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Extensive Convexity Flattening of a Synthetic Skull Implant the Overcome Major Scalp Deficiency After Multiple Craniotomies

Lukas Andereggen, MD, Serge Marbacher, MD, PhD,* Armando Dolp, MD,* Philipp Gruber, MD,† Luca Remonda, MD,† Claudia Meuli-Simmen, MD,‡ and David Eyer, MD‡*

Abstract: Multiple craniofacial surgeries and postoperative recalcitrant infections frequently can lead to secondary scalp tissue scarring and skin retraction. Although there are different methods of reducing and optimizing scalp skin tension, the authors describe a last resort treatment method of cranioplastic procedure, which despite of its unfavorable cosmetic outcome, relieves the skin tension through extensive flattening of the polyetheretherketone curvature. Thereby, a custom-made cranioplastic bone flap was extensively flattened in the curvature of the fronto-parietal area with consideration of the related brain hemisphere extension. The extent of bone curvature flatting reduced the skin tension significantly and allowed for plain and simple tension-free wound closure in a chronic smoker patient with poor skin quality and brain atrophy. Although brain extension was sufficient, the cosmetic outcome was unfavorable with regard to skull symmetry, but well accepted and satisfactory for the patient due to preoperative discussion outcome expectation from surgery. Thus, extensive polyetheretherketone curvature flattening is a straightforward and simple last resort treatment option for tension-free skin closure in high-risk patients with extensive skin scarring and retraction and previous reconstructive plastic skin relief procedures. However, this method is limited in patients with normal brain hemisphere extension.

Key Words: Cranioplasty, cranium surgery, PEEK cranioplasty, reconstructive scalp skin flap, reconstructive scalp surgery

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From the *Department of Neurosurgery, Kantonsspital Aarau; †Department Neuroradiology, Kantonsspital Aarau; and ‡Clinic of Plastic, Reconstructive and Hand Surgery, Kantonsspital Aarau, Aarau, Switzerland.

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Address correspondence and reprint requests to Lukas Andereggen, MD, Department of Neurosurgery, Kantonsspital Aarau, 5000 Aarau, Switzerland; E-mail: lukas.andereggen@ksa.ch

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Informed consent was obtained from the patient. A copy of the written consent is available for review by the Editor of this journal. This study fulfills the requirements of the Ethics Commission of the canton of Bern, Switzerland, and has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

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Highlights

- Multiple craniofacial surgeries and infections can lead to skin retraction.
- Extensive bone curvature flattening is a last resort treatment method for tension-free skin closure.
- Discussion with the patient of an impaired cosmetic outcome is necessary.

Secondary scalp reconstruction and cranioplasty is a common neurosurgical procedure that is accompanied with several challenges.[1–5] Among others, primary tension-free defect closure to prevent scalp wound dehiscence and distal scalp flap necrosis and consecutive exposure of the autologous or alloplastic customized bone flap is critical.[6,7] In particular, any degree of alloplastic implant exposure leads to contamination and infection, which forces implant removal and adjacent bone flap osteomyelitis, which in turn can be an independent risk factors for further complications.[8–11] In addition, infection at the scalp defect site aggravates skin scarring and scalp tissue thinning, which further increases the possibility of wound dehiscence.[12]

In the case of tension-free wound closure, however, alloplastic implants offer excellent functional and cosmetic outcomes in case autologous bone reimplantation is infeasible.[7] At the time of this writing, there are different methods available,[6,13–15] with slightly curvature flattening recently proposed to optimize scalp skin tension with consideration of the cosmetic outcome.[16]

Here, we describe a last resort treatment strategy for scalp release in a patient with substantial skin tension despite bridging flap and split-thickness skin graft. A custom-made alloplastic implant was extensively flattened in the curvature of the fronto-parietal area with consideration of the related brain hemisphere extension but less the cosmetic outcome. Different surgical approaches with functional as well as cosmetic outcomes are discussed.

CLINICAL PRESENTATIONS

A 65-year-old woman with a long history of smoking fell on her head obtaining a lacerated wound and gradual loss of consciousness. She was then admitted to our hospital, where a computer tomography (CT) scan revealed an acute subdural hematoma on the left side, and an urgent osteoplastic craniotomy and hematoma evacuation was performed. Due to the absence of severe brain swelling, an autologous bone flap was directly reinserted and fixed with titanium screws. The perioperative course was uneventful. However, the patient developed surgical site infection 11 days later. An emergency empyema evacuation along with autologous bone removal was conducted. Broad-spectrum antibiotic treatment was

FIGURE 1. Bridging flap and split-thickness skin graft to achieve moderate tension following skin necrosis. (A) Occipital demarcated distal flap necrosis might have been induced by damaging the blood supply during subgaleal dissection, along with patient's active smoking status. (B and C) wound debridement along with an occipital bridging flap and split-thickness skin graft from the upper right leg to achieve moderate tension.

initiated, which was later adjusted according to the intraoperative culture results for another 4 weeks. Six weeks following bone removal, a cranioplasty with customized synthetic polyetheretherketone (PEEK) (Ad Mirabiles AG, Basel, Switzerland) was performed. Intraoperative circumferential dissection of the scalp in a subgaleal plane for better mobilization of the scalp allowed a subgaleal flap preparation and direct wound closure with moderate tension. On postoperative day 12, a small fronto-parietal wound dehiscence 3 × 4 mm in size and a well-established, demarcated skin necrosis occipital was evident (Fig. 1). Wound debridement along with another occipital bridging flap and split-thickness skin graft from the upper right thigh was required to achieve moderate tension. Samples were taken intraoperative from the scalp, the adjacent bone, and underlying dura, all with negative results on the cultures.

Two months later a new discrete wound dehiscence on the frontoparietal side of the incision appeared which was initially sutured. A month later this was followed by necessary removal of the PEEK plastic due to recurrent wound gaping with an unobstructed view on the underlying implant. Sonication of the PEEK plastic along with intraoperative samples revealed growth for *Staphylococcus haemolyticus*, *Streptococcus oralis*, *Candida parapsilosis*, and *Corynebacterium granulosum*. This was treated by intravenous caspofungin and daptomycin for 1 month, followed by per os doxycycline and diflucan for 2 months.

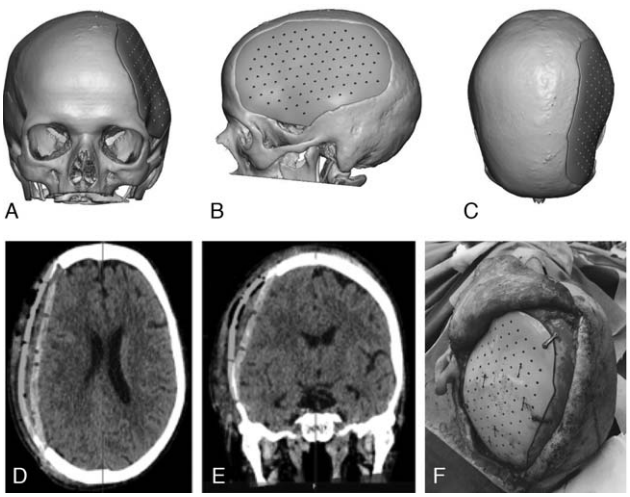

FIGURE 2. Reconstruction of the PEEK implant after extensive curvature flattening. (A-C) 3D reconstruction of the PEEK implant after curvature flattening in 3 different planes. This virtual 3D model served for preoperative discussion with the patient for better decision making of the cosmetic outcome. (D-F) Comparison of the initial PEEK expansion and after extensive PEEK flattening with overlapped CT scan of the initial PEEK plastic and the final customized plastic reveals extensive PEEK flattening. 3D, three-dimensional; CT, computed tomography; PEEK, polyetheretherketone.

