Facial prosthetic rehabilitation: preprosthetic surgical techniques and biomaterials

James C. Lemon[a], Sudarat Kiat-amnuay[b], Lawrence Gettleman[c], Jack W. Martin[a] and Mark S. Chambers[a]

Purpose of review

Attention to detail ensuring a successful facial prosthetic rehabilitation must be considered a priority at the time of presurgery, surgery, and at every stage in fabricating the prosthesis. Teamwork between the surgeon and maxillofacial prosthodontist will ensure an optimal surgical preparation and definitive prosthesis.

Recent findings

Evidence of interaction between team members can most certainly be encouraging to the patient. During the prosthetic phase of treatment, focusing on tissue assessment, impression making, sculpting, mold fabrication, familiarity with materials, appreciation of color, delivery of instructions, and patient education will ensure a satisfactory outcome. With the desire, determination, and encouragement from the restorative team to make the most of this artificial replacement, a patient can have a higher quality of life and a more normalized lifestyle.

Summary

This review presents current concepts regarding facial prosthetic rehabilitation of patients with head and neck cancer and facial prosthetic biomaterials.

Keywords

facial, prosthetic, rehabilitation, surgery

Curr Opin Otolaryngol Head Neck Surg 13:255–262. © 2005 Lippincott Williams & Wilkins.

[a]Section of Oncologic Dentistry, Department of Head and Neck Surgery, MD Anderson Cancer Center, University of Texas, Houston; [b]Department of Restorative Dentistry and Biomaterials, The University of Texas, Dental Branch at Houston; and [c]Department of Diagnostic Sciences, Prosthodontics, and Restorative Dentistry, University of Louisville School of Dentistry, Kentucky, USA

Correspondence to Mark S. Chambers, DMD, MS, The University of Texas, MD Anderson Cancer Center, Department of Head and Neck Surgery, Section of Oncologic Dentistry, Box 441, 1515 Holcombe Boulevard, Houston, TX 77030-4009, USA
Tel: 713 745 2672; fax: 713 794 4662; e-mail: mchamber@mdanderson.org

Current Opinion in Otolaryngology & Head and Neck Surgery 2005, 13:255–262

Abbreviation

CPE chlorinated polyethylene

1068-9508

Introduction

Most patients requiring prosthetic facial rehabilitation have undergone tumor ablative surgery for head and neck cancers. Multidisciplinary therapeutic techniques are commonly used in the care of patients with advanced disease of the head and neck, involving a team effort between the head and neck surgeon, maxillofacial prosthodontist, and reconstructive surgeon to optimize the patient's quality of life. Planning and preparation for rehabilitation should be coordinated by the responsible specialists before the surgical procedure. Miscommunication or lack of communication between the surgeon and the prosthodontist can cause post-treatment complications associated with the rehabilitation of patients with head and neck disease [1,2]. Maxillofacial prosthodontics is the branch of dentistry providing the prosthetic rehabilitation of intraoral and extraoral structures that have been affected by disease, injury, surgery, or congenital malformation [3]. Patients should be referred to the maxillofacial prosthodontist as early as possible in their treatment workup to evaluate the facial and oral status and discuss the treatment options of prosthetic rehabilitation. The primary surgeon can then integrate the results of this evaluation into the overall treatment plan.

Cancer of the head and neck region can profoundly affect patients' quality of life, as they are constantly reminded of their affliction. These cancers are emotionally debilitating to patients and their families [4–7]. Correction of such defects goes far beyond aesthetic considerations. Lesions involving facial structures can necessitate prosthetic rehabilitation. Prostheses can be made from a variety of materials, such as polymethyl methacrylate or urethane-backed, medical-grade silicone. These prostheses are retained with adhesives, tissue undercuts, or in some cases extraoral osseointegrated implants [8–10]. Facial and intraoral prostheses can be connected with magnets. The aesthetic result depends on the amount of tissue removed, type of reconstruction, morbidity of multimodality adjunctive treatment, and the physical characteristics of the tissue base available to support and retain the prosthesis [1–3,8]. Facial prosthetics has expanded over time as improvement in surgical techniques and materials developed [8].

Reconstructive and microvascular surgery remains the treatment of choice for many cancer and trauma patients, although there will always be a need for extraoral

maxillofacial prostheses, in which manmade materials substitute for missing biologic structures [11,12]. Prosthetic replacement of missing facial tissues has several advantages over surgical reconstruction. The process is relatively inexpensive, allows for periodic evaluation and cleaning of the surgical site, and is an alternative to surgery in unsuitable candidates. The fabrication process is relatively short, and unlike the surgeon, the maxillofacial clinician has complete control of the color, shape, and position of the prosthesis. Disadvantages include possible irritation of the tissue site, the need for periodic remakes, and reliance on adhesives or some other form of retention. Furthermore, the patient may view the prosthesis as a mask and not a part of his or her body. It is reported that 12% of patients who receive ear, nose, eye, and cheek prostheses using silicone materials never wear them [13], and there are numerous reports of dissatisfaction with the aesthetics, color stability, function, or longevity of prostheses [14–28].

