Preliminary technique and planning of a cost effective customised cranioplasty implant using 3D printing and bone cement

Authors:
TANG Long Ching Lusanda¹, NG Yuen Ting Rebecca¹, FUNG Kai Hung², TONG Ka Shun Carrison³

Institutions:
¹Department of Neurosurgery, Pamela Youde Nethersole Eastern Hospital, Hong Kong
²Department of Radiology, Pamela Youde Nethersole Eastern Hospital, Hong Kong
³Department of Medical Physics, Pamela Youde Nethersole Eastern Hospital, Hong Kong

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Background and Objective

Cranioplasty is a common neurosurgical operation performed for the repair of cranial skull defects. They may be a result of prior traumatic insults, decompressive craniectomies, tumour resections, infections or congenital defects. In cases where an autologous bone graft cannot be used, an artificial prosthetic implant can be used instead.

Polymethyl-methacrylate (PMMA) bone cement is a commonly used material for this purpose. However intra-operative moulding of the bone cement often cannot provide optimal cosmetic results, due to inability to achieve a fitting contour, and the moulding process exposes the dura to heat produced by the exothermic reaction from the polymerisation process.

Customised cranioplasty implants made with titanium or polyetheretherketone (PEEK) have been available on the market to be commercially purchased for some time, however they are often expensive. Prior studies [1] have outlined the use of computer aided design (CAD) and three-dimensional (3D) printing technology for a more cost effective method of producing a customised cranioplasty implant, by prefabrication of a 3D printed negative mould which can then be used intra-operatively to shape the PMMA bone cement into the desired 3D shape.

This study aims to test the feasibility of applying this method at our centre in Hong Kong prior to operative application of the technique on a patient.
Method and Results
We experimented with data obtained from a patient who had received a unilateral decompressive craniotomy.

1. Digital Imaging and Communications in Medicine (DICOM) data was obtained from post operative computed tomography (CT) scans of the patient.

2. The DICOM data was converted into three-dimensional (3D) images with OsiriX Software.

3. Using Autodesk Meshmixer software, a mirror image of the normal side of the patient’s skull was generated, then the cranial defect area was digitally subtracted to formulate a 3D model of the planned implant.
4. A negative mould of the skull defect was printed with thermoplastic polyurethane (TPU) filament by 3D rapid prototyping technology.

5. As TPU could not be autoclaved, the moulds were wrapped in sterilised plastic sheets. Saline was added to the plastic to avoid adhesion to the bone cement.

6. The PMMA bone cement was applied to the mould during the viscous liquid state.
7. The 2 parts of the negative mould were compressed against each other, to shape the bone cement into the pre-designated shape.

8. After the PMMA bone cement hardened, the formed prosthetic implant was removed from the mould.

Images of the final PMMA bone cement implant from different angles.

Image of the PMMA bone cement implant alongside the TPU negative mould pieces.
Discussion and Conclusion

This method is technically feasible and can be applied to patients requiring cranioplasty with an artificial prosthetic implant in the future, to provide a more aesthetic outcome.

However the technique can be improved by:

• Finding a material that can be sterilised and does not adhere to the bone cement to be used for producing the mould, so that the sterilised plastic sheet can be omitted and hence improve the fitting of the bone cement to the negative mould

• Use of computer techniques to calculate the volume of the cranial skull defect, so that the volume of bone cement required can be approximated to ensure appropriate thickness of the implant

References: