Eur J Plast Surg (1986) 9:94–99

European Journal of Plastic Surgery

The Use of Methyl Methacrylate Cranioplasty in Forehead Reconstruction

L.C. Argenta and M.H. Newman

Section of Plastic and Reconstructive Surgery (Head: Prof. L.C. Argenta), The University of Michigan Medical Center, Ann Arbor, Michigan, USA

Summary. The use of methyl methacrylate for forehead reconstruction in congenital anomalies, tumor infection, trauma and cosmetic defects is presented. Seventy-one cases are analyzed with long term follow-up. The complication rate is low and the operating time is short. This is recommended as a rapid and safe method of forehead reconstruction. It should be avoided in the growing child and if there is any suggestion of direct connection with sinuses.

Key words: Methyl methacrylate – Cranioplasty – Forehead defects – Reconstruction.

Abnormalities and irregularities of the forehead are the result of congenital abnormalities, tumor, infection, and trauma. Because of the functional as well as cosmetic requirements of reconstruction, they are particularly difficult problems for the reconstructive surgeon.

In this paper we present our technique using methyl methacrylate cement for correction of forehead abnormalities. Deformities secondary to multiple etiologies have been addressed. The technique offers significant advantages including ease of reconstruction, minimal morbidity, long term stability and safety.

Procedure

Access to the cranial forehead is best obtained through a transcoronal modified Meisterschmidt incision. This incision is confined to the hair bearing scalp. The distance from the anterior hairline is modified in each case depending upon recession of the hair temporally or previous scars. The incision is extended to periosteum and Michel clips are placed to minimize blood loss. Dissection is then carried anteriorly to the supraorbital rims in the subperiosteal plane. While this dissection is slightly more difficult than leaving the subgaleal in place, it affords the surgeon the ability to develop pericranial flaps if necessary and permits visualization of all of the cranium in the area of reconstruction. The orbital rim is exposed and the supraorbital vessels reflected from their foramena. The temporalis muscle is freed from the skull if lateral extension of the cranioplasty is required.

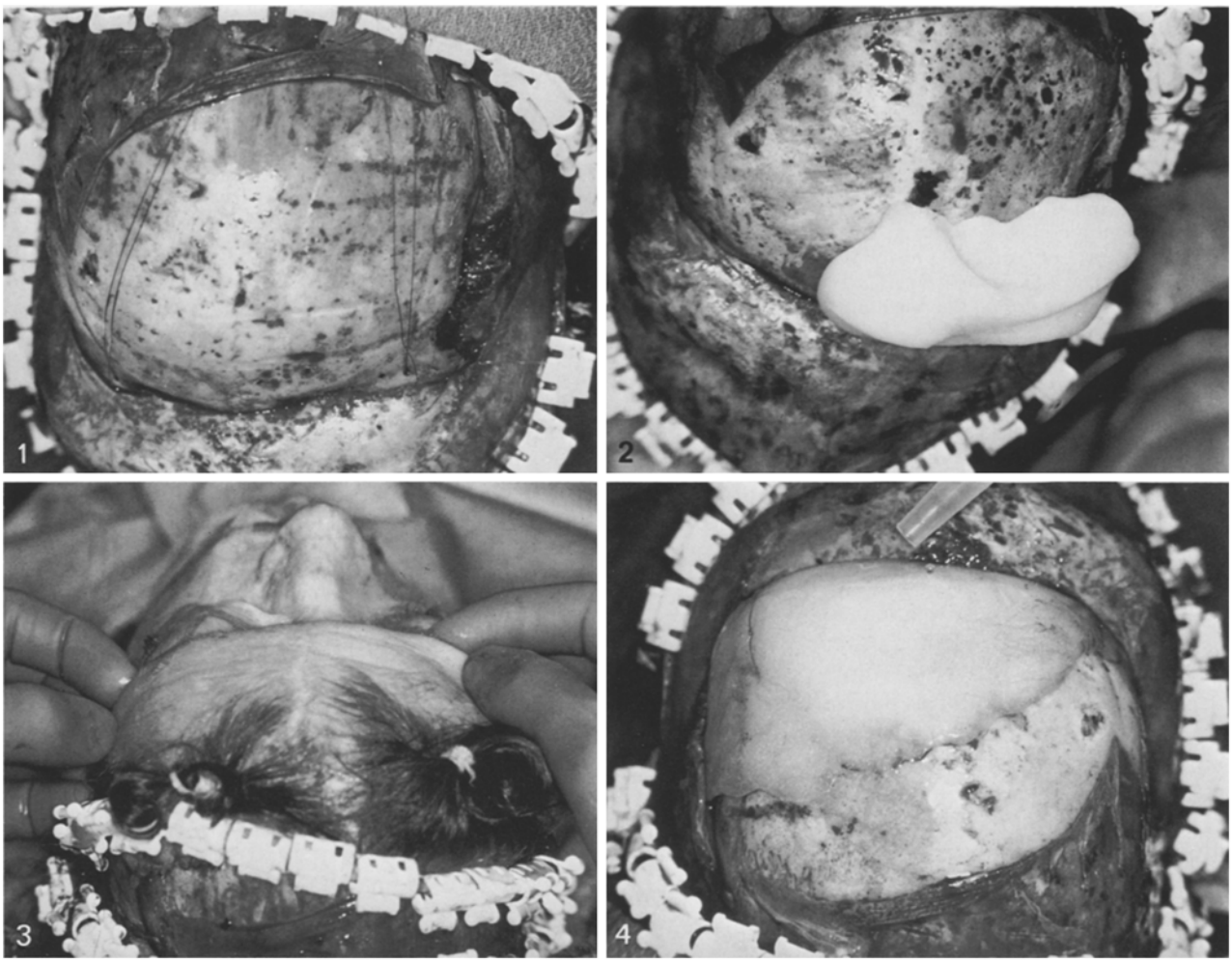
In contour defects such as congenital abnormalities or with post trauma defects with an intact cranium, this procedure can be performed entirely by the plastic surgeon. If defects are present in the skull then the scalp must be separated from the dura, consultation with neurosurgeons should be obtained preoperatively and their assistance sought for the procedure. Violation of the dura requiring repair does not contraindicate methyl methacrylate cranioplasty provided that adequate closure can be achieved.

