Does The Craniotomy Bone Flap Resorb?

INTRODUCTION

For over a century, craniotomy has been performed in neurosurgery to decompress the brain, remove brain tumours, and treat aneurysms in the brain. This procedure begins with an incision through the scalp, followed by retraction of skin muscles. Depending on how badly the brain is affected, one or more burr holes may be created in the skull before a craniotome connects the burr holes to result in a bone flap being removed to gain access to the affected brain (Figure 1A).

As part of a craniotomy, the bone flap is immediately placed back in the same surgery. However, there are situations where this cannot be done. In these instances, the bone flap is either temporarily stored in the peritoneal cavity or frozen in a bone bank, awaiting for the subsequent bone flap surgery known as a cranioplasty.

Bone flap resorption: A worrying and increasing trend over time

According to Adaaquah [1] and colleagues from the Mayo Clinic, "although we know that fusion occurs, because most surgeons have had the experience of reopening craniotomies years later that they themselves or their colleagues have performed, we do not know whether fusion occurs completely, nor do we know the rate at which it occurs." Hence, they endeavoured to study and investigate the rates of free flap fusion, and when they occur, after craniotomies in neurosurgical practice.

171 craniotomy patients were reviewed as part of this study (operated over a 72-month period). In this study, fusion is split into 3 categories (Table 1). Approximately 40% of cases did not achieve solid fusion while no fusion was reported in 25% of the cases. The time to fusion was also studied and it was reported that fusion rates reach 80-90% at 60-72 months (approximately 5-6 years) post-surgery.

Definition of fusion	Observation
Solid fusion: Patient would not need any more plating if hardware was removed	60% of cases
Probable fusion: Bony connections are partial and solid fusion questionable	15% of cases
No fusion: No bony connection with the skull	25% of cases

Table 1 Definition of the different types of craniotomy fusions and the reported ratio in the 171 patients.

The 103 patients in the solid fusion group were further analyzed for the percentage diameter of the craniotomy flap fused (Figure 1A). In this respect, the rate of incomplete fusion may be considered high as the median rate of fusion is only 40% (Figure 1B).

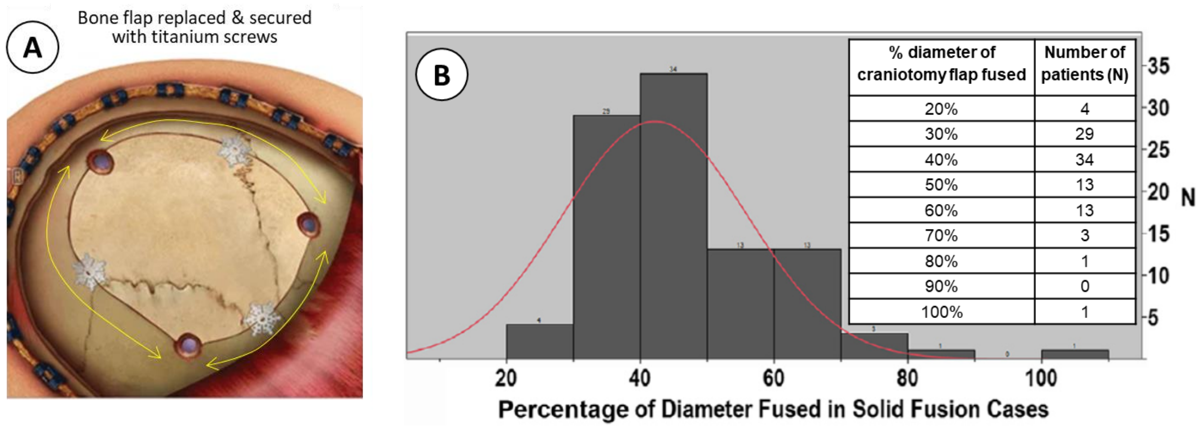

Figure 1 (A) Illustration of a bone flap created via a combination of burr holes and a connecting craniotome cut. The yellow lines indicate the method by which the "diameter of craniotomy" fused, is determined. (B) A histogram representation of percentage of diameter fused in the 103 patients where solid fusion occurred. The median percentage of diameter fused is 40%. Figures adapted from Adaquaah and colleagues[2].

In a separate study by Jeon and colleagues [2], the resorption of bone flaps in craniotomies were compared with cranioplasties. From Figure 2, it can be observed that moderate resorption begins to occur in the craniotomy group from 9 months post-op, while severe resorption begins at 36 months post-op. Contrastingly in the cranioplasty group (where the bone flap had been stored for some time before re-implantation), it can be observed that there is an obvious and increasing trend of moderate and severe resorption over the same period of 36 months.

Given time in the craniotomy group, the extent of resorption may become severe over time. It can be observed that at 36 months, the number of patients with severe, moderate, and mild resorption is similar to the cranioplasty group at 12 months. The trend suggests that in another 24 months, it could attain the severity similar to cranioplasty bone flap resorption at 36 months. This mean that craniotomy patients may reach similar bone flap resorption at 60 months, necessitating a revision surgery then.

