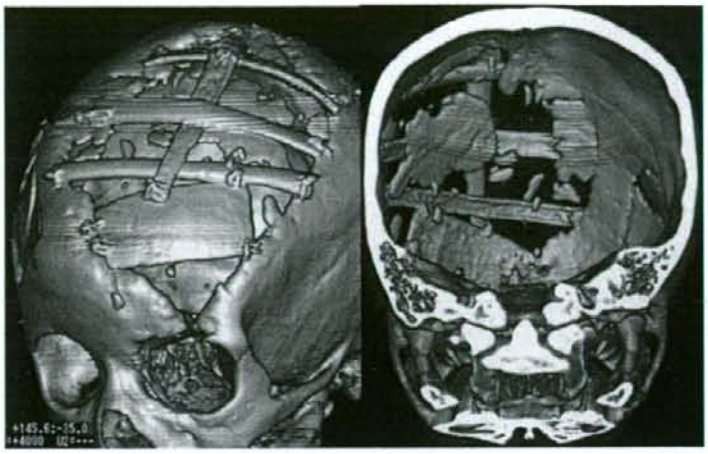

Fig. 4 Patient 2—catcher's mask cranioplasty. A calvarial graft was placed to shape the forehead. The rib grafts were placed across each other. The 3-D CT scan was taken 6 days after the surgery. The islands of osteoanagenesis, observed at surgery, were used to shape the cranium

be covered by areas of osteoagenesis. At present, that is 7 months after the cranioplasty, this patient is leading a normal school life.

Discussion

We report pediatric patients who underwent successful catcher's mask cranioplasty and present the long-term follow-up results. In every case, the patient suffered a severe, extensive open head trauma, and wound contamination made re-use of the removed bone flaps impossible. Since allografting was not advisable due to the patients' young age, we performed our autologous catcher's mask cranioplasty. We obtained a smooth forehead contour and no patient developed sinking skin flap syndrome. Our experience clearly demonstrates the efficacy of autograft catcher's mask cranioplasty, using rib grafts and calvarial grafts, in pediatric patients with huge cranial defects.

Fig. 5 Patient 3—catcher's mask cranioplasty. Note that only the supratentorial defect is covered, as the infratentorial portion has already been covered by islands of osteoagenesis

Cranioplasty has long been performed for huge cranial defects, either using autologous skull, allografts, or autologous grafts to protect the brain and to avoid sinking skin flap syndrome [31, 11, 3]. Cranioplasty using the preserved skull is primarily the widely accepted procedure. However, despite the safety of cryopreservation, the most commonly performed preservation method, the issue of infection never disappears with the minimum occurrence remaining at 2% [12]. Subcutaneous preservation of the skull seems to be another ideal method of preservation, but there are cases of bone infection both during the preservation period and after craniotomy, of postoperative preserved site infection, or of bone resorption during the preservation period [20]. A large iliac graft procurement may induce a dynamic ileus. So far, there has been no report of a series in which post-surgical infection of the autologous skull was totally prevented. In a study on severe head trauma, the prevalence of infection was significantly associated with brain contusion, low GCS score, and dural tear [1]. Efforts should be made to lower the risk of post-surgical infection.

Allografting is appropriate when the preserved skull is not to be used. Various materials and methods have been developed; however, increased infection rates have been reported after allografting [19]. The results of impact test showed that PMMA cranioplasty provided protection similar to that of native osseous materials [9], and it was suggested that reinforced HA cement may provide hyperprotection against impact although the infection rate after use of reinforced HA cement increased [6]. The use of HA and biodegradable plates is widespread [8]; however, the granulation tissue observed after the placement of biodegradable PLLA plates [15] indicated that we should be cautious when using this material in our patients.

Autologous graft cranioplasty is indicated in adults when the autologous bone grafting and allografts are not possible, and in children when the autologous bone is not to be used. Autologous graft cranioplasty includes rib grafts and split-calvarial grafts. In almost all the previously reported cases of rib grafting, the grafts were placed in parallel to cover the whole defect [17, 18, 21, 25]. This parallel placement requires a certain amount of graft tissue to cover the whole area, and when the cranial defect is huge, it is not possible to cover the defect only with rib grafts unless many grafts are harvested. The harvesting amount varies, from 2 to 4 in one side [27]. Rib grafting in parallel also raises the issue of irregular contour. To achieve a smooth surface, graft extenders such as HA or demineralized bone matrix are placed to cover the free space [25]; however, this is a combination of autografts and allografts, which is not the ideal approach when the risk of infection is high. Split-rib grafts are easily bent and easily fixed with wires, so that the implementation and consolidation with the host bone is easy. Although the total amount of graft tissue is limited, taking of the graft is easier than for any other graft when the proper tool is used [29]. Moreover, thoracic deformity is avoided by skipping the graft harvest, and the complication rate is very low in the hands of experts [29]. Resorption of rib grafts is another issue. The mechanism of resorption variance is unclear, but it is assumed that blood supply from the surrounding tissues may inhibit bone graft resorption. In our patients, no marked resorption was observed; that is, they did not present sinking flap syndrome, indicating blood supply from the scalp was enough to prevent resorption.

For the management of a complicated skull defect, the calvarial graft is prepared either once the skull is removed and shaped [10, 23] or in situ [16], as was the case in our patients. Calvarial grafts are stiffer and harder than rib grafts, less resorption occurs, and they yield a smooth contour although they are difficult to shape by bending. In situ calvarial graft harvesting is not suitable to obtain large grafts. When harvesting a large calvarial graft, the skin incision is expanded, which is not desirable when repeated infection is an issue [14]; besides, harvest of a large graft leads to an uncertain dynamics of the skull.

As is often seen in children subjected to cranioplasty, we noted small islands of regenerating bone. This is one of the reasons to perform our partial cranioplasty in children; that is, to expect and to utilize the islands of osteoanagenesis even after the surgery has taken place. Bone morphogenic proteins (BMP-2) 2 and 7 [24] may contribute to introduce osteoagenesis in the future.

After considering the advantages and disadvantages of rib grafts and calvarial grafts, we successfully performed autologous catcher's mask cranioplasty to repair a huge skull defect that crossed the midline in children. At the forehead, a calvarial graft was applied to obtain a smooth contour. Placing the rib graft material crosswise yielded a supportive framework and allowed us to cover the defect area only with the limited amount of autologous grafts we had available. Islands of osteoanagenesis were also used to shape the cranium. The assessment of skull dynamics has to wait for further simulative calculations and biomechanical testing.

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