The frontal sinus, ethmoid sinuses and nose must be isolated from any contact with the alloplastic material. If the sinuses are entered or exposed during exposure, a pericranial flap is developed from the forehead and is used to ablate or isolate the sinus with appropriate bone grafting if necessary. In these cases methyl methacrylate cranioplasty is deferred for at least three months to insure that bacterial infection does not occur. Alternatively autologous bone grafts are used.

Cranial bone is exposed over the entire area to be reconstructed. In congenital abnormalities where a smooth cranium is to be onlayed, a cutting burr is used to make several grooves in the outer table of the skull to assist in adherence of the cranioplasty. Two to three drill holes are made in the supraorbital rim into which a loop of 3-0 wire is placed for later securing of the methyl methacrylate (Fig. 1). If the cranioplasty is to be extended into the temporal areas and the temporalis has been reflected, it is helpful to place at least one wire through the lateral orbital rim to reattach the temporalis muscle in its original position and avoid later retraction of the temporalis and a resulting depression.

Methyl methacrylate cement is needed for reconstruction. This material is much more versatile and dependable than commercial Cranioplast® in our experience. Methyl methacrylate monomers are mixed in an appropriate receptacle. Special mixing bowls are available to minimize inhalation of potentially toxic fumes. After approximately five minutes, the methyl methacrylate develops a doughy consistancy.

Surgical gloves are moistened with saline and the material manipulated until it does not adhere to the gloves. It is then applied directly to the frontal area and molded to the desired contour (Fig. 2). It is helpful to replace the forehead flap while this is being done to develop an appropriate contour (Fig. 2).



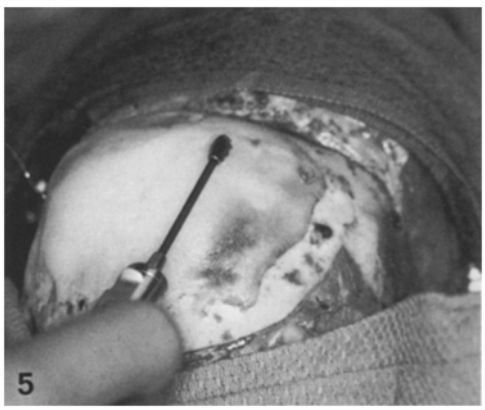


Fig. 1. To ensure fixation multiple grooves are cut in the outer table and fixation wires are placed in the supraorbital rims

Fig. 2. The firming methyl methacrylate is applied directly to the skull

Fig. 3. The scalping flap is replaced and precise contouring is done to assure symmetry with the opposite side

Fig. 4. Saline is poured over the implant when the reaction becomes exothermic and the fixation wires are secured

Fig. 5. Irregularities in edges are feathered with a rotating burr

The previously placed wires are incorporated directly into the methyl methacrylate for fixation.

