Facial skeletal augmentation continues to be an important clinical area for surgeons performing cosmetic and reconstructive facial surgery. This article reviews the current state of the art approaches utilizing alloplastic materials. Surgical goals, biomaterials, operative techniques, and complication management are discussed. Any discussion of alloplastic materials ultimately relates tissue effects to long-term clinical results. It may take a full generation (20 years) to appreciate fully most if not all possible tissue effects of an alloplastic material; however, biomaterial science has developed fundamental principles that should aide the surgeon in choosing the most appropriate alloplast for skeletal augmentation for various patient groups.

Surgical goals

Clinical judgment always remains the most important arbiter in selecting the appropriate implant and surgical approach for an individual patient. Patient implant requirements can be routinely classified as either onlay or inlay with regards to the type of skeletal augmentation. Purely cosmetic facial skeletal augmentations are onlay in nature with the goals of stability and symmetry paramount. Esthetic guidelines have been developed and refined to guide correction of common facial skeletal deficiencies [1]. Additionally, recent attention has been given to the role of skeletal changes in aging. Both Binder [2] and Pessa et al [3] have shown the value of skeletal augmentation to enhance other aspects of facial rejuvenation, thereby increasing the importance of skeletal augmentation in cosmetic facial surgery.

Inlay applications for skeletal defects (of a traumatic or oncologic etiology) additionally require volume maintenance over time to preclude defect reformation. Volume maintenance over time is a key advantage of commonly used alloplastic implants. In the past the goal of stable volume was believed to be due to utilization of an inert implant material and minimal tissue response over time. This view of implants has been found to be naive with respect to tissue–implant interface biology. Improved understanding of interface biology has revealed the limitations of many implants and helped encourage the development of bioactive implants [4]. Bioactive implants are biomaterials that allow for biologic bonding of tissue to implant, which permits natural tissue regeneration as opposed to chronic foreign body or inflammatory reaction.

Bioactive interfaces theoretically reduce micromotion and implant mobility over time. Secure implant fixation allows for less opportunity of motion at the interface to induce wound inflammation. Chronic inflammation over the long term leads to formation of avascular fibrous capsules. Although such tissue reaction may by clinically quiescent, it can lead to gross implant mobility and secondary soft
tissue changes in the long term. Therefore, stable and secure implant fixation becomes a very important clinical goal that affects outcome.

**Implant materials**

There are four commonly used implant materials for facial skeletal augmentation: (1) silicone elastomer, (2) porous polyethylene, (3) expanded polytetrafluoroethylene (ePTFE), and (4) hydroxyapatite–calcium phosphate. Detailed implantology information on these materials can be found elsewhere in this issue. The tissue–implant interfaces exhibited by these materials are important to understand so that clinical effectiveness is maximized.

**Silicone**

Silicone elastomer is a solid rubber–consistency polymer of polymethyl siloxane. Due to its relative inertness as an implant it has been developed for many medical applications and specifically facial skeletal augmentation [5]. Preformed shapes for nasal, malar, and chin augmentation have been in use for many years. The tissue–implant interface is one of an avascular fibrous capsule. Capsular contraction aides in securing the implant to a fixed position over time. Initial fixation of silicone implants should be attempted. Many surgeons prefer placement in a defined supraperiosteal pocket; others have modified this by use of nonresorbable sutures or metal screws.

The most commonly associated unfavorable result with silicone implants has been underlying bone resorption. This was identified by Robinson and Shuken [6] in 1969 and has been recounted in many reports subsequently. Matarasso et al [7] have recently summarized these reports and provide findings that call for caution in advocating silicone chin implants for certain patient groups. Despite this well-known information, silicone implants remain popular and readily accepted by surgeons and patients.

**Polyethylene**

High-density porous polyethylene (MedPore, Porex Industries, Fairburn, GA) has gained considerable acceptance as an implant for facial skeletal augmentation. It is a particulate high-density polymer of ethylene that is then fused by a sintering process into a porous solid material. Pore size ranges from 100 to 300 μm. The material is somewhat flexible and readily carved. The tissue–implant interface is characterized by various amount of fibrous and fibrovascular ingrowth. Although polyethylene can support surface conduction of viable osteocytes, true integrative osteoconduction throughout an implant has not been documented by experimental results [8,9].

Fibrovascular ingrowth makes porous polyethylene an attractive implant for facial skeletal augmentation for the following reasons. First, the ingrowth stabilizes fixation of the implant. Second, the implant may be resistant to infection and therefore potentially salvaged in the face of exposure if sufficient vascularity is present [10]. Fixation of implants is most commonly achieved with metal screws.

**Expanded polytetrafluoroethylene**

Expanded polytetrafluoroethylene (Gore-Tex, WL Gore, Flagstaff, AZ) has been used extensively as a soft tissue implant and vascular prosthesis. Various formulations of fibrils are combined to create implants with pores of up to 30 μm. The tissue–implant interface is usually that of limited fibrous tissue ingrowth without significant capsule formation. Interesting recent experimental data have revealed differential healing responses to ePTFE dependent upon the anatomic site of implantation [11]. Such experiments shed light on potential uses in facial implantation and the important questions that remain unanswered. Preformed chin and malar implants are available, but the most common use is to augment the nasal dorsum in reconstructive surgery. Extensive experience in this use has been reported with favorable outcomes [12]. Gore-Tex nasal augmentation ultimately requires comparison with autogenous tissue to make the final assessment of outcomes.

**Hydroxyapatite**

Currently, many forms of calcium phosphate and hydroxyapatite biomaterials exist and have extensive use in facial skeletal augmentation. These materials should be classified as bioactive in nature. The tissue–implant interface can be categorized as showing osteoconduction and osseointegration over time. Interested readers should consult previous reviews for comprehensive details on synthetic bone substitutes [13]. This discussion only highlights those materials in general use and emphasizes new information relevant to clinical issues.

Hydroxyapatite biomaterials can be broadly categorized into ceramic and nonceramic classes. Ceramic material of a porous nature has been used as an onlay material for facial skeletal augmentation [14]. This porous hard material (Interpore, Irvine, CA) has pore
sizes of up to 300 to 500 µm, which allows for fibrous osseous conduction at the interface. The main clinical difficulties have been contouring the edges of the implant for blending purposes and initial fixation with screws, which can lead to problematic implant fractures. Other surgeons have used granules of porous hydroxyapatite for facial augmentation by limiting dissection and exposure to subperiosteal pockets for implant placement and awaiting initial soft tissue ingrowth healing to stabilize the implant [15].

Hydroxyapatite cement (BoneSource HAC, Leibinger, Dallas, TX) is a nonceramic cement formulation recently cleared for clinical use in facial skeletal augmentation [16–19]. The key characteristics of the cement are a true setting material that starts as a powder and after mixing with a liquid phase becomes a paste or putty consistency. While in the paste state the material can be shaped to the desired contour and dimensions. It then sets to a hard consistency. BoneSource has a microporous structure with pore size approximately 3 to 9 µm. Once set the material has a compressive strength in the range of 60 to 70 mPa. Like most inorganic materials, it has limited shear resistance and therefore should not be used in areas of significant torsional loading without additional supportive hardware. The tissue–implant interface is characterized by osteoconduction and osseointegration. Over time the implant is converted to bone. The conversion to bone occurs in a progressive fashion maintaining volume. It is more rapid in void defects and younger animals. When placed in an onlay position with viable periosteum, BoneSource develops a thin overlaying surface of bone and a replacement surface at the bone–implant interface. BoneSource has excellent adhesion to bone surfaces, and therefore additional fixation devices are not routinely used.

Technical considerations for implantation

Surgical technique affects both short-term and long-term outcomes in facial skeletal augmentation. General principles of surgical implantation are well established, such as avoidance of contaminated fields, use of perioperative antibiotics, and meticulous intraoperative handling of the implant materials. Careful preoperative assessment of the recipient site should determine whether adequate vascularity and soft tissue coverage are present. If not, then consideration should be given to staged procedures with onset of vascularized tissues and soft tissue augmentation prior to skeletal augmentation.

Surgical approaches to the various sites of the facial skeleton have evolved from a direct transcutaneous surgery, to concealed incision surgery, and now minimally invasive endoscopically assisted approaches (Louis Morales, personal communication, 1997). Most of the fronto-orbital and midfacial skeleton can be exposed via coronal scalp incisions and flap elevation. The midfacial and mandibular skeleton is most often exposed via intraoral approaches. The nasal region is easily accessed with endonasal incisions. Fig. 1 illustrates the authors’ preferred technique for the placement of a chin implant. The intraoral dissection allows for better visualization, which aids placement and thus avoids malposition asymmetries. Use of metal screws provides both initial and long-term fixation. Compared with transcutaneous submental approaches, attention to reattachment of the mentalis muscle is important in avoiding postsurgical lower lip incompetence.

With any approach, selection of the final tissue plane for implantation is important. For the commonly used materials (discussed previously), consensus opinions can vary with individual surgeon’s preference. Silicone polymer is most often recommended to be placed in a supraperiosteal plane so as to encourage fibrous capsule formation, which hopefully stabilizes the implant position. Bone resorption has been noted with implants placed in the subperiosteal plane, and therefore for the chin area especially supraperiosteal placement is advocated. For Gore-Tex, a supraperiosteal placement is reasonable; however, subperiosteal placement has not been reported as advantageous or contraindicated. For porous polyethylene and hydroxyapatite implants, placement in a subperiosteal plane is recommended and advantageous from a tissue–interface perspective.

Fixation of implant material affords the best opportunity to diminish or preclude micromotion and the development of chronic inflammation. Inflammation from motion can facilitate secondary bacterial seeding, particularly when the surgical approach is introral or the implant has physical proximity to dental structures. Sometimes this goal is impractical given the surgical location or exposure. Traditionally, limited dissection pockets were advocated when the implant was placed. Surgical technique has sequentially advocated suture fixation and then metal screw and plate fixation. The caveat that should be remembered is that any fixation is better than none. In the nasal area suture fixation, particularly of Gore-Tex, is easiest. Titanium microscrew systems are now the standard fixation choice with preformed implants.

BoneSource HAC does not require adjunctive fixation due to its bone adherence qualities; however, the use of cement does require a higher level of
technical attention when used for cosmetic skeletal augmentation. This requirement is due to the actual qualities of a cement material; in order to ensure symmetric skeletal augmentation it is recommended that a titanium microscrew be placed at the point of desired maximum projection and then apply the BoneSource HACement to envelop the screw with esthetic tapering of the peripheral implant. This technique is illustrated in Fig. 2 for the malar anatomic site. The advantages of BoneSource HACe-

Fig. 1. Technique for alloplastic chin augmentation. (A) General anterior view with desired positioning of the implant. (B) Lateral view with superimposed Gonzales-Ulloa projection line. Note the idealized soft tissue profile. (C) Proposed incision in the labi-mental sulcus. (D) Surgical exposure of the mandibular mentum area. Note preservation of the mental nerves and mentalis muscle attachments. (E) Fixation of implant with screw. Note marking of midline to assure central placement and symmetry. (F) Surgical closure of the wound in layers, attention to reattachment of the mentalis muscle to prevent postoperative lip incompetence.
ment are that it affords custom implant fabrication (in situ) and a bioactive interface that results in osseointegration, and thus represents the current state of the art for facial skeletal augmentation.

Unfavorable results and complications

When patients undergo surgery, the expectation is that an uneventful surgery will result in attainment of preoperative goals. The reality is that all surgical procedures have associated unfavorable results and complications. Facial skeletal augmentation is not immune from unfavorable results; however, these outcomes appear to be infrequent and make such procedures very successful. A recent review by Rubin and Yaremchuk [20] summarizes conveniently many reports on facial implant materials. Although certain trends can be appreciated, it must be recognized that most patients with unfavorable results with facial skeletal augmentation implants rarely return to the original surgeon. Therefore, literature reports are unable to provide data of sufficient quality to make definitive statements on implant performance over time. Beyond immediate common surgical complications (ie, bleeding and hematoma), the following areas of concern need to be addressed: mobility or malposition, infection, exposure, soft tissue changes, and unwanted esthetic results.

