Textbook of Oral and Maxillofacial Surgery

Gustav O Kruger

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Chapter 22

Acquired defects of the hard and soft tissues of the face

Edward C Hinds

Deformities of the face have been existent since time began, and attempts at correction have been made almost since the dawn of surgery. However, progress in this field has been slow, with few outstanding successes until recent years. Early failures resulted from lack of adequate anesthetics and antibiotics. In addition, religious and moral taboos concerning meddling with human features were also involved.

Four thousand years ago the Hindus were attempting correction of facial deformities and defects by gluing tissues to the affected part. Evidence also indicates that they were utilizing pedicle flaps from the cheek or forehead to repair defects of the nose or lips. Tagliacozzi (1546-1599), who is given much credit for revival of plastic surgery during the Renaissance, wrote extensively on rhinoplasty, using pedicle flaps from the arm. However, he was severely criticized and ridiculed for his plastic operations because of the religious attitudes of the time. Paré and Fallopius are said to have also criticized Tagliacozzi for introducing his operation. Because of this severe criticism from many sources, the rhinoplasty fell into ill repute and did not become popular again until the early part of the nineteenth century.

In Europe, Von Graefe, Dieffenbach, Lisfranc, and Carpue then began the development of modern reconstructive surgery. Since Reverdin's report on transplantation of skin in 1869, a steady improvement has occurred in methods of reconstructive surgery, facilitated to a great extent by the development ofmodern anesthesia, aseptic technique, and more recently, the use of antibiotics.

According to Peer, König in 1896 was thought to have been the first to use cartilage transplants in man. Ollier studies autogenous bone transplants in animals as early as 1858 but considered such a procedure to be dangerous to humans. Macewen performed the first homologous bone graft in 1878. However, bone grafting did not receive any real impetus until World War I.

Soft Tissue Repair

Defects of the skin may be repaired by transplantation of free segments of skin or by segments with blood supply maintained by pedicle attachment. Free skin grafts may be split thickness or full thickness. Pedicle grafts or flaps usually contain considerable subcutaneous tissue along with the skin and may serve to restore contour defects as well as surface defects.

Free grafts

Free skin grafts find wide usage in lesions of trauma and neoplasia. Glanz states that one advantage of a free skin graft in management of neoplasms of the face is that the wound may be left open during the time that the permanent pathological sections are being made to determine adequacy of therapy. They can then be covered by a delayed skin graft.

Split-thickness grafts can be taken fairly easily and give good assurance of a "take". Disadvantages of split-thickness grafts are their marked tendency to contract, pigmentary changes, and lack of depth for contour problems. Grafts do not take well in infected areas, over exposed cartilage or bone, or in avascular areas. Split-thickness grafts may be used to convert primary traumatic wounds into closed wounds if there is not enough local tissue. They may also be of value in converting secondary wounds into closed wounds such as in the case of burns or trauma.

Full-thickness grafts are much superior to split-thickness grafts as far as matching face color is concerned, and they have less tendency to contract. They may be valuable in various types of lesions of the face, particularly if the tissue loss involves skin only. They have been used successfully in correction of ectropion of the eye and resurfacing of the lip. Perhaps the only disadvantage of the full-thickness graft is the decreased chance of graft survival as compared with the split-thickness graft.

Defects of the oral cavity, nasal cavity, and orbit are best restored by split-thickness grafts. When grafting extensive lesions of the oral cavity, particularly after excision of contractures, the importance of maintaining dilation by means of some type of stent must be realized, and it must be maintained for several weeks to prevent recurrence of the contracture. One of the most difficult problems in surgery is the management of the badly constricted oral cavity resulting from extensive scar tissue.

In repairing an extensive defect of oral mucosa with skin graft, it is best to use a thick, split-thickness graft and to secure it with a stent of gauze or cornish wool saturated in antibiotic solution. This should be left in place 7 to 10 days. These grafts have a marked tendency to shrink; consequently, a generous graft must be used.

The use of skin grafts for extending buccal and labial sulci was originally devised by Esser in 1917, later modified by Waldron, and more recently advocated by Obwegeser. This technique essentially involves the construction of a stent to provide the desired sulcus over which the skin graft is applied so that the raw surface of the graft is adjacent to the raw surface of the newly constructed sulcus. This is secured in place for 7 to 10 days.

Skin grafts applied to a bony surface such as the alveolar ridge will not shrink, but skin grafts applied to soft tissue will manifest marked shrinkage unless counteracted to some extent by an appropriate stent.

Local flaps

Paletta has aptly stated that the simplest repair that closely simulates the tissue being reconstructed should be the method of choice. This objective is probably best achieved by use of the advancement or rotation flap wherever possible.

Flaps may be classified as local and distant. Local flaps utilize contiguous tissue and include the following: advancement, rotation, and transposition. Distant flaps are those carried over an area of normal skin on a pedicle that is later sectioned and returned to the donor site. These may be divided into direct and indirect. The indirect flap may be migrated in steps from a distant area to the face or carried on the arm.

The local flap became popularized by a group of French surgeons shortly after Reverdin's description of the epidermic free graft and is sometimes known as the French flap. The simplest form is probably exemplified by undermining the edges of a wound to facilitate closure. The direct advancement flap is created by undermining the skin of one margin of wound defect and creating parallel incisions at the borders of the undermined area for the purpose of closing the defect.