This review presents current concepts regarding facial prosthetic rehabilitation of patients with head and neck cancer and facial prosthetic biomaterials.

General surgical guidelines enhancing prosthetic rehabilitation

General surgical guidelines, described here, can apply to most areas of the body, particularly the head and neck region. These guidelines should be considered on patients who will eventually undergo prosthetic rehabilitation. The success or failure of an extraoral prosthesis is dependent upon the platform onto which a prosthesis will be placed.

The first concern in oncology is local control of the cancer. The tumor should be resected and the margins clear without concern for aesthetically sensitive areas. Once the tumor has been adequately resected, attention should be directed to preparing the defect site for optimal prosthetic rehabilitation. Small areas of tissue that are not supported by bone or cartilage should be removed. This will provide a smooth border and will enhance margins of the prosthesis to blend with the surrounding skin. Loose tags are difficult to capture with an impression, in a passive position, and have no value in the final rehabilitation.

To facilitate prosthetic placement, a negative space (concavity) is desirable. If a defect site is to be filled with a soft tissue flap, such as the orbit or midface, limiting the bulk of the flap is most important. Atrophy of the soft tissue will occur over time, yet the extent is difficult to predict. If sufficient atrophy does not occur, an additional surgical procedure may be necessary to debulk the original reconstruction. In contrast, placement of bone is more critical because it cannot be debulked. Bone can provide future anchorage for extraoral implants. The use of a surgical template or having the prosthodontist present at the time of surgery can be of great assistance.

If bone has been exposed at the periphery of the defect or in the surgical site, the edges should be rounded. Thin bones are difficult to smooth and round; therefore, these projections may need to be reduced. Sharp edges can potentially erode through soft tissue or skin grafts and fracture, resulting in an infection. Such sharp edges are also uncomfortable for patients when they are inserting or removing a prosthesis. These irritated areas normally heal without sequelae yet can be problematic in an irradiated field.

In areas where bone is exposed or raw edges exist, covering these regions with a split-thickness skin graft has several advantages. It serves as an excellent base for adhesives. Lack of a glandular component makes the surface drier and less likely to form crusts. It is also useful in covering the respiratory mucosa to decrease local secretions. The skin graft is more resistant to abrasive forces when a patient inserts or removes a prosthesis. Smaller sites may only require primary closure without the need for a skin graft. The split-thickness skin graft allows the defect margins and adjacent skin areas to be less movable, compressible, and stable during facial movements and is a good adheophilic base due to absence of hair and glands [29].

Nasal region

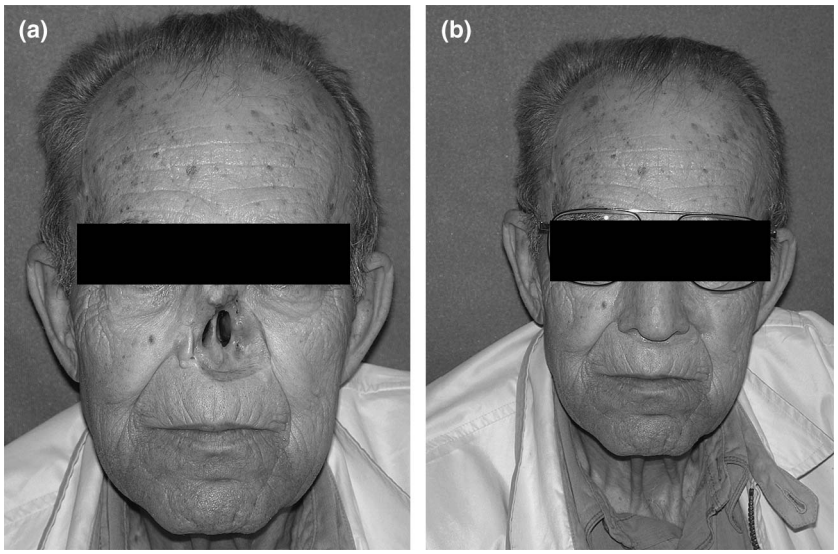
Resection of lesions involving the nose may require either a partial or total nasal restoration. A reconstructive procedure should be planned with the future restoration in mind. All unsupported tissue and alar tags that are usually out of anatomic location should be resected [9]. The nasal bone should be left intact if possible as it can provide the retention and blending of the prosthesis with the surrounding skin. Any sharp edges should be rounded to prevent exposure at a later time, which potentially could add to patient discomfort.

The nasal bone helps provide vertical support for the prosthesis, as well as for eyeglasses that may be worn (Fig. 1a and b). Minimizing the load on the prosthesis increases retentive time the patient can enjoy and prevents frequent replacement of adhesives. The cartilaginous septum should be reduced in an anterior-posterior dimension and should be more of a concavity than a convexity. The space gained will allow a subframework to be placed for additional retention or guidance. In addition, it will move mucosa back into the cavity to prevent drainage or moisture accumulation on or near the prosthesis.