A small amount of methyl methacrylate is held by the scrub nurse and when it begins to become warm, the surgeon is notified. At this point the forehead flap is again turned down and copious amounts of saline are irrigated on the wound (Fig. 4). We have not found it necessary to remove the methyl methacrylate cranioplasty during curing even in cases where it directly contacts the dura. Within two to three minutes the reaction is completed and the material cools rapidly.

All wires are secured and turned so that they do not perforate the flap. With a sharp rotating burr, the margins of the cranioplasty can then be contoured and feathered to the skull (Fig. 5). It is important that irregularities be removed since the forehead tissue will in time thin over these areas and make them obvious. When necessary, the temporalis muscle is secured to the lateral orbital rim through the previously placed wires. The forehead flap is then replaced and the scalp closed in one layer with running 2–0 nylon. Postoperative widening and depression of the scar can be minimized by incorporating the

galea in this suture. The wounds are not drained and a loose dressing is applied. Perioperative cephalosporin antibiotics are routinely given, but these are not continued for more than one dose postoperatively. Sutures are removed at two weeks.

If irregularities or discrepancies are noted postoperatively, these can be corrected with a second procedure without removing the original cranioplasty. Excesses can be removed with a rotating air driven burr. If insufficient material has been placed at the initial operation, the primary cranioplasty is exposed through the previous incision, and several grooves are made with a burr in the original prosthesis to facilitate adhesion of a second application of methyl methacrylate. The additional cranioplasty is overlayed on the original prosthesis.

Results

In this series 71 patients have undergone reconstruction of the frontal cranium within in situ cured methyl methacrylate. Defects secondary to trauma (Fig. 6), tumor ablation (Fig. 7), infection (Fig. 8), and congenital abnormalities (Fig. 9), have been successfully treated as well as cosmetic deformities (Fig. 10). In each case an acceptable aesthetic contour has been achieved.

All patients in this series have been followed for at least one year. Twelve have been followed for over eight years; 27 for over five years. Despite being "foreign material" the implants have been extremely well tolerated.

Operating time varied considerably with individual cases. When neurosurgical intervention was necessary because of exposed dura or large cranial defects, the length of procedure was significantly lengthened. When an onlay with an intact skull was performed, operating time averaged 2.5 h. Hospitalization time averaged two days.

Three patients required removal of the cranioplasty secondary to infection. In one post-traumatic case the frontal sinus was exposed during the procedure and probably incompletely ablated. Infection occurred in the immediate postoperative period. One patient developed an infection two months postoperatively for unknown reasons. The cranioplasty was removed and successfully replaced six months later. One patient with recurrent brain tumor exposed her cranioplasty by chronically excoriating the scalp. Her cranioplasty was removed and she expired before reconstruction could be attempted.

Four early patients required a secondary procedure for contour irregularities. Two of these occurred at the junction of the temporalis muscle and the cranioplasty where the muscle retracted. Since modifying our procedure by wiring the temporalis to the cranioplasty, this complication has been avoided. Two cases were corrected by simple burring without removal of the original cranioplasty. Two were corrected by onlay of new methyl methacrylate over the previous implant.

Discussion

Trauma accounts for the vast majority of defects requiring cranial reconstruction. Skull fractures resulting from high speed motor vehicle accidents and penetrating wounds frequently result in irregularities and deficiencies of the skull. Initial operative care of these patients is directed at decompression of the brain and restoration of the overlying integument. Often restoration of the cranial vault is purposely avoided to provide an external decompression after craniotomy. Infection from sinus contamination or loss of replaced bone flaps after craniotomy may also result in irregularities and loss of significant portions of the cranium [1, 2]. Significant defects of the skull may be a necessary situation for complete extirpation of locally invasive tumors such as osteomas or meningiomas. Although cranial defects of congenital origin are unusual, irregularities and malformations of the skull secondary to craniosynostosis are quite common. Adults with craniosynostosis who do not have significantly increased intracranial pressure and whose deformity is isolated to the skull are candidates for cosmetic onlay cranioplasty to correct these abnormalities. Irregularities and incomplete corrections of congenital abnormalities after craniofacial surgery may also be corrected secondarily [3].

Correction of disfigurement and mechanical protection of the brain from trauma are the major indications for cranioplasty. Individuals with an unprotected brain may be restricted from athletic competition, employment, and in many cases, meaningful social interaction. Noticeable cranial abnormalities of the forehead unfortunately carry social stigma as signs of mental aberration or retardation.

The sine qua non for all reconstructions of the cranium is an adequate overlying full thickness integument. A split thickness skin graft or compromised skin must be replaced prior to cranial reconstruction with adequate full thickness tissue. This may be achieved either by rotation flaps or by tissue expansion of adjacent normal tissue [4].

Autogenous bone has been the classic material for reconstructive cranioplasties. Since it becomes a viable part of the patient it is ideally suited for pediatric reconstruction as it grows with the child and it is resistant to infection [5, 6, 7]. Split cranial grafts have recently become popular, especially in major craniofacial reconstructive procedures [8].

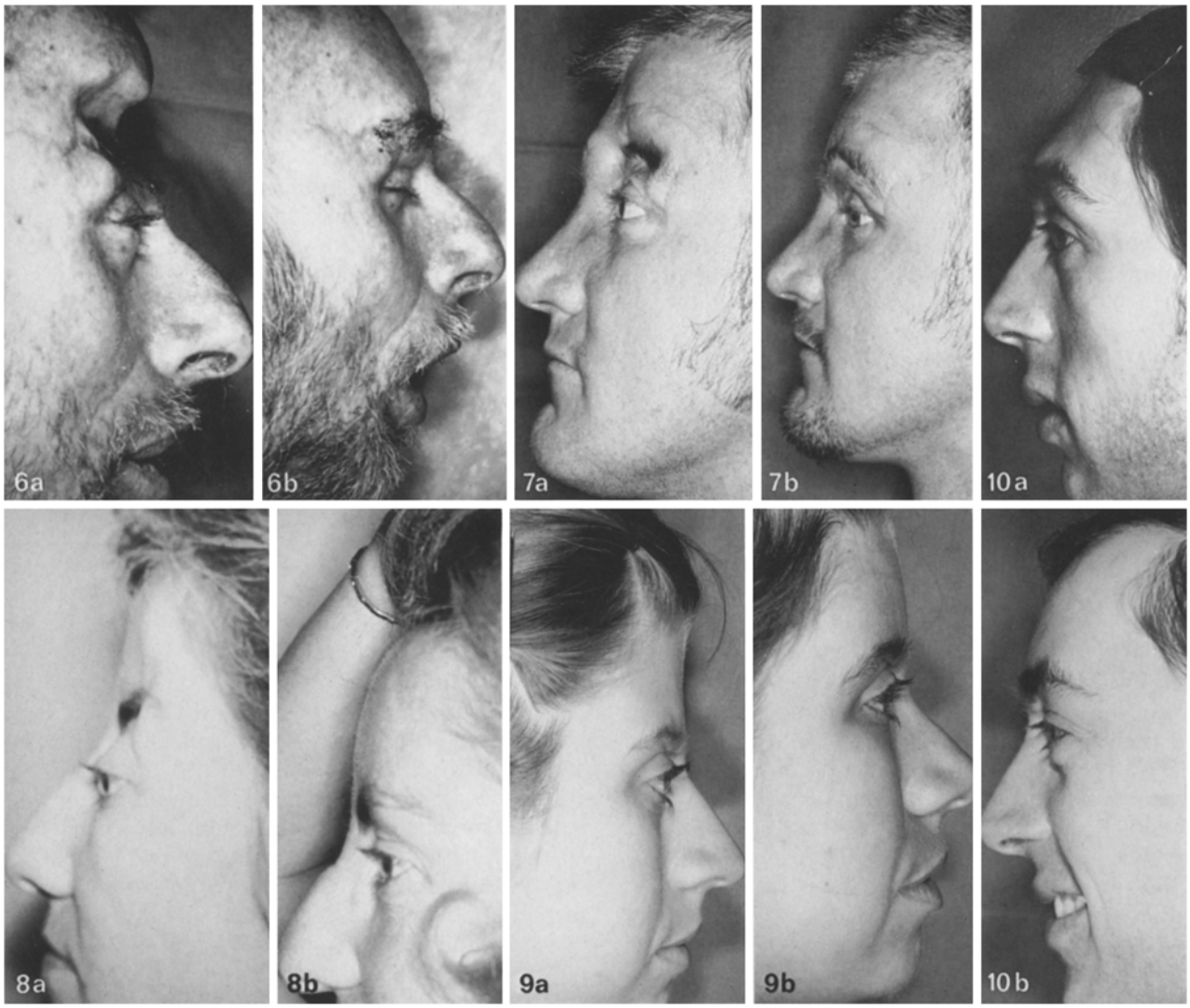


Fig. 6a, b. This 48-year-old biochemist sustained severe trauma to the frontal bone and brain in an automobile accident (**a**) **b** Three months after reconstruction of the forehead with methyl methacrylate cranioplasty

Fig. 7a, b. This 35-year-old man had undergone frontal craniotomy for a meningioma which had involved the frontal bone (**a**). The specimen was completely resected with resultant defect. **b** The forehead and supraorbital area were reconstructed with methyl methacrylate

Fig. 8a, b. This woman had undergone ablation of the frontal sinus and developed an osteomyelitis of the left frontal bone and left supraorbital rim (**a**). **b** A year later the forehead and supraorbital rim were reconstructed with methyl methacrylate cranioplasty

Fig. 9a, b. This 26-year-old woman suffered a cosmetic deformity from oxycephaly (**a**). There were no signs of increased intracranial pressure. **b** The forehead was reconstructed by onlaying methyl methacrylate over her existing cranial vault

Fig. 10a, b. A 30-year-old male complained of cosmetic deformity of the forehead (**a**). X-rays demonstrated a very large frontal sinus with no other abnormalities. **b** The deformity was corrected with methyl methacrylate over the existing skull and frontal sinus. Malar implants were simultaneously placed through buccal incisions

While large segments of bone may be obtained by splitting the inner and outer tables of the skull after craniotomy, much smaller pieces are safely available if craniotomy is not performed. Despite its advantages, the use of autologous bone has several major disadvantages: 1) absorption and some loss of contour occurs with almost all bone grafts, even when a single large piece of bone is used; 2) it is difficult to obtain an optimal cosmetic result in the forehead where irregularities of multiple

