in remaining structures that provide stability. In these cases, microvascular composite free flaps can achieve outstanding functional and aesthetic results. Even with complex resections, these composite flaps provide adequate bone length and tissue to fill the defect.⁷⁵ A combination of techniques using local advancement flaps or microvascular free flaps in addition to maxillofacial prostheses may achieve a more satisfactory functional and aesthetic result.^{73,75,85}

Orbital Prostheses

The eyes are integral to vision and an important component of self-image and expression. Orbital exenteration heavily impacts a patient's self-confidence, thus necessitating speedy repair.⁸⁶ Orbital enucleation involves removal of the globe by severing the optic nerve and extraocular muscles, while evisceration consists of removal of the entire globe, leaving the surrounding orbital contents intact including Tenon's capsule, extraocular muscles, and the optic nerve.⁸⁷ Exenteration is the most radical where all orbital contents including the globe are removed. Reconstruction



Fig. 8 Patient with orbital defect following exenteration.

after exenteration is patient dependent and can be done with a microvascular free flap or orbital prosthesis.⁸⁸ However, for the aforementioned lesser defects, repair with a prosthetic eye is the most common form of reconstruction. After removal of the eye, an orbital implant is placed for 4 to 6 weeks. The implant occupies the space that will eventually support the prosthesis, and prevents scar formation and tissue contraction. The bony cavity is lined with a split-thickness skin graft to create an adhesive base for the implant.⁵³ The orbital boundaries must be stable and healthy, the sinuses must be closed from the orbital contents, and the depth of the defect must be maintained to prevent endophthalmos.⁸⁹ The inferior margin of the resection should have solid contour and the stability to support a prosthetic load.⁹⁰ The superior portion should take careful consideration to maintain the position of the eyebrow. In cases of evisceration surgery, the extraocular muscles remain attached to the scleral envelope that lines the implant. Enucleation requires reattachment of the muscles directly onto the implant or indirectly to a wrapping material over the implant for anchoring.^{91,92} The cosmetic success is largely due to the orbital implant. If properly placed, the prosthetic eye will look and move with similar behavior to the contralateral eye.⁹³

The orbital implant is either made from a nonporous material such as silicone and polymethyl methacrylate or a porous material such as porous polyethylene, hydroxyapatite, and aluminum oxide.⁹¹ Nonporous materials are best used for implants that will not be integrated or pegged, and are well tolerated. Porous materials have become the mainstay in orbital implant material, as they promote a fibrovascular ingrowth of host tissue, improving stability, lowering the risk of rejection, and allowing the insertion of pegs or posts.⁹² The material and size of the implant are determined by the surgeon to meet the patient's anatomic needs. These implants achieve 65 to 75% of the volume of the original ocular globe,⁹⁴ with the remaining space filled by an external prosthesis.

An orbital or ocular prosthesis covers the orbital cavity and underlying implant. Ocular prostheses may be either fit



Fig. 9 Orbital prosthesis custom designed for patient in ► Fig. 8.

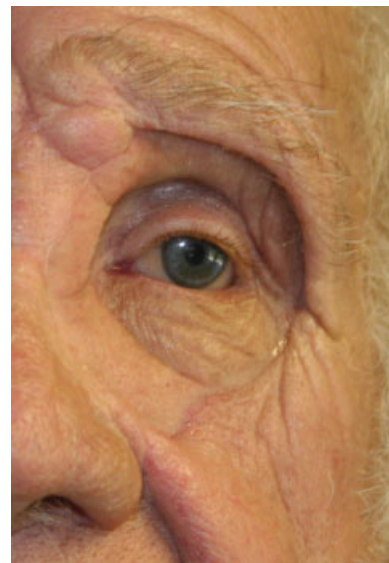


Fig. 10 Patient with orbital prosthesis in place.

from a stock set of prefabricated eyes matched to the patient or custom made.⁹⁵ Custom-made prosthetics is made from an impression of the patient's eye socket, and hand painted to match the contralateral eye.⁹² Retention of an orbital prosthesis is most successful after osseointegration.⁹⁶ Adhesive retention should be used in patients with incomplete bone growth or low bone density. Orbital prostheses present a viable reconstructive option after removal of the globe. ► Figs. 8 to 10 show a patient following orbital exenteration successfully restored using an orbital prosthesis.

Conclusion

Head and neck prosthetic rehabilitation is an excellent alternative to surgical reconstruction for patients who have undergone treatment for malignancy, congenital deformities, or trauma. This review presents the current standards of care, limitations, and data behind the materials used for prosthetic head and neck rehabilitation.

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