Maintaining the anterior nasal spine is important in the final position of the upper lip [30]. Every effort should be made to keep the upper lip in an appropriate position and not cause the lip to migrate superiorly. The length of

Figure 1. Patient with a rhinectomy defect

(a) Nasal bone will help provide vertical support for the prosthesis as well as a split-thickness skin graft covering the ablated margins. (b) Nasal prosthesis with a polyurethane backing blending well with the defect margins.



the nasal prosthesis can be shortened in some instances to maintain an anatomic ratio to minimize the shorter upper lip.

Auricular region

As with the nose, surgeries of the ear can vary from subtotal resections to a total auriculectomy. From a prosthetic standpoint, it is easier to replace the complete ear. With a total replacement, there is complete freedom of shape, size, and location. The recipient area should be flat or concave. Convexities from excessive tissue bulk can hamper aesthetic results [1]. Skin devoid of hair provides a good adhesive base, yet a split-thickness skin graft is better (Fig. 2a and b). Tissue pockets assist in the orientation and stability of the prosthesis and allow the margins to extend in a zero degree emergence profile.

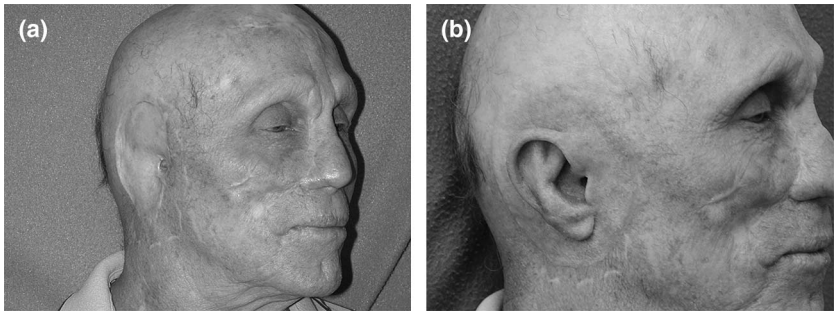
If tissue can be spared, the tragus should be the first choice. It is a good landmark that is not easily displaced and allows the anterior margin of the prosthesis to be hidden behind the posterior flexure. Hair and the angle of the helical rim provide posterior margin concealment. The inferior half of the soft tissue pinnae is of little or no use. Due to lack of cartilaginous support, the lobe of the auricle is normally drawn inferior and away from the head. It is difficult to capture with an impression in a passive manner and hampers bilateral symmetry. Such margins are difficult to maintain and can be a problem when the patient attempts to insert or place the prosthesis.

The superior half of the auricle has better cartilaginous support, yet tends to distort post-surgically. This distortion is further accentuated when the residual auricle is rotated and used to close the defect. Leaving a portion of the root of the helix preserves a good landmark and provides a base for short-term use of eyeglasses. This may help later in vertical support of the prosthesis.

Loss of the middle third of the pinna is seen occasionally. This defect is easy to restore, yet retention can be a problem. The location and size of the defect require the use of a prosthesis with multiple infoldings and grooves that make proper placement difficult for the patient.

Figure 2. Patient with a history of multiple skin cancers

(a) Recent squamous cell carcinoma of the auricular region requiring a total auriculectomy, split-thickness skin graft placement, and postoperative external beam radiation therapy. (b) Auricular prosthesis adhered to the underlying reconstructed tissue with a biocompatible adhesive.



Orbital region

The most difficult and complicated head and neck defect to restore is that of an orbital exenteration. The ablative surgeon can greatly assist in the rehabilitation process by doing several things. First, from a prosthetic standpoint, the inferior margin must have good contour and not sag due to the weight of a prosthesis [2,3]. If the inferior bony cavity is left intact, this can lead to a good prosthetic result. If missing, soft tissue (cutaneous) or osseous tissue should be used to reconstruct this region for a proper platform for prosthetic support (Fig. 3a and b). When the defect extends beyond the orbital region, movable tissue is encountered. Attempts should be made to avoid occluding the orbit completely with bulky flaps that severely hamper the aesthetic placement of the ocular portion of the prosthesis and other components.

It is preferable to line the bony cavity with a split-thickness skin graft. This will provide ample space for a prosthesis and a good adhesive base and will make it easier for the patient to clean. Orbital frameworks or soft silicones placed in the orbital cavity will engage soft tissue and bony undercuts to augment retention and lessen the reliance on adhesives. The external bony margins of the orbital defect, prior to surgical closure, should be smoothed to decrease discomfort and prevent future bone exposure.

At the superior aspect of the orbit, care should be taken not to disturb the position of the eyebrow. A lower position (actively pulling the skin inward at closure or scar contracture) will result in a prosthesis that must overlay the hair. This hair can be shaved, yet provides a poor base for the adhesive. A superior position of the eyebrow makes it difficult to create a more normalized appearance and gives an 'inquisitive' expression. Surgical correction may be necessary. Soft tissue should not be allowed to sag into the cavity. This is typically displaced outward and creates asymmetric skin folds. Patient discomfort will result if these tissues are displaced inward.