After an antibiotic window, a customized PEEK cranioplasty with extensive flattening of the curvature with consideration of the given brain extension was reimplanted (Fig. 2). Potentially impaired cosmetic outcome was preoperatively discussed with the patient. The result of this last resort treatment strategy was promising as it prevented the need for a more complex free latissimus dorsi myocutaneous microvascular flap reconstruction and allowed a tension-less scalp and skin closure without the need for another flap reconstruction, which was refused by the patient (Fig. 3A-C). Postoperative CT-scan revealed extensive curvature flattening of the PEEK with sufficient brain expansion (Fig. 3D). Follow-up at 3 and 11 months was uneventful with no irritated wound conditions.

METHODS

The curvature of the customized PEEK implant was modified based on a three-dimensional (3D) reconstruction computer based model and adapted with regard to tissue shrinkage and area and volume contraction. According to a preoperative thin-layer CT scan, the patient skull was reconstructed to a virtual 3D model (Brainlab, Munich, Germany). On the basis of this model, the exact location of the curvature flattening was assessed. The scan was then sent to Ad Mirabiles for 3D reconstruction of the PEEK implant with the goal of curvature flattening. The result was evaluated and once again readapted for more extensive curvature flattening with regard to the skin tension (Fig. 2). The degree of curvature flattening was based on the extent of sufficient brain extension and was finally discussed with the patient for impaired cosmetic reason. The final result was used to customize the PEEK implant.

DISCUSSION

Quite a frequent problem in neurosurgery is that wound edges are often under significant tension, and therefore, difficult to readapt for primary wound closure following craniectomy and cranioplasty. This problem is often due to scalp tissue shrinkage and volume contraction, and subgaleal dissection techniques to reduce skin tension can compromise the vascularity of the skin edges, thereby impairing wound healing.[13] In addition, despite of the implementation of infection prevention bundles in our hospital,[17] infection is common and necessitates multiple operations that end up requiring custom made implants due to autologous bone involvement.[18] Thereby, the most challenging aspect comprises of the significant scalp shrinkage and volume contraction during the different time intervals required to allow for adequate recovery from the prior infections. Furthermore, any secondary surgical procedure is accompanied by an increased rate of postoperative infections, as technical challenges of operating in a scarred scalp area increases.[19] In addition, complex secondary reconstructive procedures without a plastic surgeon might increase the risk of complications and subsequent infections.[20] In the setting of highly complex scalp reconstruction with simultaneous cranioplasty,

FIGURE 3. Tension-less scalp and skin closure without the need for another flap reconstruction due to massive PEEK flattening. (A-C) Promising and cosmetically acceptable result after PEEK flattening. (D) Note that the extensive PEEK convexity flattening is appropriate with the CT scan revealing extensive curvature flattening of the PEEK but with sufficient brain expansion. CT, computed tomography; PEEK, polyetheretherketone.

Wolff et al[21] reported on a simple technique using full-thickness skin grafting to cover local defects in order to obtain scalp closure in a tension free manner. This technique represents a valuable option improving aesthetic outcome, which was less favorable in our patient. In addition, Cabbad et al[22] reported on their experiences of covering skull defects using split rib grafts, iliac graft, or split cranial bone from the contralateral side when the implantation of the autologous bone flap was not feasible, thus reducing the infection rates associated with customized implants. In view of their results, a split cranial bone graft from the contralateral side might have been an alternative option given the extension of the craniectomy to cover up. Despite alloplastic implants are mostly safe and offer good cosmetic outcomes when autologous bone implantation is not feasible,[2,7] their application can be limited. Alternatively, free hand molding of polymethylmethacrylate implants harbor less acceptable cosmetic results, wherefore novels methods to develop 3D-printer-assisted methods are increasingly used.[23] However, side effects of polymethylmethacrylate such as allergic reactions, or exothermic injuries have been described.[24] On the other hand, titanium meshes have been associated with significant less infection rates compared to other custom implants, yet postsurgical discomfort including an unfavorable cosmetic outcome in large and complex defects might limits its application in selected patients.[4,18] To reduce scalp volume contraction, early cranioplasty might be considered.[25] In case of an infection, however, its application is limited. Also, few studies report on the use of scalp tissue expansion before cranioplasty in selected cases.[13,15] Nonetheless, tissue expansion has to be performed before the cranioplasty and thus is limited in patients with infected bone flap. Further disadvantages of external tissue expansion is that, despite of its high costs, it yields only moderate area increase.[26,27] Although there is no consensus in the guidelines for the repair of these complex cranial reconstructions when in situ infection is encountered, curvature flatting has been shown to harbor has lower complication rate and is less invasive.[16]

