THE USE OF REFRIGERATED AUTOGENOUS BONE FLAPS FOR CRANIOPLASTY

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This report concerns experience with the use of frozen autogenous bone flaps for delayed cranioplasty. The use of frozen autogenous bone fragments for the repair of cranial defects has previously been reported by Elliott and Scott.

We report 6 cases in which it was necessary on 7 occasions to remove the bone flap because of cerebral swelling. In all 7 instances, the osteoplastic technique had been used to enter the skull. The pericranium was stripped away from the flap and left attached to the integument. No special effort was made to reconstruct continuity of the pericranium. The scalp was closed in routine fashion in layers. Upon removal, the flap was wrapped steriley in dry gauze and a towel, labelled, and stored in a deep freeze unit maintained at minus 4.0°C. After varying intervals the flaps were reinserted as delayed autogenous free grafts. Each case has been followed clinically and with serial x-rays of the skull.

Case 1. P. B. (D.H. B-638) was operated upon in March 1943 and in two stages. On the first occasion a large parasagittal meningioma was exposed through a mid-parietal flap which was removed and refrigerated. Excessive vascularity leading to free hemorrhage from the tumor influenced the decision to stage the procedure. Ten days later the tumor was removed and the flap replaced.

![Fig. 1. Case 1. (A) X-ray appearance of a frozen autogenous bone flap 1 year after replacement. (B) Approximately 8 years after replacement.](image-url)
The postoperative course was entirely uneventful. One year later there was x-ray evidence of bony union along the medial edge of the flap (Fig. 1A). However, at this time mottling indicated some central absorption. Eight years postoperatively the patient was essentially asymptomatic. The bone flap appeared firmly united on palpation. X-rays revealed evidence of firm union along the anterior and posterior edges. The previously mottled areas had increased in density and practically disappeared (Fig. 1B).

Case 2. M. L. (D.H. C-11962) had a right frontal craniotomy for glioblastoma. To facilitate a subsequent biopsy in the course of attempted chemotherapy of the tumor, the flap was removed and refrigerated. Two weeks later it was replaced.

The postoperative course was uneventful. Four months later the patient was readmitted. X-rays of the skull revealed slight absorption about the suture wires but otherwise no definite changes. There was little x-ray evidence of union. Progression of tumor growth necessitated sacrifice of the flap for decompression 4½ months after insertion. When operatively exposed the flap was found to be firmly united requiring removal with the Gigli saw. The flap was observed to be extremely vascular with abundant evidence of vascular ingrowth. Save for some thinning of the diploe the appearance was not remarkable.

![Roentgenogram of a frozen autogenous bone flap 1 week after replacement.](image1)
![Appearance 31½ months after cranioplasty.](image2)

Case 3. J. W. (D.H. C-61509) was subjected to a right temporal-occipital craniotomy for parasagittal meningioma. Because of cerebral swelling the bone flap was removed and refrigerated. One week later it was replaced and a small piece of tantalum was added to completely cover the bony defect (Fig. 2A).

Postoperatively small amounts of serosanguineous fluid were aspirated from beneath the scalp flap, but otherwise the course was smooth. He was readmitted 22½ months later for progressive mental confusion of 3 months’ duration. X-rays of the skull revealed firm union with little or no absorption. At this time there was evidence of tumor on the opposite side and additional meningioma was removed through a left craniotomy. At operation the flap in place on the right was found to be firmly united. It was necessary again to refrigerate the bone flap. Roentgenograms
31½ months after replacement showed continuing union of the right flap with little evidence of absorption (Fig. 2B). At this time the left flap refrigerated for 9 months was replaced. Biopsy of the right flap and the adjacent intact skull was obtained at this time.

Case 4. B. P. (D.H. C-81547) had a left occipitoparietal craniotomy with removal of a large subdural hematoma. The postoperative course was troubled. He remained drowsy and became progressively unresponsive and 24 hours after operation the wound was reopened and a postoperative extradural hematoma was removed with immediate improvement. Twenty-four hours later he was again unresponsive and fluid was aspirated from beneath the scalp flap. This was repeated on several occasions with but little improvement. Seven days after the original craniotomy the bone flap was removed and refrigerated. Recovery was now uneventful and rapid.

Six months later the bone flap was replaced. Wound healing was prompt. The patient was without complaint 6½ months later. X-rays now revealed slight absorption along an edge of the flap and no evidence of union.