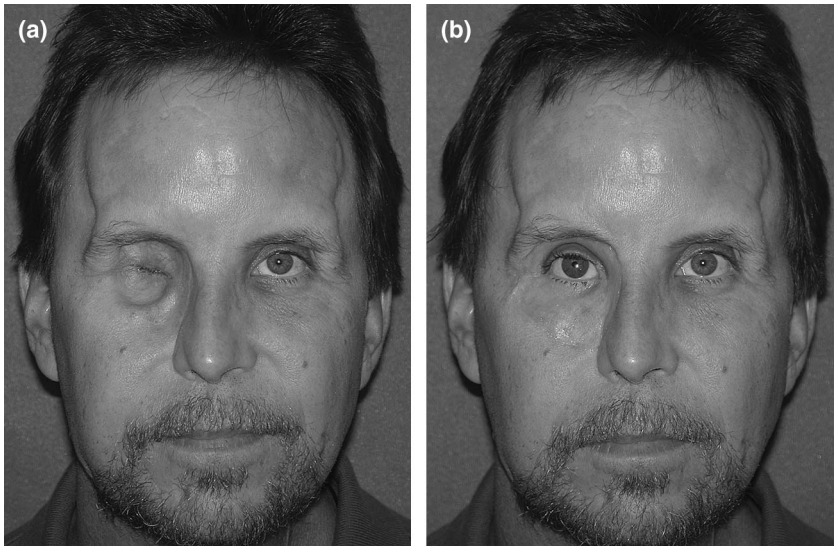
Osseointegrated dental implants

Dental implants have become an excellent adjunct in facial prosthetic rehabilitation [8,10,31–35]. Implants can vastly improve the retention and stability of a facial prosthesis. The surgeon and maxillofacial prosthodontist should participate in a presurgical planning session to determine the number, type, and positioning of implants in the defect. Three or four implants are required for most midface defects whereas one or two implants are used for most auricular prostheses [8,36]. Suitable recipient sites for midface implants are the zygomatic buttress, the supraorbital rim, the horizontal part of the hard palate, and the vomer [37]. A free tissue transfer flap composed of bone, muscle, associated soft tissue, and skin can be removed from a donor site and, through microvascular surgery, can be used to restore supporting tissues resected during cancer ablative surgery of the head and neck [37,38]. Microvascular techniques can also be used to create or improve sites for implant placement.

The principle of osseointegration of pure titanium with surrounding bone expanded the scope of biotechnology in prosthetic dentistry [36,39]. Implant designs fall into three main categories: endosseous, subperiosteal, and transosteal. The most common implants used today are endosseous implants in various lengths and widths that are surgically inserted and integrate with the surrounding bone [31]. Endosseous implants provide the support, retention, and stability needed in compromised oral cavities following tumor ablative procedures [31].

Figure 3. Patient with a traumatic injury to the right orbit requiring an enucleation

(a) The lids were positioned in the reconstruction for a concave topography allowing for greater adaptation of the orbital prosthesis. (b) Orbital prosthesis with a customized ocular component.



Meticulous surgical and prosthetic planning is required prior to the placement of implants [8,9,31]. Several types of implants are currently used for intraoral and extraoral maxillofacial uses [8,10,40]. Most implants used in maxillofacial prosthetics are made of titanium and are cylindrically designed using threads that anchor them in the bone. Such implants are produced in a variety of lengths and widths. In most of these implant systems, placement involves a two-stage procedure. The first stage, performed with the patient under local or general anesthesia, is the placement of the implant into the bony recipient site [8,31]. Placement is performed in a very precise fashion to ensure the least amount of damage to the adjacent bone and soft tissue, particularly in irradiated tissues. Following placement, the implant is covered primarily by the initial tissue flap and allowed to integrate with the bone for 12 or more weeks. The purpose is to promote perimplant integration with the implant interface, as described previously. Confirmed osseointegration, by radiographic and clinical interpretation, implies a direct and lasting connection between vital bone and the titanium implant of defined surface topography and geometry [8,31,39]. In the second stage, only the superior portion of the implant is uncovered and an abutment, usually made of titanium alloy, is placed onto the implant [1]. This connection will join the implant to the prosthesis. The number of implants and type of retention as well as prosthetic designing are at the discretion of the restoring prosthodontist. In general, the prosthesis is fabricated so that it can be easily removed by the patient and allows maintenance and proper hygiene.

Patients with facial defects may present with complex deformities that require management by a combination of both autogenous and osseointegration techniques [8]. Such patients may have both bony and soft tissue deficits that must be addressed in conjunction with the osseointegration procedure [8,41,42]. The methods of constructing a facial prosthesis that is retained by extraoral osseointegrated implants is well described in terms of general principles [8,9,43–45] and more specifically for the ear [8,9,45–47], orbit [8,9,48–50], and nose [8,9,51]. Opportunity exists to change the perceived value of prosthetics by employing advanced technology in facial prosthesis design and construction [41]. Very few studies have been completed since 2003 describing facial prosthetic rehabilitation with conventional or implant technology. The future potential of facial prosthetics as a modality of head and neck reconstruction depends on technologic advances and evidence-based research. The increasing rate of development of microvascular reconstruction and other autogenous surgical techniques over the past two decades has significantly impacted the multidisciplinary care of the facial patient [41].

Materials

A successful facial prosthesis depends on several factors: durability, biocompatibility, flexibility, weight, color, hygiene, thermal conductivity, ease of use, texture, and availability [9,10]. No facial material has all of these ideal properties although several materials are available that possess most of these properties with increased tear resistance and tensile strength and significant durability [9,10]. The currently available facial prosthetic materials can be divided into methacrylate or acrylic resins, polyurethane elastomers, and silicone elastomers. The Dow Corning Medical Products Division (Midland, Michigan, USA) was established in 1962 and a great variety of silicone products have been developed in the ensuing years. Different types of silicones may be selected, dependent on the properties desired [52]. In general, the goals of a facial prosthetic material should include processing characteristics, mechanical properties, and patient factors.

Most silicone-based facial prostheses today are relatively color stable and can be colorized very easily. Many skin adhesives are compatible with silicones, adhere well under moist conditions, and are simple to use. These adhesives may be irritating to the skin and require special removers, however. Water-based adhesives are milder to the skin but are not moisture resistant and do not adhere as long as silicone-based adhesives [52–55]. The interior of a surgical defect can be used to mechanically retain the prosthesis. As the defect becomes larger, for instance, approaching the medial canthal region of the eyes, or involves intraoral components, surface adhesion becomes limited and mechanical augmentation becomes more important [9]. By using interlocking pieces (a combination prosthesis), many tissue surfaces in the surgical site can be used. Acrylic resins are normally used for prosthetic eyes in ocular or orbital prostheses and for structural frameworks, subprostheses, or as a liner in a cavity to augment retention and orientation.

After an impression has been obtained and a master stone cast made, sculpting of the ablated anatomic structure is started and made to complement the area, or in some instances, match the opposite structure. The sculpting material is usually clay or wax and is placed onto the surgical defect to appropriately contour the future prosthesis and adapt its margins. Following the sculpting, stone or metal molds are made to capture the negative and positive surfaces of the future prosthesis. A silicone material is injected into the molds following appropriate coloration and addition of a catalyst [56]. When the material has set, it is removed, trimmed, and tried onto the patient. Modifications are made, if necessary, along with extrinsic coloration. Prosthetic placement and removal instructions are given and the patient is followed closely for a short period and then placed on a scheduled recall.

Evidence-based facial prosthetic biomaterials

There exists a significant and important opportunity to deliver an enhanced service in facial prosthetics through

technology implementation: three-dimensional data acquisition, three-dimensional modeling, and computerized color formulation. Evidence-based studies pertaining to the value of facial prosthetics will have to be addressed to better understand the economic, functional, and psychological burden of having a facial ablative procedure involving the orofacial, ocular, auricular, and nasal tissues. Additionally, well-structured and randomized studies are necessary to evaluate the next generation of facial biomaterials [57–62].

Silicone rubber materials have been used for more than 40 years in fabricating facial prostheses, with few improvements [12]. Meanwhile, industrial polymers and elastomers have constantly been refined. There is a clear need for new or improved facial prosthetic materials in all clinical situations. Clinical placement of facial prosthetic materials often requires modifications after an extended healing period following surgery or radiation therapy. In such situations, a totally new prosthesis may be required every 3, 6, or 9 months for up to 2 years, taking up to five visits for completion each time when using thermosetting, and thus unmodifiable, silicone rubber [9,10]. Other disadvantages of silicone elastomer include low tear and edge strength, relatively low elongation, potential to support bacterial or fungal growth, problem of color retention and color stability, and high cost [10].

Extension of maxillofacial prosthetic service to developing countries or underserved populations is severely limited by the high cost of materials such as silicone rubber. Legal impediments to some products have been affected by the recent breast implant controversy. Court judgments in the 1980s and early 1990s held some manufacturers of raw materials liable for failures of biomedical devices that were attributable to the compounders, fabricators, clinicians, or surgeons. Public Law 105-230, the Biomaterials Access Assurance Act, enacted on 13 August 1998, limits the liability of basic materials manufacturers except in cases of gross negligence. This assurance has been slowly reopening the field to new products.