Although the lip shave (vermilionectomy) in the past has been considered a modification of the advancement flap, in recent years surgeons have performed this procedure without a true advancement in the following manner. The area of altered vermilion tissue to be excised is outlined in an elliptical fashion, beginning anteriorly at the margin of the vermilion. Approximately 5 to 6 mm of vermilion is included in the ellipse near the midline. Posterior and anterior incisions are outlined and brought together near the commissure. Dissection is then carried down to the muscle area, and the entire mucosa and submucosal tissues are excised. The wound is closed directly without undermining the mucosa posteriorly. This allows an ideal closure, without the ecchymosis that occurs when extensive mucosal undermining is carried out. The slight decrease in fullness of the lip, if anything, is helpful in protecting the lip from the harmful rays of the sunshine. If one area of the lip is more pathological than the rest, a wedge excision of this area should be done in combination with the lip shave.

A rotation flap is created by incising the donor tissue in semicircular fashion to allow rotation into a defect. The advancement flap and the rotation flap may both be facilitated by either the cut-back or a triangular excision of skin. A transposition flap is one that is rotated at an angle, jumping an area of normal tissue to reach the defect. Another variety of local flap is the inturned flap in which the margins of a defect are incised, undermined, and turned in to form the back side of the defect if a double lining is required, such as in a nasopalatine fistula or an antral-cutaneous fistula.

Pedicle flaps, in general, have the advantage of possessing subcutaneoous tissue as well as skin, thereby providing depth and pliability to the repair. Local flaps have the additional advantages of desirable color and texture as well as simplicity and diminished time requirements. These flaps have wide application, and several variations have been used in closure of oroantral fistulas for many years. The use of a combination of local flaps in repairing an oronasal fistula caused by trauma is demonstrated.

Common modifications of the local flap are the Z-plasty and V-Y flap. The Z-plasty is a double rotation flap and may be used as a series of transposition flaps. It is the most effective method for releasing tension on a linear contracture. The rotation of the flaps allows the direction of tension to be changed, with consequent relaxation of the tension of the original axis. It is also applicable if a corner of the mouth or the ala of the nose is depressed or elevated. The V-Y flap is a type of advancement flap that acts as a lengthening procedure when the incision is made in the form of a V and converted into a Y. It acts as a shortening procedure when made in the form of a Y and converted into a V. This may be particularly useful in repairing notch defects of the lips. It may be carried out by mucosal advancement

alone or by full-thickness advancement as described by Gillies and Millard.

The commissure of the mouth may be extended by excising a triangular or arrow-head section of skin, cutting through the orbicularis oris, and undermining and advancing the mucosa to form the new lining of the commissure. Palleta described a simple method for reconstruction of the commissure after excision of lesions in this area, using the principle of advancing mucosal flaps.

Two additional methods for reconstructing the commissure of the mouth are described by Kazanjian and Roopenian. The fist involves excision of skin, extension of the line of commissure through the muscle, and advancement of adjacent vermilion lip rather than buccal mucosa. The second involves incision of skin, incision of the orbicularis oris and mucosa, and utilization of upper and lower transposition flaps of buccal mucosa for lining the defect of the vermilion.

Full-thickness losses of the lips are best repaired by local flaps and can usually be carried out by one of the following three methods or a variation of one of these:

1. The Abbé or Estlander flap.

2. Straight advancement with triangular excision of skin.

3. Transposition flap, such as the nasal labial flap.

The most common method for repair of full-thickness losses of the lip is probably the rotation flap from one lip to the other. Although rotation flaps from one lip to the other are associated with the names Abbé and Estlander, Pietro Sabattini in 1837 repaired an upper lip defect by rotating a lower lip flap through 180 degrees. Stein in 1847 utilized double adjacent flaps from the upper lip to repair a defect in the midline of the lower lip. Estlander in 1865 first repaired a defect of one lip by a pedicle flap from the other and published his procedure in Germany first in 1872. His technique was characterized by a rotation flap consisting of a single wedge of lip substance and, if necessary, a part of the cheek. The pedicle was located at the angle of the mouth, and the operation, as a rule, was completed in one stage. Abbé in 1898 utilized a rotation flap from the lower lip to the upper lip.

In excising lesions of the lower lip it should be remembered that a V-shaped wedge containing up to one third or more of the lower lip may frequently be repaired by primary suture. Recently a composite V-shaped graft has been transferred from one lip to the other, without use of a pedicle, with success. It does not, however, seem advisable to take this added risk when the disability of the pedicle is minimal. Pedicle flaps of mucosa only from one lip to the other may also be used to advantage. Schneider has described a Z closure of a V excision of the lower lip that gives a more normal-appearing lip.

The literature is somewhat confusing on the origin of the closure of lip defects by excising a triangle of skin and advancing the flaps medially. Burow and Bernard are both mentioned in association with this procedure. The methods of Burow and Bernard were both first published in 1853. Burow's method apparently involved excision of lateral triangles from the upper lip and a V excision of the primary lesion from the lower lip, followed by advancement of the lower flaps to re-create the lower lip. Bernard's procedure involved the formation of lateral cheek flaps mobilized from the mandible, allowing greater excision of the primary lesion, which could be rectangular in outline rather than V shaped.

A great variety of lateral rotation or transposition flaps have been used for closure of lip defects. Bruns, Denonvilliers, and Nelaton and Ombrédanne were among the first to describe flaps of this type. The possibilities for use of this principle are almost limitless.

Because of the pliability of the cheek tissue, a large variety of defects can be corrected by rotation, advancement, or transposition flaps. Defects in the anterior portion of the cheek lend themselves to such correction better than defects in the posterior areas. Full-thickness losses of cheek usually require pedicle flaps from a distance for repair.

Distant flaps

Distant flaps are those that are carried over an area of normal skin on a pedicle that is later sectioned and returned to the donor site. It is sometimes difficult to fit all procedures into precise categories. For example, some local flaps, because of their complexity, might best be included in this group rather than in the previous section on rotation of local tissues. Generally speaking, pedicle flaps, or distant flaps, may be divided into the forehead or scalp flaps, which are supposed to have been developed in ancient India, the open pedicle flap described by Tagliacozzi in Italy, and the tubed pedicle flap developed by Filatov in Russia and Gillies in Great Britain.

A variety of the tube graft is the pillowed or pin-cushioned graft wherein a flap is elevated and turned on itself. Both the tube and the pillowed graft avoid an open wound. The forehead flap, sometimes lined with a free graft, has found wide usage, particularly for extensive repair of the nose. It has also been used for repair of full-thickness defects of the cheek, particularly involving the wall of the antrum. Large flaps from the neck lined with free grafts have also been used for repair of pharyngeal fistulas.

Tubed pedicle flaps seem to have definite advantages over open flaps. Tubing a pedicle flap avoids an open wound, provides better circulation, and may be handled withgreater ease, both to the patient and the operator. Pedicle flaps are required for repair if extensive loss of tissue is involved or bone grafting procedures are anticipated and soft tissue covering is not adequate. Of the tube pedicles the thoracoepigastric, the acromiopectoral, and the neck pedicle are used most often.

Although most surgeons have thought that repair of radical loss of the maxilla is best handled by prosthetic appliances, some have advocated repair of these defects by means of tubed pedicle flaps. Longacre and Gilby state that a prosthesis for an extensive defect is unsatisfactory, and the efficiency of a prosthesis is inversely proportional to the size of the defect. They have reported reconstruction of extensive palatal defects, utilizing local flaps as well as tubed pedicle flaps. For perforations and defects not exceeding one half of the hard and soft palates, local mucoperiosteal flaps may be utilized. For more extensive losses they have used tubed pedicle flaps from various donor sites such as the arm, the chest, and the neck.

Edgerton and Zovickian also mention difficulties of retention of prostheses. They make use of a cervical tube inserted through an incision beneath the border of the mandible rather than through the mouth. They also use the bulk of the tube to fill out the defect of the zygomatic area where indicated.

Gillies and Millard have used tubed pedicle flaps for repair of traumatic palatal defects as well as cleft palates. In many instances a combination of local and tube flaps is necessary

for a satisfactory reconstruction.

Contour Replacement

Soft tissue

Lacerations of the cheek frequently leave depressed scars, which may be corrected by excision of the scar, undermining of the skin, and development and imbrication of fat flaps. Free dermal grafts have been used for filling out such soft tissue defects but have definite limits in regard to the amount of correction that can be made. Peer prefers a free graft containing both dermis and fat. This is effective in creating a soft, even contour in the cheek and should be inserted with the dermis placed deep in the wound and the fat superficially facing the skin. These grafts almost universally will show a certain amount of shrinkage, and consequently they must be inserted with overcorrection.

Cartilage

Contour loss of the hard structures of the face is usually repaired by substances of a similar texture. Contour defects characterized by loss or displacement of supporting structure may involve the frontal, mental, or malar prominences, the orbital floor or margins, and the external nose and ear. These defects have been corrected by a variety of substances, including viable autogenous tissue as well as a variety of inert materials. Kazanjian and Converse have filled out the prominence of the chin by rotating a fat flap from the neck below the chin, and Gillies and Millard describe the use of a temporal muscle flap for restoration of the malar prominence. These problems are more frequently managed by use of bone or cartilage or an inert material, such as tantalum, Vitallium, or rubber silicone. Good results have been reported with a wide variety of materials, but in some instances this must reflect the amazing tolerance that the tissues sometimes exhibit to any kind of foreign body. A satisfactory implant material by itself will not guarantee success. Meticulous surgical technique must be used, and a satisfactory bed for the implant is necessary as well as adequate skin and subcutaneous tissue covering.

Adequate exposure of the graft bed is essential and requires proper underming. However, unnecessary extensive undermining is to be condemned. The supraorbitalarea may be approached through incisions in the eyebrow; the malar bone may be approached by way of the temporal route, through previous scars, or through an infraorbital incision. The orbital floor is approached by way of the infraorbital route. The chin prominence may be approached either submentally or through the oral vestibule. With either cartilage or bone, the use of preconstructed molds as a pattern for shaping the implant may be of value.

Millard has reported several successful cases of chin implants, utilizing homologous and heterologous cartilage inserted through the oral labial sulcus.

Bone

Bone continues to be popular for correcting contour defects, particularly fresh autogenous bone. As in the case of cartilage, bone grafts have been of three types: autogenous, homogenous, and heterogenous. The physiology of bone growth and bone grafting is one of the most interesting phases of medical science and still a fertile field for new discovery. Excellent historical reviews have been published by Converse and Campbell and by Chase and Herndon.

Opinion overwhelmingly favors iliac bone for grafting procedures. This apparently results from the fact that the large spaces within the substance of the cancellous iliac bone allow early rapid revascularization with survival of many of the graft cells. Abbott and co-workers report new formation of trabeculae, demonstrated microscopically as early as 10 days, with iliac grafts. They state further that tibial cortical bone is low in osteogenic power because of the need for resorption and replacement of the increased amount of dense bone that does not survive. They further state that the same is true of rib grafts, although not to such a great extent, and that split-rib grafts compare more favorably with iliac grafts because of the open spaces presented for revascularization.

Mowlem during World War II began correcting facial defects with chip grafts to facilitate revascularization and survival of graft cells. He found that fixation of these grafts was obtained as early as 10 days, using pressure dressing only.