An autogenous bone flap cranioplasty was carried out 11 months later. The postoperative course was smooth. Roentgenograms 5½ months later showed union along the edges with slight central absorption; 17 months later union was firm about the edges but there was slight absorption still apparent.

Case 6. S. J. (D.H. C-80990) had a right parieto-occipital craniotomy with ligation of large feeder vessels to an arteriovenous angioma. Cerebral edema necessitated storage of the flap in the deep freeze. After 1 week the flap was replaced. The postoperative course was uneventful.

At 15 months there was still no evidence of union roentgenographically. However, there was little evidence of absorption and the flap appeared firmly fixed and the scalp was well healed.

**DISCUSSION**

There have been no failures when refrigerated bone was used for cranioplasty. In this series the refrigeration period varied from 10 days to 11 months. Prompt clinical wound healing without excessive fluid collection or foreign-body reaction was the rule. Serial x-ray studies reveal an initial mild absorption, particularly at the edges of the flap, during the first few months which may gradually increase through the period of a year. After this time the x-ray density increases towards uniformity. Clinically union has always been firm from the time of immediate wound healing. Verification of the gross occurrence of bony union was found 4½ months after cranioplasty in 1 case. Further evidence for bony union appears in the microscopic sections of biopsy material taken 31 months after cranioplasty. The temporal arrangement of healing resembles closely that reported by others with free bone flaps immediately replaced without physical treatment.1,7

In 4 additional cases, after removal from the freezer, the flap was boiled in the autoclave for 10 minutes prior to reinsertion. In 3 of the 4 instances it has been necessary to remove the flap. In 2 cases the flap was removed after
5 weeks and 8 months respectively because of infection following scalp aspiration present at the time of original removal. In the third case failure was engendered by progressive absorption occurring in a 9-year-old boy (Fig. 3). This flap was removed after 5 months.

![Figure 3](image-url)

*Fig. 3. Demonstrating marked absorption observed in a frozen autogenous bone flap boiled for 10 minutes prior to replacement. (A) Immediate postoperative film. (B) Appearance at 5 months.*

In the fourth case there has been persistent drainage of serosanguineous material from a small sinus in the scalp, and the x-ray demonstrates a degree of absorption far exceeding that shown by flaps that have not been boiled.

This experience with boiled bone flap replacement parallels the experience of others. Thus, Naftziger, recording a portion of his early experience in 1935 noted absorption in boiled free bone plates. Ray and Parsons found it necessary to remove 4 of 11 flaps subjected to boiling for reasons of excessive absorption and apparent infection. They suggested that boiled flaps were more satisfactory if replaced immediately, as in techniques for treatment of bony tumors of the skull, than when replacement was delayed. We suggest that combined refrigeration storage and subsequent boiling may place the flap in double jeopardy and should probably be avoided.

We are not prepared to enter the controversy as to whether the refrigerated bone remains viable or simply serves as a trellis for the ingrowth of new bone from the adjacent structures. The consensus of various workers is that the latter idea obtains for long bone grafts. Our few microscopic studies provide no adequate answer. In a single biopsy specimen obtained 31½ months after replacement (Fig. 4) the marrow of the graft is fibrotic, but revascularization and cellular activity is evident in the Haversian system. This suggests the concept of healing by “creeping substitution.”

Regardless of the question of viability the refrigerated autogenous bone flap grafts appear most satisfactory for covering cranial defects. The replacement of such flaps is a safe, simple procedure yielding the best cosmetic result and we believe that the method when feasible is superior to other methods of cranioplasty involving the use of inert metals or plastics.
Fig. 4. Section through the line of union of an autogenous bone flap in place 31½ months. Note the fibrotic marrow, but evidence of revascularization in the flap which is to the right.

SUMMARY

Replacement of refrigerated autogenous bone flaps removed 10 days to 11 months previously has been carried out 7 times in 6 cases. Results have remained satisfactory for periods of 6 weeks to 9 years in all instances.

Three of 4 refrigerated autogenous flaps boiled 10 minutes prior to replacement have been subsequently removed because of marked absorption or infection.

When feasible it is believed that refrigeration of the bone flap upon its removal and its subsequent replacement is superior to other methods of cranioplasty made necessary if the flap is sacrificed completely.

REFERENCES