Taken together, the findings of Adaaquah[1] and Jeon[2] suggest that incomplete diameter of craniotomy fusion may lead to craniotomy bone flap resorption.

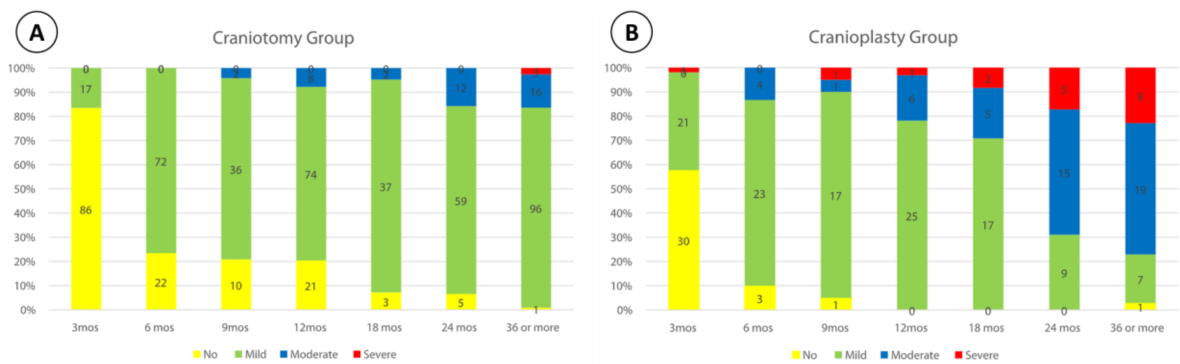

Figure 2 Resorption rates in (A) craniotomies and (B) cranioplasties. In general, a growing trend of severity is observed, particularly in the cranioplasty group.

The role of a biomimetic scaffold in supporting craniotomy bone flap fusion

Among the potentiating factors that support bone formation, vascularization is known to be an important contributor to the success of bone regeneration. Murphy and colleagues [3] reported that vascularization can enhance bone regeneration by speeding up the differentiation and/or maturation of infiltrating osteoblasts and osteoblast precursor cells during neobone development. A critical requirement to achieve functional integration of bone repair constructs is early revascularization to nourish cells located deep within the construct. In order to achieve this extent of vascularization, it is imperative that the structure enables vascular ingrowth throughout the reconstruction area.

When applied to a bone implant, this necessitates an interconnected, porous structure from a microstructural level. In an early pre-clinical study by Rai and colleagues [4], a highly porous and interconnected structure incorporating Osteopore's unique scaffold architecture was implanted into the rat tibia. At 12 weeks, the scaffolds were explanted and micro-CT showed that within the connective tissue, numerous vascular structures and collagen fiber deposition were seen (Figure 3). Dense new bone was observed to span most of the defect site as well as infiltrate into the scaffold pores. Bone marrow tissue occupied some cavities within this newly formed bone. Resorption cavities and vascular structures were interspersed in new bone as well. It should be noted that the struts of the scaffold are seen as regular-sized gaps in the connective tissue and new bone.

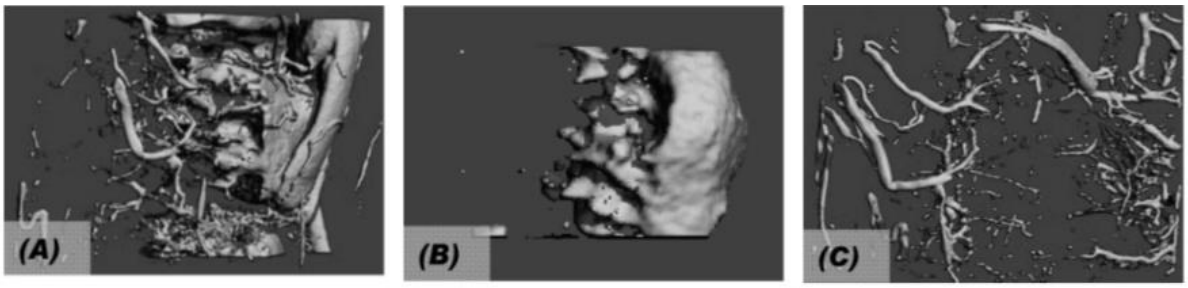

Figure 3 Representative 3 week post-surgery micro-CT images of control (A) bone and vasculature; (B) bone only; (C) vasculature only. Vascular ingrowth in scaffold constructs is evident in the 3D micro-CT images.

The way forward: Scaffold supported bone fusion through vascularization

The growing trend of bone flap resorption, which may necessitate a corrective surgery, is a clinical need that may be addressed by ensuring that one of the modulators of bone growth, vascularization, is enabled. Osteopore' porous scaffold has demonstrated its ability to facilitate thorough vascularization during bone regeneration.

Applied to craniotomies, Osteopore's scaffold technology has the potential enable sufficient vascularization to support fusion between the bone flap and surrounding native bone. This may prevent or ameliorate bone flap resorption in patients.

References

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