Iliac bone seems to be much more resistant in the presence of infection. Stuteville and more recently Obwegeser have reported the use of homogenous iliac block graft in the presence of infection. It seems evident that the greater the area of graft recipient bone contact, the more certain and more rapid the regeneration. Adequate fixation is essential, although this does not present such a problem in contour defects as it does in full-thickness defects of the mandible. As with all types of implants adequate soft tissue covering is desired, although ultimate healing in the presence of incomplete soft tissue closure has been reported, particularly with iliac chips.

Iliac grafts for facial defects are implanted by means of similar routes to those used with cartilage in the temporal region, eyebrow, hairline, infraorbital margin, previous scars, and submental area. Ragnell has reported bone implants of the maxillary and nasal areas inserted through an incision in the columella. Adams and associates have applied bone implants to the maxilla through an incision at the alar margin. Converse and Campbell have achieved remarkably good results, inserting iliac grafts to facial defects through the oral cavity.

Block grafts of the ilium are somewhat harder to shape than cartilage. Shaping is done with rongeurs or a Stryker saw. With block grafts a somewhat more extensive dissection is required than with cartilage, and bare bone must be exposed. For this reason Mowlem resorted to chip graft restorations, maintaining that they could be inserted with much less extensive dissection through smaller incisions of access, with easier molding and more rapid consolidation.

It may be advantageous to combine a shaped block graft with iliac chips in filling contours. This will aid both in accuracy of restoration and in early consolidation. The block graft may be placed with the cortex external or with the cortex against the graft bed. More accurate shaping usually can be done if the cortex is left toward the external surface. Usually a moderately firm pressure dressing is all that is necessary for fixation, although direct wiring may be utilized. Where large block grafts are used on a curved surface, it may be necessary to cut or fracture the cortex to allow more accurate bending and shaping of the graft.

Some rather extensive defects of the maxilla have been corrected by bone graft. Gillies and Millard have described replacement of the maxilla by graft from malar prominence to malar prominence. Campbell has reported two rather extensive reconstructions of the maxilla. One was made necessary by trauma; the other was an immediate repair at the time of removal of extensive malignant disease. Converse has reported reconstruction of the floor of the orbit

and malar bone after extensive excision for neoplastic disease.

Artificial implants

Alloplasts. The use of inert foreign body implants (alloplasts) in surgery continues to be a matter of considerable disagreement. Smith, Kiehn and Grino, and Peer all advised against the use of foreign body replacements. Kiehn and Grino maintained that with slight trauma alloplastic transplants may become infected, absorbed, or extruded and advised use of autogenous tissue transplants whenever possible. In spite of certain apparent objections, there seems to be an increasingly wide usage of such materials, particularly Vitallium and tantalum among the metals, methyl methacrylate. polyethylene, Ivalon, and Teflon among the synthetic resins, and more recently the rubber silicones.

Conley dates the search for a foreign body for implantation purposes back to 1565, when Petronius devised a gold plate for the repair of defects of the cleft palate. Since then many materials have been tried and some, such as ivory and paraffin, discarded because of poor and sometimes harmful results.

In spite of the advantages of cartilage and bone as a filling material, they nevertheless possess certain disadvantages, such as (1) resorption, (2) distortion, (3) difficulty of shaping, and (4) need for additional surgery. For this reason alloplasts continue to be investigated and utilized for purposes of contour reconstruction.

Criteria for a successful alloplastic implant will vary slightly, depending on its function, particularly with regard to texture of the implant. However, in general, a successful implant (1) should not produce a reaction in body tissues, (2) should not produce tumor, and (3) should be easily workable, whether soft or hard, resilient or rigid, according to individual needs.

Metals. Until the work of Venable and Stuck, use of metallic implants was characterized by frequent failure. Venable and Stuck showed that corrosion took place through the process of electrolysis in most of the metals then in use. Their investigations revealed three metals that were sufficiently electropositive to be used in surgery: (1) Vitallium, an alloy of cobalt, chromium, and molybdenum; (2) tantalum, a metallic element discovered by Ekeburg in Sweden in 1892; and (3) 18-8-SMO steel, stainless steel alloy containing 18% chromium, 8% nickel, and 4% molybdenum. Since then these three metals have been used extensively in bony surgery as plates, screws, wires, and trays.

Tantalum and Vitallium have both been used with success for filling in facial defects. Tantalum is strong and, because of its ductibility, can be drawn, stamped, or formed in complicated shapes. It may be machined with ordinary steel tools. It has been used in the form of plates for cranioplasty and is easily adapted to defects, although it tends to leave a dead space on the undersurface.

Perforated tantalum plates are readily adapted for correction of facial deformities. Figure shows reconstruction of the infraorbital floor and rim with a perforated tantalum plate supported by autogenous iliac bone chips. Construction of such a tantalum plate is carried out as follows.

The bony contours of both orbits are palpated and marked on the skin with indelible pencil for transferring to the plaster model. Vertical and horizontal dimensions of the

uninjured orbit are measured and recorded. The impression is made of the patient's face, using hydrocolloid material, and a cast is poured in plaster. From the actual measurements and x-ray films of the facial bones (taken at a 6-foot distance), a skull approximating the patient's dimensions is chosen. Undercuts are eliminated, and a plaster impression is made of that portion of the skull represesing the corresponding orbit. The plaster negative is used as a template to restore the orbital margin on the facial cast. The malar portion of the defect is then filled out with Plastiline to correspond to the opposite cheek. From the restored facial cast a stone die and counterdie are constructed, the die extending at least 1 inch beyond the periphery of the involved area in all directions. A tantalum plate, 1/100 inch thick, is perforated with a mechanical drill. The plate is outlined from a tin-foil pattern previously adapted to the defect. It is then swaged and adapted over the defect with a wooden mallet. Final adaption is obtained by swaging between the die and counterdie with a hand press.