In this patient, wound edges were under moderate tension while re-implanting the first PEEK plastic, thereby requiring subgaleal release techniques. Alongside, the patient is an active smoker resisting cessation, increasing the risk of initial wound dehiscence and necrosis, given its potential of compromising the vascularity of the flap and its edges.[28] Although smoking is known to negatively impact postoperative wound healing and increases the infection risk, the patient was not placed in a smoking cessation program, despite multiple attempts of patient's counseling on smoking cessation failed.[29] Subsequently, we performed a local scalp flap with additional lengthened incision adjacent to the placed cranioplastic construct with a bridging flap and split-thickness skin graft from the upper right leg to release and optimize scalp skin tension. The drawback for this procedure is the risk of losing the flap and devitalizing tissue adjacent to the implant.[6] Although the posterior auricular artery bridging flap is vascularized by horizontal and vertical branches of the contralateral occipital artery, with their supply preoperatively confirmed by Doppler flowmetry, the incision for the bridging flap transected the occipital vessels thus increasing the risk of ischemia and subsequent infections.[19,20,21] For tension-free skin coverage, Mikami et al[16] reported on a total of 25 cranioplasty patients with minor flattening the curvature achieved skin release with acceptable cosmetic outcome. Unlike in the patient presented here, the major restraints of the extensive skin scarring, along with existing bridging flap forced us to consider an extensive flattening of the PEEK cranioplasty, in spite of obviously diminished cosmetic outcome. A free microvascular latissimus dorsi myocutaneous flap was discussed with the patient but finally refused.[30]

We thus propose that under these conditions, the cosmetic outcome can be compromised, when the primary goal is a straightforward method to allow tension-free PEEK reimplantation in high-risk patients with certain brain atrophy. This requires an extensive briefing with the patient on the outcome. To get a better idea, a visual presentation of a patient specific virtual 3D model preoperatively might thus help for better decision making in this regard. Namely, it has been shown that it is frequently difficult for patients to comprehend the involved treatment plan,[31] leaving patients often with an inaccurate understanding of their potential final outcome.[32] Hence, adequate information facilitates patients' understanding of the procedure's advantages or disadvantages and enables them to be more open to accept cosmetic compromises. Nevertheless, we have to keep in mind that extensive PEEK convexity flattening is inappropriate in patients without encephalomalacia or brain atrophy, therefore, the curvature flattening should be adapted to the extend of the given anatomical circumstances. Thus, the convexity flattening of the cranioplasty is not only based on the skull shape and skin tension, but also in relation to brain hemisphere extension. Mikami et al[16] do not report on any neurological complications arising due to curvature flattening in cranioplasty. Yet, curvature flattening was very minimal in all of their cases presented. In addition, scalp expanders were used in some of their patients.[16]

CONCLUSIONS

Extensive PEEK curvature flattening is a straightforward and simple last resort treatment option for tension-free skin closure in high-risk patients with extensive skin scarring and retraction and previous repeated reconstructive plastic skin relief procedures. Discussion with the patient for better decision making of the impaired cosmetic outcome is necessary, and the method is limited in patients with normal brain hemisphere extension.

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