In 1973, the National Institute for Dental Research held a conference on the state of the art of maxillofacial prosthetic materials. From that conference, a request for proposals was issued to which Gulf South Research Institute in New Orleans responded, proposing research to examine a variety of industrial rubber materials. A grant was funded from 1976–1979 for which an early version of the presently used new facial prosthetic materials made of low-cost thermoplastic chlorinated polyethylene (CPE) was formulated and tested. This project was refunded from 1983–1987, when the formula was refined and a small clinical trial was carried out at Charity Hospital of New Orleans (Louisiana State University), the equivalent of today's phase II clinical trial [57–62].

Chlorinated polyethylene may have advantages over conventional silicone rubber materials in its ability to be repaired, relined, or reconditioned, extending the life of the prosthesis. It is possible to key a new anatomic cast to the prosthesis, registering the tissue changes the patient has undergone, and to reprocess in one short visit to correct small changes in anatomy, without a total remake. In addition, it could be used with any adhesive type. It has greater edge strength, does not support fungus growth, and is much lower in cost compared with silicone materials.

Currently, a randomized, single-crossover, double-blinded phase III clinical trial funded by the National Institutes of Health/National Institute of Dental and Craniofacial Research at two cancer centers in the United States and Canada has been initiated to evaluate CPE (experimental) and silicone (control: Silastic Adhesive A/MDX4-4210 [Dow Corning Co., Midland, Michigan, USA]) materials for noninferiority of CPE compared with silicone elastomer [57]. Only a carefully constructed clinical comparison of conventional silicone rubber and the experimental CPE will reveal the substantial as well as the subtle differences between these two materials in practice [57]. Valid, well-justified, and cost-effective recommendations can then be made to the profession based on the outcome of the clinical trial.

Conclusion

The success of facial prosthetic rehabilitation depends on the surgeon's commitment to following prosthodontic guidelines during the ablative and reconstructive procedures. The surgeon creates the hard and soft tissue foundation upon which the removable facial prosthesis will be attached. Conventional means of retaining both facial and intraoral prostheses are well established. Frequently, conventionally retained facial prostheses are the most practical, trouble free, cost efficient, and successful types of prostheses. Implants may be considered when careful planning with the prosthodontist and surgeon has been established. The team approach is the best way to achieve optimal rehabilitative results. By understanding the requirements of the other specialists, each specialist is best able to contribute to the total facial rehabilitative effort. For facial prosthetics to achieve its full potential in the field of head and neck reconstruction, evidence-based research will be necessary to determine outcomes assessment and economic burden of rehabilitation.

References

1 Parr GR, Goldman BM, Rahn AO. Maxillofacial prosthetic principles in the surgical planning for facial defects. J Prosthet Dent 1981; 46:323–329.

2 Parr GR, Goldman BM, Rahn AO. Surgical considerations in the prosthetic treatment of ocular and orbital defects. J Prosthet Dent 1983; 49:379–385.

3 Worthington P, Branemark PI. Advanced osseointegration surgery: applications in the maxillofacial region. Chicago: Quintessence; 1992.

4 Gritz ER, Hoffman A. Behavioral and psychological issues in head and neck cancer. In: Beumer J, Curtis TA, Marunick MT, editors. Maxillofacial rehabilitation: prosthodontic and surgical considerations, St Louis: Ishiyaku EuroAmerica; 1996. pp. 1–14.

5 Gotay C, Moore T. Assessing quality of life in head and neck cancer. Qual Life Res 1992; 1:5.

6 Gotay C, Korn E, McCabe M, *et al*. D. Quality of life in cancer treatment protocols: research issues in protocol development. J Natl Cancer Inst 1992; 84:575.

7 Strauss R. Psychosocial responses to oral and maxillofacial surgery for head and neck cancer. J Oral Maxillofac Surg 1989; 47:343.

8 Wolfaardt J, Gehl G, Farmand M, Wilkes G. Indications and methods of care for aspects of extraoral osseointegration. Int J Oral Maxillofac Surg 2003; 32:124–131.

9 Beumer J, Ma T, Marunick M, *et al*. Restoration of facial defects: etiology, disability, and rehabilitation. In: Beumer J, Curtis TA, Marunick MT, editors. Maxillofacial rehabilitation: prosthodontic and surgical considerations. St Louis: Ishiyaku EuroAmerica; 1996. pp. 377–453.

10 Heller HL, McKinstry RE. Facial materials. In McKinstry RE, editor. Fundamentals of facial prosthetics. Arlington: ABI Professional Publications; 1995. pp. 79–97.

11 Cantor R, Webber RL, Stroud L, Ryge G. Methods for evaluating prosthetic facial materials. J Prosthet Dent 1969; 21:324–332.

12 Andres C. Survey of materials used in extraoral maxillofacial prosthetics. In: Gettleman L, Khan Z, editors. Proceedings of conference on materials research in maxillofacial prosthetics. Transactions of the Academy of Dental Materials 1992; 5:25–40.

13 Chen M-S, Udagama A, Drane JB. Evaluation of facial prostheses for head and neck cancer patients. J Prosthet Dent 1982; 21:324–332.

14 Sweeney AB, Fisher TE, Castleberry DJ, Cowperthwaite GF. Evaluation of improved maxillofacial prosthetic materials. J Prosthet Dent 1972; 27: 297–305.

