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# Paediatric cranioplasty: A review

Anooja Abdul Salam[a], Imogen Ibbett[b], Nova Thani[a,*]

[a] Department of Neurosurgery, Royal Hobart Hospital, 48 Liverpool Street, Hobart, Tasmania 7000, Australia
[b] Royal Hobart Hospital, 48 Liverpool Street, Hobart, Tasmania 7000, Australia

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ABSTRACT

*Objective:* This study reviews the current literature for the optimal material to use in paediatric cranioplasty surgeries.

*Materials and methods:* A search of Medline (Ovid)/PubMed/Scopus was undertaken to assess the current methods in use for the reconstruction of cranial defects in paediatric patients.

The search terms used were: cranioplasty", calvarial reconstruction", "cranial defect, "allograft", "biomaterial", "methyl methacrylate," "titanium," "hydroxyapatite," all in association with "paediatric," "adolescent," or "infant." Articles were limited to materials published from 2005 onwards.

*Results:* The above search identified 7104 papers relating to paediatric cranioplasty published after 2005, of which 7070 did not meet inclusion criteria. The remaining 34 papers were included in this review.

*Conclusion:* An ideal material for cranioplasty, especially in the paediatric age group, has not been established based on the available evidence. The current trend in practice appears to be the use of particulate bone grafts or exchange cranioplasty in infants. In older children, custom made implants using titanium or hydroxyapatite have been used successfully.

## 1. Introduction

Cranioplasty is an integral aspect in surgery involving cranial vault tumours, infection, trauma or congenital defects [1]. Reconstruction of the integrity of the calvarium protects the underlying brain, improves cosmesis [2] and importantly promotes the establishment of a homeostatic environment for the autoregulation of cerebral blood flow [3]. Characteristics of the paediatric population differ from adults due to variance in anatomy and the effect of growth of the skull [4].

The cranial vault grows by deposition of bone perpendicular to the sutures, namely intramembranous ossification [5]. Fig. 1 summarises the stages of suture morphogenesis and fusion [6]. Moulding takes place by absorption of the inner layer and osteoblast-mediated thickening of the outer layer [5]. At birth the bones of the vault are solid. In adulthood, vascular channels develop with cancellous bone matrix forming the diploe, thus developing inner and outer table. Parts without diploe, namely squamous temporal bone, parietal bone, foramen magnum, skull base, cribriform plate and orbital roof, are prone to fracture [7].

Hence, a material that does not allow bony ingrowth has increased risk of failure because of the peculiar growth of the immature skull, with prevalent deposition of bone at the outer layer and resorption of bone at the inner layer as described above [8].

In the paediatric population, an ideal cranioplasty material should integrate to the adjacent bone with the ability to 'grow' with the child's calvarial growth. Other desirable properties would include availability, cost effectiveness, light-weight, nonmagnetic, radiolucent, sterilisable, and easily secured to the calvarium [3]. The aim is to select the safest material with fewest complications thus resulting in less morbidity and a higher success rate, but being cost effective at the same time [3].

Materials used for cranioplasty can be categorised into three main groups: organic, synthetic-organic, and inorganic [9].

Organic cranioplasty materials include autograft (harvested from the same individual), allograft (bone graft from another individual), and xenograft (taken from another species) [9] We have summarised below the materials used in paediatric cranioplasty and reported complications seconday to its use (see Table 1).

Synthetic-organic materials ("biomaterials") are manufactured natural bone minerals or proteins found in the human body. Examples include hydroxyapatite and bone morphogenic protein [9]. Autologous bone and biomaterials are the two major sources for cranial reconstruction in adults and children [10].

*Abbreviations:* PMMA, polymethylmethacrylate cranioplasty; HA, hydroxyapatite; BMP, bone morphogenetic protein; ADSCs, adipose-derived stem cells; CSF, cerebrospinal fluid; CBS, Custom Bone Service

* Corresponding author.
*E-mail address:* novathani@gmail.com (N. Thani).

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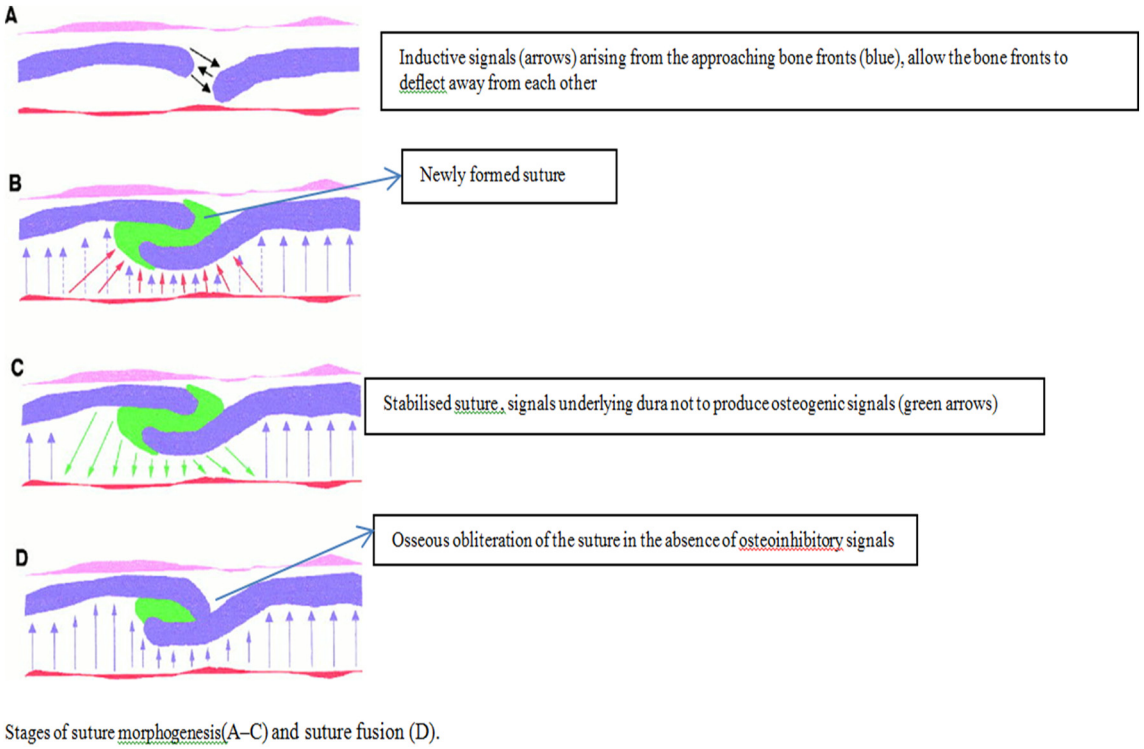


**Fig. 1.** Stages of suture morphogenesis and fusion [6].
[The figure above is taken and modified from Opperman, L. A. (2000).]

Inorganic substances do not have biological activity. These include methyl methacrylate, silicone, porous polyethylene, titanium mesh, and bioactive glass [9].

While there are various studies to support the use of biomaterials in adult cranioplasty, it is very limited in paediatrics. The use of biomaterials as a substrate for cranioplasty rather than autologous bone is controversial in paediatrics due to the potential harmful effects caused by a non-flexible, foreign material on normal cranial growth, intracranial migration of biomaterial, higher incidence of infection, inflammatory tissue reaction and material disintegration or fracture [2].

### *1.1. Materials and methods*

A search of Medline (Ovid)/ PubMed/Scopus was undertaken to assess the current methods in use for the reconstruction of cranial defects in paediatric patients.

The search terms used were: cranioplasty", calvarial reconstruction", "cranial defect, "allograft", "biomaterial", "methyl methacrylate," "titanium," "hydroxyapatite," all in association with "paediatric," "adolescent," or "infant." Articles were limited to materials published from 2005 onwards.

All titles and abstracts were reviewed to identify eligible papers. The reference sections of included studies were also searched to identify any omitted studies.

Inclusion criteria were: publication since 2005, patients aged < 18 years and articles specifying cranioplasty material used. Data extracted included type of cranioplasty, number of patients, patient age, follow up data, and complications requiring second cranioplasty procedure.

### *1.2. Results*

The above search identified 7104 papers relating to paediatric cranioplasty published after 2005, of which 7070 did not meet inclusion criteria. The remaining 34 papers were included in this review.

In this paper we will discuss the preferred materials used in paediatric cranioplasty, including their advantages and disadvantages, as per the data obtained from our literature search.

## 2. Autologous cranioplasty

In the paediatric population, as in the adult population, autologous cranioplasty is considered the gold standard. Hence, when available and appropriate, this is the commonest technique used [9]. The most common donor areas for autologous bone are the cranium, ribs and iliac crest [9].

The advantages of using autologous bone include decreased infection risk and minimal dislodgement or disintegration due to higher rate of revascularisation and integration with adjacent bone [9,10]. Autologous also means that there are no issues with host rejection and tends to merge well with the cranial cavity, resulting in lower risk of fracture [11].

One of the main disadvantages in paediatric age group is availability of autologous bone. Moreover, harvesting autologous bone involves prolonged operative time, donor site pain and infection, graft resorption and difficulty moulding to the defect. Often, and in particular with the paediatric population, the graftable tissue is insufficient to cover the defect [9]. For example, in paediatric patients with traumatic brain injury requiring decompressive craniectomy, cranioplasty can be a challenge due to the large residual defect requiring a large graft [4].

Martin et al. [4] reported on the long-term outcomes after replacement of the autologous bone flap over a 13 year period. In their study, the incidence of resorption of the bone flap was higher in children under eight years (81.8%) compared to older children (42%). Even though a preserved autologous bone flap is an attractive option for paediatric cranioplasty, the increased rate of resorption requiring secondary cranioplasty, particularly in patients under eight years, suggests this technique should be used preferably in older children [4,12]. Synthetic cranioplasty should be considered for children below eight years of age [4].

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