Similar replacements may be made using preconstructed Vitallium implants; however, technically this may be somewhat more difficult, and adjustment at surgery is impossible.

Beder and co-workers have performed extensive studies with titanium, a metal characterized by extreme lightness, a high degree of strength, resistance to corrosion, and low conductivity. These studies indicate that titanium implants are well tolerated by animal tissues. An additional potential advantage of titanium consists of the fact that it is radiolucent and, when buried in the area of facial bones, will allow satisfactory radiographic evaluation of surrounding and underlying tissues. Tantalum and Vitallium both have the disadvantage of being radiopaque, consequently interfering with postoperative x-ray studies.

Synthetic resins. For contour restoration the synthetic resins have probably found much wider usage than metals in recent years. Ingraham and associates published an excellent review of the use of synthetic plastic materials in surgery. Of the synthetic resins only the thermoplastic products have been used in surgical procedures. A thermoplastic resin can be molded without chemical change, for example, by softening under heat and pressure and cooling after molding. Of these synthetic resins, methyl methacrylate, polyethylene, polyvinyl alcohol (Ivalon), and polytetrafluoroethylene (Teflon) have been used successfully. Ingraham, Alexander, and others caution against the use of synthetic resins containing plasticizers and other foreign irritants. They also point out that controlled experimental studies should be carried out before utilizing new plastic materials.

Freeman has reported on 20 clinical cases, using Ivalon sponge for facial reconstruction. He reported four complications, two of which resulted in removal of the sponge. In one instance the sponge survived "a localized infectious process". Freeman noted that the remaining implants, without complications, maintained in a large measure the desired size, position, and fixation but were firmer than desired. He further noted that sufficient time had not elapsed to evaluate the effect of friction, trauma, late scar contracture, and carcinogenic stimulation.

Campbell reports the use of polyethylene in a variety of defects of the facial bones over a period of 4 years with satisfactory results. It has not been necessary to remove any of the implants during this period.

In 1956 Quereau and Souder reported on the use of polytetrafluoroethylene (Teflon) in restoring the floor of the orbit and maxillary contour. They refer to the experiments by LeVeen and Barberio, corroborated by Calnan, indicating that Teflon was the least irritating of the plastics to tissue. The material is white, the surface feels waxy, and the plastic can be

whittled and shaped with a sharp knife like soft wood. It is the most chemically inert plastic ever developed. It is stable to temperatures up to 327°C and can be autoclaved. It has a relatively high tensile strength, is flexible, has a memory, and undergoes nearly complete recovery from a deforming load. Nothing will stick to Teflon with any appreciable strength, and water will not wet it.

Rubber silicones. At the present time a rubber silicone (Silastic) is enjoying a high degree of popularity and may prove to be one of the most useful materials yet developed for contour correction. It has several outstanding advantages in that it comes in several different forms and is readily contoured, it can be autoclaved, and it is apparently nonirritating. Of particular interest is an injectable form, which at present is being used experimentally for elimination of wrinkle lines as well as correction of contour deformities.

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Unquestionably the use of alloplastic materials must still be considered to be in an experimental stage. However, the eminent surgeon Sir Harold Gillies suggested that one of the plastic materials may eventually take the place of all nonautogenous grafts.

Of particular interest is the current trend to intraoral insertion of the alloplastic implants. Apparently, with improvement in sterile technique, surgical technique, and use of antibiotics, the margin of safety has increased remarkably as far as intraoral procedures are concerned.

Recently Proplast, a microporous implant material consisting of a composite of polytetrafluoroethylene (Teflon) and pyrolytic graphite, has been investigated, both as an implant material and as a stabilizing interface for metal prostheses. Its outstanding qualities are that it allows the tissue cells to grow into its substance, allowing greater stabilization and that it is biocompatible. As of this time, it has been used extensively in facial contour corrections, particularly chin implants.

Repositioning procedures

Fractures of the mandible may be corrected by open reduction as late as 6 or 8 weeks after injury. Fractures of middle facial bones usually heal in a shorter time. Even after bony union has taken place, it is possible in certain instances to perform osteotomies and reposition displaced fragments such as is done in treatment of developmental deformities.

Dingman and Natvig have described those procedures that are particularly applicable to the maxillary and mandibular dentition. Impressions may be made and the models cut and repositioned for the fabrication of cast splints where indicated. If feasible, such procedures are preferred to contour corrections or correction by extraction of teeth and construction of prostheses.

Reconstruction of the Mandible

Reconstruction of the mandible presents several problems not found in simple contour restorations, particularly in regard to adequate fixation. Mandibular continuity may be lost because of infection, trauma, or neoplastic diseases and may be restored with alloplastic materials or bone grafts.

Alloplasts

The use of alloplastic materials such as Vitallium, stainless steel, and methyl methacrylate has been largely restricted to restoration of continuity after excision of neoplastic disease, particularly with reference to immediate repair. Prostheses used for restoring the continuity of the mandible may be in the form of intramedullary bars or Kirschner wires or in the form of preformed prostheses constructed of methyl methacrylate or Vitallium.

Maintenance of the continuity of the mandible is desirable not only from a cosmetic viewpoint but also to preserve adequate swallowing, speech, and, in some instances, respiration. Losses of the posterior mandible are tolerated much better than losses from the symphysis area. Plates and intramedullary bars may serve the additional function of maintaining the fragments in position until bone grafts can be done, if immediate bone grafting is not indicated.