15 Lemon JC, Chambers MS, Jacobsen ML, Powers JM. Color stability of facial prostheses. J Prosthet Dent 1995; 74:613–618.

16 Koran A, Yu R, Powers JM, Craig RG. Color stability of a pigmented elastomer for maxillofacial appliances. J Dent Res 1979; 58:1450–1454.

17 Yu R, Koran A, Raptis CN, Craig RG. Cigarette staining and cleaning of a maxillofacial silicone. J Dent Res 1983; 62:853–855.

18 Turner GE, Fisher TE, Castleberry DJ, Lemon JE. Intrinsic color of isophorone polyurethane for maxillofacial prosthetics. Part II color stability. J Prosthet Dent 1984; 51:673–675.

19 Abdelnnabi MM, Moore DJ, Sakumara JS. In vitro comparison study of MDX-4-4210 and polydimethyl siloxane silicone materials. J Prosthet Dent 1984; 51:523–526.

20 Kouyoumdjian J, Chalian VA, Moore BK. A comparison of the physical properties of a room temperature vulcanizing silicone modified and unmodified. J Prosthet Dent 1985; 53:388–391.

21 Bell WT, Chalian VA, Moore BK. Polydimethyl siloxane materials in maxillofacial prosthetics: evaluation and comparison of physical properties. J Prosthet Dent 1985; 54:404–410.

22 Lontz JF. State-of-the-art materials used for maxillofacial prosthetic reconstruction. Dent Clin North Am 1990; 34:307–325.

23 Gettleman L, Khan Z. Welcome address and summary. In: Gettleman L, Khan Z, editors. Transactions of the Academy of Dental Materials 1992. pp. 5, 6, 175.

24 Haug SP, Andres CJ, Munoz CA, Bernal G. Effects of environmental factors on maxillofacial elastomers. Part IV: optical properties. J Prosthet Dent 1992; 68:820–823.

25 Haug SP, Andres CJ, Moore BK. Color stability and colorant effect on maxillofacial elastomers. Part III: weathering effect on color. J Prosthet Dent 1999; 81:431–438.

26 Beatty MW, Mahanna GK, Dick K, Jia W. Color changes in dry-pigmented maxillofacial elastomer resulting from ultraviolet light exposure. J Prosthet Dent 1995; 74:493–498.

27 Kiat-amnuay S, Lemon JC, Powers JM. Effects of opacifiers on color stability of pigmented maxillofacial silicone A-2186 subjected to artificial aging. J Prosthodont 2002; 11:109–116.

28 Markt JC, Lemon JC. Extraoral maxillofacial prosthetic rehabilitation at the M. D. Anderson Cancer Center: a survey of patient attitudes and opinions. J Prosthet Dent 2001; 85:608–613.

29 Lemon JC, Martin JW, Jacob RF. Prosthetic rehabilitation. In Weber RS, Miller MJ, Goepfert H, editors. Basal and squamous cell skin cancers of the head and neck. Philadelphia: Williams and Wilkins; 1996. pp. 305–312.

30 Marunick MT, Harrison R, Beumer J. Prosthodontic rehabilitation of midfacial defects. J Prosthet Dent 1985; 54:553–560.

31 Eckert SE, Desjardins RP. The impact of endosseous implants on maxillofacial prosthetics. In: Taylor TD, editor. Clinical maxillofacial prosthetics. Chicago: Quintessence; 2000. pp. 145–153.

32 Hong WL, Chu SA, Dam JG, *et al*. Oral rehabilitation using dental implants and guided bone regeneration. Ann Acad Med Singapore 1999; 28:697–703.

33 Jensen OT, Bround C, Blacker J. Nasofacial prostheses supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992; 7:203–210.

34 Jacobsson M, Tjellstrom A, Fine L. A retrospective study of osseointegrated skin penetrating titanium fixtures used for retaining facial prostheses. Int J Oral Maxillofac Implants 1992; 7:523–528.

35 Granström G, Jacobsson M, Tjellstrom A. Titanium implants in irradiated tissue: benefits from hyperbaric oxygen. Int J Oral Maxillofac Implants 1992; 7:15–25.

36 Branemark PI, Zarb G, Albrektsson T. Tissue-integrated prostheses. In: Branemark PI, editor. Osseointegration in clinical dentistry. Chicago: Quintessence; 1985. pp. 1–50.

37 Lemon JC, Chambers MS, Wesley PJ, Reece GP. Rehabilitation of a midface defect with reconstructive surgery and facial prosthetics: a case report. Int J Oral Maxillofac Implants 1996; 11:101–105.

38 Howard G, Osguthorpe JD. Concepts in orbital reconstruction. Otolaryngol Clin North Am 1997; 30:541–562.

39 Scortecci GM. Introduction to oral implantology in restorative dentistry. In: Scortecci GM, Misch CE, Benner KU, editors. Implants and restorative dentistry. New York: Martin Dunitz, Ltd.; 2001. pp. 1–25.