Mobility and malposition are complications that appear to be infrequent and with the use of stable fixation preventable. The most common implant to exhibit mobility has been silicone polymer. When one considers the nature of the tissue–implant interface, it
Fig. 2. Surgical technique of alloplastic midfacial augmentation with BoneSource-Hydroxyapatite (Leibirzen, Inc., Dallas, TX) cement. (A) Lateral profile of midfacial hypoplasia. Note lack of malar eminence projection. (B) Anterior view of midfacial hypoplasia. Note elongated appearance of the midface. (C) View of malar eminence where augmentation is required. (D) Surgical exposure of the malar eminence and maxilla through gingival-buccal/labial inc. Note careful identification and preservation of the infraorbital nerve. (E) Placement of titanium microscrew in the malar eminence, and use of calipers to determine the exact amount of desired projection. (F) Placement of BoneSource-Hydroxyapatite cement by spatulation of the setting paste. (G) Closure of the wound in layers. Note the screw is totally embedded in cement.
is readily appreciated as to why this occurs. Implants that exhibit tissue ingrowth are less likely to become mobile, whereas implants such as hydroxyapatite, which have bioactive tissue interfaces, are ideal. Patients with mobile implants should be evaluated for chronic low-grade infection versus inflammation related to the underlying implant mobility. If chronic infection becomes manifest, then implant removal is recommended. Immediate replacement should only be entertained in those instances of inadequate implant fixation and not infection.

Infection related to biomaterial implants is for the most part localized to the area of implantation. The anatomic location of colonized areas (nasal, oral, and dental structures) near facial implants imparts an increased risk. Traditional surgical principles tell us that clean-contaminated surgeries have an inherent infection rate of approximately 1% to no more than 1.5%; facial skeletal alloplastic implants necessarily have a somewhat greater incidence of infection requiring implant removal. Thus, reported rates of infection have ranged up to 12%, with most studies somewhere between 3% to 7%. Those studies that report infection rates of less than 1% usually have serious methodology issues and should be carefully scrutinized. As previously noted, the nature of the tissue-implant interface dictates success in managing infection with antibiotics. In particular, implants such
as MedPore may be salvaged if significant fibrovascular ingrowth has occurred. Patients with implants should have prophylaxis for procedures that can induce transient bacteremia. If infections cannot be eliminated with appropriate antibiotic therapy, then removal is necessary.

Exposure of implants presents a difficult clinical management dilemma. Dependent upon the location and nature of the implant material, exposure can be managed with several strategies. If the exposure is limited and thought to be related to wound margin issues, such as tension or inadequate blood supply, then careful reclosure can be attempted. If the exposure is limited and thought to be related to infection, then local wound care and hygiene along with antibiotics can be attempted. If, however, the exposure is great or significant implant mobility discerned, then removal should be performed. Silicone polymer and Gore-Tex are less likely to be salvaged, particularly if implant mobility is documented. Hydroxyapatite is unusually inert and intraoral exposures (in absence of mobility) can be salvaged. Transcutaneous exposures are usually the result of poor soft tissue coverage or chronic muscle action and mobility; for cosmetic augmentation this situation is unacceptable, but in reconstructive situations coverage with vascularized flap tissue can be attempted with some success.

Exposure is one part of the spectrum of soft tissue changes overlying implants. Soft tissue atrophy and other changes have been reported and will most likely be seen more often now that we are into a generation of facial implants. Management should be individualized with the goal of correcting the soft tissue change with vascularized tissue or tissue substitutes. Very little consensus exists on management of these changes and thus remains an important area of clinical research study.

Unwanted esthetic results can and do occur. These situations are like most others in cosmetic surgery. They are related to patient selection, physician esthetic judgment, and patient education. Unlike other cosmetic procedures (ie, rhinoplasty, facelift), facial skeletal augmentation can be reversed. The ability to remove an alloplastic implant affords less opportunity for an unfavorable esthetic outcome to become permanent. The nature of the tissue–implant interface should be considered when removing or modifying alloplastic implant. For example, hydroxyapatite implants that have been in place long enough to osseointegrate necessitate use of ostectomy techniques, whereas silicone implants (particularly in the chin) might require correction of underlying bone resorption. Fortunately, these cases can usually be managed with success.

Summary

Alloplastic implants are commonly used for facial skeletal augmentation with good success. Understanding the tissue–implant interface is important for the successful clinical application. Current implant technology is focusing on bioactive implants that modulate normal wound healing to promote a natural tissue–implant interface and, it is hoped, better long-term functional outcomes.

References

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