Full-thickness mandibular segments may be replaced by intramedullary bars or wires, usually of stainless steel. These can be adapted easily to contour. They present the problem of telescoping, which may be solved by means of threaded pins with flanges or by making L-shaped bends in the pins to prevent further penetration of the marrow cavity. These take up little space and are easily covered with soft tissue. Stainless steel or Vitallium plates, either preconstructed to the individual case or selected from standard kits, may be used. The stainless steel plates are readily adapted to contour. These are secured by means of two screws at each fragment. The screws, ideally, should engage both cortices.

Vitallium replacements of various parts of the mandible may be preconstructed to the individual case, using various-sized mandibles as patterns and the patient's x-ray films and actual measurements for selection of proper size. Such replacements have been used on many occasions inthe past, and indeed one author has reported complete replacement of the mandible with such a Vitallium prosthesis functioning without difficulty at least 2 years after surgery. Dewey and Moore have recently reported 13 successful cases wherein varying portions of the mandible were replaced with Vitallium prostheses.

The figure demonstrates an appliance that has remained in place and functioning for 10 years. Matalon has modified Hahn's adjustable Vitallium prosthesis for replacement of segments of mandible lost because of malignant disease. These are cast in ticonium rather than Vitallium, and their chief advantage is their use in more extensive resectioning involving the symphysis area.

Similar replacements may be constructed of methyl methacrylate. These should be somewhat smaller than the original mandibular segment to facilitate soft tissue closure. They should be perforated to allow better fixation and fluid drainage and to allow for muscle attachment. Usually direct fixation is all that is necessary, although fixation can be supplemented with other methods such as external pins. Fixation of these prostheses may be facilitated by use of perforated, wedge-shaped attachments at each end that are impacted into the marrow caviity of the mandible.

In all these problems greater difficulty is found in replacement of loss as a result of malignant disease than benign, and it is more difficult to replace the symphysis area than more posterior areas.

It has been my belief that the multiple stresses exerted by the mandible in function would tend to create loosening of most artificial implants, although Freeman noted new bone growth over the screw-heads in one implant that had to be removed because of exposure. I have used a Sherman plate as an immediate replacement after excision of a rather large adamantinoma of the body of the mandible. This stayed in place 15 months but had to be removed because of loosening of the screws at the anterior attachment.

Proplast may provide a solution to some of these problems. Proplast may be permanently bonded to a metallic prosthesis such as Vitallium. Three cases have been reported in which ankylosis was corrected using ticonium implants with a Proplast interface, which allowed tissue cells and bone to become attached to the prosthesis. In one case in which bilateral ankylosis was corrected and the mandible advanced, the implant has been observed to function satisfactorily for a period of 2 years after surgery. Proplast is also being investigated as a possible means of facilitating long-term fixation of blade vent implants and for alveolar ridge augmentation.

Bone

In spite of the recent successes with alloplastic substances, it is desirable to replace lost tissue with tissue of a similar nature, and this is particularly true of the mandible. Hayward and Roffinella have aptly described the peculiar problems associated with reconstruction of the mandible. They describe the mandible as a mobile functioning unit, influenced to considerable degree by the pull of the adjacent muscles and being shaped and constructed in such a manner as to complicate problems of fixation.

An excellent review of bone grafting in defects of the mandible was published by Ivy in 1951. Bardenheuer is credited with being the first to perform an autogenous bone graft of the mandible in 1891. This was in the form of a pedicle flap from the forehead, containing skin, periosteum, and bone. Sykoff in 1900 is believed to have been the first to employ a free bone transplant to the lower law. In 1908 Payr reported on the use of free transplants of the tibia and the rib. During World War I, Lindemann and Klapp and Schoeder began to use the iliac crest as the donor site. Klapp also reported on the use of the fourth metatarsal as a transplant to replace the lost ascending ramus and condyle. More recently, Dingman and Grabb have also reported on the use of the metatarsal bone as a replacement for the condyle. Efforts to use this as a growth center graft have not been rewarding.

In spite of the lack of antibiotics and proper metallic fixation of appliances, Ivy reported 76% successful, 7.7% partly successful and 13.5% failures of 103 bone grafting operations of the mandible during and immediately after World War I. Broken down into types of grafts, the figures were as follows: 31 cases of pedicle graft, 87%; 38 cases of osteoperiosteal, 71%; 7 cases of crest ilium, 71%; 17 cases of cortex of tibia, 65%; 6 cases of rib graft, 100%; 3 cases of sliding ramus graft, 2 successul; 1 case of heterologous (ox bone graft), 1 failure. Blocker and Stout, reporting on a large collection of cases from all maxillofacial centers in the USA treating casualties of World War II, reported a total of 1010 mandibular grafts as follows: 90.7% successful primarily, with an increase to 97% if regrafts are included. Broken down as to types of grafts, they were as follows: 836 from the ilium, 151 from the rib, and 23 from the tibia.

Indications for bone grafting of the mandible. Bone grafts are indicated in cases of the nonunion of fractures of the mandible in which freshening of the fractured ends would result in foreshortening of the mandible. Bone grafts may be indicated in cases of extreme

atrophy of the mandible. They may be used for filling out contour defects and for full-thickness loss of mandibular segments resulting from infection, trauma, or excision of neoplastic disease.

Watson-Jones has pointed out that variations are possible in healing time of a fracture and that delayed union does not necessarily mean nonunion. Prolonged and proper immobilization may result in union. Inthe case of the mandible, because of the absence of weight bearing, osseous union may eventually occur even without immobilization if the patient is maintained on a controlled diet.

Types, forms, and techniques of bone grafting of the mandible. All three source types of bone grafts have been used: autogenous, homogenous, and heterogenous. Autogenous bone has been used most widely and is the graft of choice. Preserved homogenous bone has been used both as a block replacement and as chips.