40 Granstöm G, Tjellström A, Brsnemark PI, *et al*. Bone anchored-reconstruction of the irradiated head and neck cancer patient. Otolaryngol Head Neck Surg 1993; 108:334–343.

41 Wolfaardt J. Advanced technology and the future of facial prosthetics in head and neck reconstruction. Int J Oral Maxillofac Surg 2003; 32:121–123.

42 Johnson F, Cannavina G, Brook I, Watson J. Facial prosthetics: techniques used in the retention of prostheses following ablative cancer surgery or trauma and for congenital defects. Eur J Prosthodont Restor Dent 2000; 8:5–9.

43 Bergström K. Materials and artistic conceptions. In: Brånemark P-I, Tolman DE, editors. Osseointegration in craniofacial reconstruction. Chicago: Quintessence; 1998. pp. 207–212.

44 Bergström K. Anaplastological techniques for facial defects. In: Brånemark P-I, Ferraz De Oliveira M, editors. Craniofacial prostheses: anaplastology and osseointegration. Chicago: Quintessence; 1997. pp. 101–110.

45 Farmand M, Klaassen P-P. Reconstruction of facial defects using osseointegrated titanium implants. J Craniomaxillofac Surg 1996; 24:133.

46 Fehrencamp S. An implant-supported and retained auricular prosthesis: a case report. Journal of Facial and Somato Prosthetics 1997; 3:125–133.

47 Ferraz DeOliveira M. Auricular prosthesis. In: Brånemark PA, Tolman DE, editors. Osseointegration in craniofacial reconstruction. Chicago: Quintessence; 1998. pp. 213–221.

48 Bergström K. Prosthetic procedures for orbital techniques. J Facial Somato Prosthet 1996; 2:27–35.

49 Reisberg D, Habakuk SW. Orbital prosthesis. In: Brånemark P-I, Tolman DE, editors. Osseointegration in craniofacial reconstruction. Chicago: Quintessence; 1998. pp. 245–258.

50 Van Oort RP, Reintsema H, Dijk G, *et al*. Indications for extra-oral implantology. J Invest Surg 1994; 7:275–281.

51 Fyler A, Lavelle WE. Nasal prosthesis. In: Brånemark P-I, Tolman DE, editors. Osseointegration in craniofacial reconstruction. Chicago: Quintessence; 1998. pp. 141–153, 223–244.

52 Moore DJ, Glaser ZR, Tabacco MJ, *et al*. Evaluation of polymeric materials for maxillofacial prosthetics. J Prosthet Dent 1977; 38:319–326.

53 Parel SM. Diminishing dependence on adhesives for retention of facial prostheses. J Prosthet Dent 1980; 43:552–560.

54 Kiat-amnuay S, Gettleman L, Khan Z, Goldsmith LJ. Effect of adhesive retention on maxillofacial prosthetics. Part 1: skin dressings and solvent removers. J Prosthet Dent 2000; 84:335–340.

55 Kiat-amnuay S, Gettleman L, Goldsmith LJ. Effect of multi-adhesive layering on retention of extraoral maxillofacial silicone prostheses in vivo. J Prosthet Dent 2004; 92:294–298.

56 Kiat-amnuay S. Maxillofacial prosthetics materials. In: Paravina RD, Powers JM, editors. Color training in dentistry. Philadelphia: Elsevier; 2004. pp. 96–102.

57 Gettleman L, Kiat-Amnuay S, Johnston DA, *et al*. Design of multicenter phase III clinical trial for maxillofacial prosthetics. J Dent Res 2004; 83: Special Issue A, 1625.

58 Gettleman L. Chlorinated polyethylene and polyphosphazene. In: Gettleman L, Khan Z, Setcos J, editors. Proceedings of a conference on materials research in maxillofacial prosthetics. Transactions of the Academy of Dental Materials 1992; 5:158–174.

59 Gettleman L, Goist KC, Vargo JM, *et al*. Processing and clinical testing of a thermoplastic material for maxillofacial prosthetics. In: Kawahara H, editor. Oral implantology and biomaterials. Progress in biomedical engineering series, vol 7. Amsterdam: Elsevier; 1989. pp. 7–13.

60 Gettleman L, Guerra LR, Huband M, *et al*. Clinical comparison of chlorinated polyethylene with Silastic for maxillofacial prosthetics: 4 month results. Soc Biomat Trans 1987; no. 252.

61 Gettleman L, Vargo JM, Gebert PH, Rawls HR. Thermoplastic chlorinated polyethylene for maxillofacial prostheses. In: Gebelein CG, editor. Polymer science and technology series, vol 35, Advances in biomedical polymers. New York: Plenum; 1986. pp. 55–61.

62 Gettleman L, Gebert PH, Ross LM, *et al*. Extraoral maxillofacial prostheses molded from chlorinated polyethylene. J Dent Res 1985; 64:368.