grafts become evident in an attempt to reconstruct normal supraorbital rims; 3) correction of large defects may be hindered by a lack of sufficient available donor sites, and 4) except for the use of skull grafts there is a second surgical donor site with all the inherent complications.

There is little doubt that major craniofacial deformities secondary to craniosynostosis are best corrected early in childhood by craniofacial repositioning procedures. Although some craniofacial surgeons feel that all patients with craniosynostosis have some degree of increased intracranial pressure, this concept is not uniformly accepted. Occasionally adults with oxycephaly, trigonencephaly or plagiocephaly present without evidence of increased intracranial pressure. Rather than exposing such patients to the multiple complications inherent in major craniofacial reconstructive procedures, the simple onlay cranioplasty achieves many of the same results with a minimal operative procedure and reduced risk. Similarly, a large number of patients who have undergone craniofacial repositioning procedures have irregularities of the forehead which can be easily addressed by onlay procedures rather than a major intracranial reoperation.

Tantalum, vitalium, silicone and polyethelene have all been used with reasonable success for cranial reconstruction. Unfortunately, these prostheses must be fabricated prior to the procedure and frequently do not fit well, thus potentiating exposure. Autopolymarizing methyl methacrylate in our experience has been the most satisfactory synthetic. Methyl methacrylate is extremely well tolerated by soft tissue, bone and dura [9]. Its specific gravity of 1.8 is almost identical to bone. The material does not rapidly transmit either heat or cold. It is radiolucent so that diagnostic x-rays can be taken, and since it does not conduct electricity, it does not interfere with electroencephalography. The material is available in premeasured sterilized packets of monomer in unlimited quantities [10]. No long term complications attributable to toxicity have been described.

When compared to autografts, several major advantages are noted: 1) a secondary reconstructive procedure to secure appropriate grafting material is avoided, 2) residual defects secondary to resorption of autograft do not occur, 3) cranial radiographs taken in one large series of patients failed to reveal any evidence of sclerosis or resorption of bone adjacent to the methyl methacrylate cranioplasty [11], 4) the availability of unlimited quantities of methyl methacrylate allows uniform coverage of any size of defect. 5) the great plasticity of methyl methacrylate allows the reproduction of any desired contour, thus greatly facilitating symmetrical reconstruction of the cranium in the nasal and supraorbital areas.