Considerable use has been made of homogenous bone grafts in repair of non-union for fractures in which defects are small. Here they seem to exert an osteogenetic effect of definite value. Although full-thickness replacements of mandibular defects with homogenous bone have been reported by Converse and Stuteville, itsuse in such instances appears to be decidedly inferior to autogenous bone.

Grafts may be used in the following forms: (1) block from tibia, rib, or ilium; (2) osteoperiosteal graft, usually from tibia; (3) chip grafts from ilium; and (4) pedicle grafts from mandible. The osteoperiosteal graft contains all the elements necessary for osteogenesis; it is flexible and easily adjustable to size and shape of defect but is suitable only for small defects. The technique for removal and insertion is simpler than that of any of the other methods. The use of the pedicle graft should also be limited to small defects. Of the block grafts, use of the tibia has for all practicable purposes been discontinued. Most surgeons prefer the ilium; however, the rib still finds favor with some.

Joy has reported on correction of nonunion of a mandibular fracture by means of a sliding bone graft from the inferior border of the mandible. This is an efficient method for correction of a limited mandibular defect, avoiding a second operation necessary for obtaining a bone graft from a rib or ilium. The figure demonstrates nonunion of a fracture, which was subsequently treated, utilizing this same principle.

The iliac block graft has several definite advantages. It is largely cancellous, it allows rapid transmission of tissue fluids and nutritive elements, and it provides innumerable pathways for ingrowth of growing cells. It may be readily shaped to meet contour and mortising requirements, and because of its cortical layer and bulk, it may serve to a great extent as its own fixation appliance. Iliac chips have been used extensively in facial reconstruction since Mowlem's report. He was impressed by their resistance to infection and the rapidity with which vascularization and consolidation took place. In addition to contour defects, iliac chips have found considerable use in the management of nonunions and as an added osteogenetic factor in osteotomies. They are also used to a great extent in combination with larger block grafts for the purpose of filling in minor irregularities and adding to the osteogenetic stimulus. Mowlem's original report described such a technique involving the use of a large cancellous block medially and cancellous chips laterally, the block graft being used to prevent soft tissues from bulging through the mandibular defect and to protect the chips from movement transmitted from the floor of the mouth.

Excellent discussions of the approach to the ilium and the obtaining of the graft are given by Dick and Abbott and associates. The ilium is approached by a transverse skin incision made below the crest to prevent pressure irritation. It is exposed after severing gluteal muscle attachments externally, the external oblique muscle above, and the iliacus medially. Full-thickness grafts may be used, or grafts may be limited to either the outer or the inner plate and medulla.

Chip grafts may be obtained with a gouge after creating a window in the outer cortex, thus leaving the inner cortex undisturbed. I have obtained circular plugs through the outer cortex with an Illif trephine attached to a Stryker saw for repairing nonunions. A circular plug is removed with a No 7 trephine at the fracture site. The graft is taken with a No 8 trephine. The outer diameter of the No 7 trephine matches the inner diameter of the No 8. The trephine graft is then wedged into the nonunion defect, providing a precise fit.

Complications after removal of iliac grafts are infrequent, the most common being hematoma formation, which can be prevented to a great extent by careful hemostasis at the time of surgery and the use of fibrin foam or bone wax. However, postoperative pain may be more severe at the iliac site than at the graft site.

Replacement of the angle and entire ascending ramus and replacement of large defects of the midline present unusual problems in mandibular bone grafting. Two methods have been used for restoring the angle and ascending ramus. A rib with a portion of its adjacent cartilage may be used, the cartilaginous portion of the graft being placed in the glenoid fossa. The contralateral anterior superior spine and iliac crest may be adapted well to the replacement of this portion of the mandible. However, the chances of resorption in such an extensive graft, attached at one end only, are considerable. There may be some advantage in preserving the condylar fragment when possible to facilitate function and regeneration. In such cases the coronoid process should always be removed because of the harmful muscle pull. In most cases in which a large graft must be prepared, it is advisable to construct a stent of polymethyl methacrylate that will aid in developing the graft bed and in obtaining a graft of the proper shape and size.

Description of the surgical approach to the restoration of the angle and ascending ramus is difficult to find in the literature. The object is to develop a plane between the masseter and the medial pterygoid muscle. Kazanjian and Converse utilize three nerves as landmarks in developing this plane. These are the lingual, the inferior alveolar, and the mylohyoid nerves. Because of previous difficulties encountered, Rehrmann made a detailed study of the anatomy of this area and described a method for preparing this area with minimum danger to nerves and vessels. He made use of the stylohyoid muscle and process as landmarks in reaching the glenoid fossa.

The symphysis area may be restored with a split-rib graft or a shaped iliac block. It may be restored by a skewer graft as described by Gillies and Millard consisting of blocks of iliac crest impaled on a Kirschner wire and molded to shape.

Abbott and co-workers, in discussing the merits of cortical and cancellous bone, mentioned the possibility of late fracture in cortical grafts replacing large gaps. Ghormley, in discussing Abbott's paper, stated that cortical grafts, after reaching a stage where they have good circulation, go through a stage of atrophy, during which period some of them may fracture. I have had such an experience with a rib graft. This neccessitated replacement with an iliac graft. Because of this problem in large gaps, Abbott has suggested a two-stage

procedure wherein cancellous grafts are used initially to establish vascularization, followed by cortical grafts that could then be vascularized throughout their entire length. The necessity for doing this in two stages is not convincing, particularly if one should use split ribs, enclosing cancellous chips for the mandible. The cancellous block, because of its adequate strength, greater bulk, and opportunities for self-splinting, seems more desirable.

Adequate soft tissue covering is of great importance in bone grafting, and, if necessary, grafting should be postponed until soft tissues may be brought in from a distance. Many surgeons advise postponing the graft if the oral cavity is entered during the procedure. In view of the excellent results with iliac crest, the work of Converse on intraoral bone grafts, and the present-day trend toward immediate bone grafting, it would seem that contamination from compounding into the oral cavity should not be cause for postponing the procedure. It may be well to remove teeth near the ends of mandibular fragments prior to grafting to avoid cutting through tooth roots when freshening the mandibular stumps.

In spite of the fact that many reports of grafting in the presence of infection have been published, most present-day surgeons believe that it is advisable to eliminate all infection and allow a waiting period of from 2 to 6 months. At the present time, with the use of cancellous iliac bone and antibiotics, it is thought that defects resulting from gunshot wounds and other trauma may be grafted soon after injury, provided adequate soft tissue covering is present. Such early repair facilitates the grafting procedure because of minimal scarring and distortion of fragments. The mandibular stumps should be cut back to an area of good vascularity. Graft and stump should be corticated in areas of contact. The wider the area of contact, the better the chance of "take". Avascular scar tissue should be removed from the muscle bed also.

Fixation. Probably, the most important factor in bone grafting, next to the use of the proper type of graft, is fixation. In mandibular grafts in which teeth are present, intermaxillary fixation is the method of choice. The problems of fixation arise in relation to edentulous fragments and to proximal fragments posterior to the last tooth.

Watson-Jones has pointed out that immobilization serves two significant purposes: (1) control of position of the fragments and (2) protection of growing cells preventing delayed union and nonunion. Fixation may be obtained by tantalum trays; by stainless steel, tantalumor Vitallium plates; by external pin fixation; by intramedullary pins; or by a modified gunning splint-type appliance. In addition, direct wiring with 24-gauge stainless steel is advisable and may in itself provide sufficient fixation. A mattress suture should be used. Decortication and mortising at the graft junction will enhance the opportunities for primary union. Mortising may be accomplished by holding the graft in a bone forceps or vise and cutting with a Stryker saw. Decorticating a portion of the body of the graft will aid in revascularization, although some cortex should be maintained for strength.

All these methods have been used with success, and it should be emphasized that perhaps more important than method is the exercise of sufficient care in technique. In using the Gunning splint principle, I prefer the two-piece modification shown. Walden and Bromberg have avoided pressure necrosis with this method by constructing the splint larger in all dimensions over the graft area to allow for the pressure of postoperative edema. The upper splint may be wired directly to the alveolar ridge, the piriform fossa, the zygomaticomaxillary pillar, or the infraorbital margin. The lower splint is fixed by means of circumferential wires, and intermaxillary fixation is instituted by means of rubber tractior or wires.

The criticism of bone plates is that they hold fragments apart and prevent osteogenesis by compression. This does not seem to be valid from the many reports of successful results. It would seem advisable to use screws that engage both cortical plates. Branemark and co-workers recently reported 31 cases of mandibular reconstruction utilizing autogenous bone supported by specially constructed titanium splints. My personal preference has been for direct wiring of the graft with fixation augmented by tantalum trays or direct wiring. The figure shows a graft supported by a tantallum tray, inserted when the patient was 5 years old, with subsequent normal and symmetrical development of the mandible over a 7-year period. Intermaxillary fixation, when used, should be maintained for a period of from 8 to 12 weeks. Antibiotics should be used routinely and the patient's general health and nutrition maintained at an optimum level.

Boyne advocates use of particulate grafts of marrow and cancellous bone, containing a metal implant mesh device lined with a microporous filter material for bone graft reconstruction of large defects of the mandible.

External pin fixation and intramedullary pins may serve both to retain fragments in position at the time of original loss of mandibular structure as well as for immobilization when the graft is performed. Henny has obtained excellent results in such cases with a threaded Stainmenn pin containing washers and bolts for additional stabilization.

In recent years there has been a renewed interest in the biphase external pin technique developed by Morris in 1949 and more recently elaborated on by Fleming and Morris.

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The insertion of alloplastic implants, bone grafting, and other surgical procedures on the mandible and maxilla are being increasingly performed through the oral cavity and oral mucosa rather than the extraoral route with remarkable success for reasons already cited.

The factors most commonly associated with graft failure seem to be mobility, infection, and inadequate soft tissue coverage.

Alveolar ridge

Restoration of the edentulous alveolar ridge may be the area of greatest promise for the future as far as reconstruction with autogenous bone is concerned. It is true that such efforts in the past have frequently proved unrewarding, but some authors are reporting successes.

Genest has reported several successful cases using split autogenous ribs and limiting reconstruction to the posterior portion of the alveolar ridge. Obwegeser reports good results utilizing an extensive incision over the alveolar crest, with incision of the periosteum and detachment of the muscles to allow extensive relaxation and advancements of the mucosal flaps. He has used both iliac crest and rib with success. The technique currently preferred has been described by Baker and Connole in a recent issue of the *The Journal of Oral Surgery.*

Immediate Repair of Compound Defects Resulting From Cancer Surgery

The trend toward immediate repair of extensive wounds created by removal of malignant tissue, noted on the occasion of the initial publication of this text, not only is

surviving but is becoming even more popular, as evidenced by recent articles. These procedures involve methods previously discussed, including use of free bone grafts, skin grafts, utilization of adjacent pedicle flaps in skin, mucosa, or muscle, and stabilization of mandibular fragments with metallic pins. Such reconstruction done at the time of resection allows optimum exposure as well as prevents contraction of tissues and degeneration of morale. Whether such a philosophy may compromise adequate surgery or hide recurrent disease remains somewhat controversial. Stark has recently reviewed current philosophy with regard to this problem.