It has been our practice to allow the cranioplasty to cure in situ. In full thickness defects some surgeons have placed oxycel or surgicel over the dura attempting to protect the brain during the period of exothermia [11]. Others have recommended a wire mesh foundation [12]. In our experience, neither of these are necessary. Removal of the implant during the brief period of exothermia results in considerable difficulty replacing the prosthesis to achieve maximum stabilization. The use of pre-formed implants and implants which have been allowed to cure on the side table we feel has been the major source of instability and irregularity of these implants in the past. Copious irrigation with saline during the period of exothermia protects the underlying and adjacent tissues. Although some tissue culture studies have demonstrated toxicity of the liquid monomer, the lack of inflammatory response or any toxic complication in this series attests to the contrary.

The critical issue in the use of all alloplastic material is patient tolerance. Methyl methacrylate, when used within specific guidelines, has proven to be an extremely versatile, well tolerated material. Almost a million joint substitutions employing methyl methacrylate bone cement have been performed, with few reported cases of methyl methacrylate intolerance. When needed in cranial reconstruction, even when in contact with dura, intolerance is unusual [13, 14]. Two direct contraindications to the use of methyl methacrylate cranioplasty must be stressed. Since the material forms a rigid structure, methyl methacrylate should not be used in skull reconstruction of the growing child. Subsequent cranial bone growth in the young child may cause distortion and possible restriction of normal growth.

Methyl methacrylate should not be used in cases where the risk of contamination from the nose or sinuses is high. This procedure should not be performed simultaneously with major exenterative surgery [15]. It should be reserved as a secondary reconstructive procedure once sinuses have been isolated and the integrity of the skin coverage assured.

References

1. Longacre JJ, DeStefano GA (1957) Further observations of the behavior of autogenous split-rib grafts in reconstruction of extensive deficits of the cranium and face. Plast Reconstr Surg 20:281

2. Kazanjian VH, Holmes EM (1944) Reconstruction after radical operations for osteomyelitis of the frontal sinus. Surg Gynecol Obstet 79:397
3. Ousterhout D, Balar S, Zlotolow L (1980) Methyl methacrylate onlay implants in the treatment of forehead deformities secondary to craniostenosis. J Maxillofac Surg 8:228
4. Argenta LC (1984) Controlled tissue expansion in reconstructive surgery. Br J Plast Surg 37:520–529
5. Marchac D (1978) Radical forehead remodeling for craniostenosis. Plast Reconstr Surg 61:823
6. Ortiz-Monasterio F, DelCampo A, Canello A (1978) Advancement of the orbits and mid-face in one piece, combined with frontal repositioning for the correction of Crouzons deformity. Plast Reconstr Surg 61:507
7. Cabanela ME, Coventry MB, MacCarty CS, Miller EW (1972) The fate of patients with methyl methacrylate cranioplasty. J Bone Joint Surg 54:278
8. Hammon WM, Kenpe LG (1971) Methyl methacrylate cranioplasty. Acta Neurochir 25:69
9. Olson NR, Newman MH (1969) Acrylic frontal cranioplasty. Arch Otolaryngol 89:116
10. Stinson NE (1964) The tissue reaction induced in rats and guinea pigs by polymethyl methacrylate and stainless steel. Br J Exp Pathol 45:21
11. Jackson IT (1986) Personal communication
12. Session RB, Wolfe SK (1974) Wire mesh foundation for methyl methacrylate cranioplasty. Hargroove 84:1020
13. Harris P, Jackson IT, McGregor JC (1981) Reconstructive surgery of the head. In: Krayenbühl H (ed) Advances and technical standards in neurosurgery. Springer, Wien, pp 213–275
14. Schultz RC (1979) Restoration of frontal contour with methyl methacrylate. Ann Plast Surg 13:295
15. Futrell J, Edgerton M (1979) The use of methyl methacrylate in reconstructive craniofacial surgery. In: Converse J, McCarthy J, Wood-Smith D (eds) Symposium on diagnosis and treatment of craniofacial anomalies. Mosby, St. Louis, p 194