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Review

Materials and techniques used in cranioplasty fixation: A review

Basel A. Khader, Mark R. Towler *

Department of Mechanical & Industrial Engineering, Ryerson University, Toronto, M5B 2K3, ON, Canada

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ABSTRACT

Cranioplasty is the surgical repair of a deficiency or deformity of the skull. The purpose of cranioplasty is to provide protection for the brain following cranial surgery, and to offer relief to psychological disadvantages while increasing social performance. There are several materials that had been used for cranioplasty but an ideal product has yet to be developed, hence the ongoing research into biologic and non-biologic alternatives to the existing materials. This article critiques the products currently used for cranioplasty in order to facilitate the development of new materials, which can improve patient outcomes.

Contents

1. Introduction

The most common indications for cranioplasty include birth defects, trauma, neurological procedures, infection of the cranial contents and, in children, the absence of an intact cranial vault for normal growth and development of the brain [1]. During cranioplasty, the patient is placed under local anesthetic while the over the defect scalp is cut and displaced [2]; the defect is then addressed in line with the surgical need and the skull surface smoothed to facilitate attachment of the graft [2]. The bone or synthetic flap (in the event where the patient's bone flap cannot be reattached) is secured to the skull using specific

* Corresponding author.
E-mail address: mtowler@ryerson.ca (M.R. Towler).

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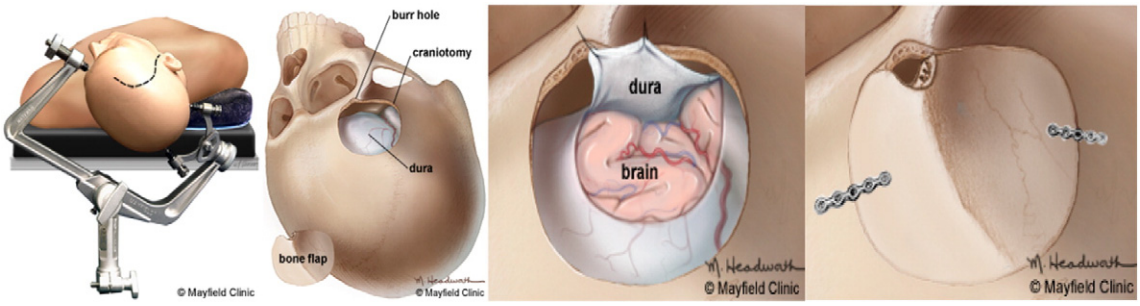

Fig. 1. (Left to right) The steps taken during a cranioplasty technique after craniotomy [3].

devices and screws. The scalp is then re-attached around the skull using sutures [2].

The objective of this review is to identify the outages in the materials currently used for cranioplasty in order to facilitate the development of new materials, which may improve patient outcomes (see Fig. 1).

1.1. Anatomy of the cranium

The cranium shelters the brain, meninges, and cerebral vasculature. It consists of eight cranial bones: two parietal, two temporal and the frontal, occipital, sphenoid and ethmoid bones [4]. The parietal bones form part of the top and sides of the cranium. The temporal bones are on the sides of the head, under the parietal bones, and above and behind the ears. The frontal bone forms the forehead. The occipital bone forms the back and base of the cranium. The sphenoid bone forms the eye orbit and the ethmoid bone forms part of the nasal and eye cavities [4].

2. Cranioplasty fixation techniques

All clinically utilized techniques for improving cranial rigidity and minimizing complications, such as wiring, plating, clamping, strips and sutures, are considered in this review.

Wiring using stainless steel is the most common technique due to its simplicity, strength of the construct and short healing time [5]. This involves the drilling of holes in each bone flap and in the adjacent skull edge [6] and stainless steel wires then being threaded through the holes. The wires are subsequently twisted together, excess wire removed and loose ends are tucked in the holes around the skull edge [6]. Suturing techniques have been applied for many years and offer reasonable protection [7]. However, both settling and deformation, such as recurrent displacement of the bone plates, which result in depression of the flap, are common with suture fixation [8,9] (see Fig. 2).

2.1. Miniplate technique

Cranioplasty is often performed using custom-made hydroxyapatite (HA) implants affixed to the skull with screws. However, problems can result which are related to HA's characteristic brittleness. In this surgery, the plates are positioned 120° apart along the perimeter of the craniotomy defect and secured to the free craniotomy flap. A drill is used to tap holes through which screws are then applied. The flaps with attached plates are then situated in the skull defect and fastened in to secure the skull edge [6]. This technique can be time consuming and expensive [6].

Titanium screws of varying lengths have been used for securing titanium miniplates to HA (40% porosity, 30 × 30 × 5 mm) flaps (APACERAM, provided by Pentax, Co, Ltd. Japan) [10]. Pull out strength tests determined fixation strengths were directly dependent on screw length.

Miniplates have also been made from titanium and employed in a study of twenty-five patients with large skull deficiencies initiated by gunshot or shrapnel injuries [11]. Following dural closure a stencil was cut out from the titanium (0.61 mm thick) and shaped to fit the skull [11]. Holes were then drilled into the plate, titanium screws inserted into the holes, and the scalp sutured [11]. This method was reported to offer many benefits including ease of fixation; significant reductions in operating time, good tissue acceptance [11] and radiolucency (see Fig. 3).

2.2. Clamping technique

Titanium clamps are an alternative method for cranioplasty fixation (Fig. 4) and were compared with miniplates, sutures and wires in four separate studies. A study conducted by Shu-Xu et al. [13] found that the titanium clamp system had distinctive advantages compared to sutures and stainless steel wires in cranial flap re-fixation, as their

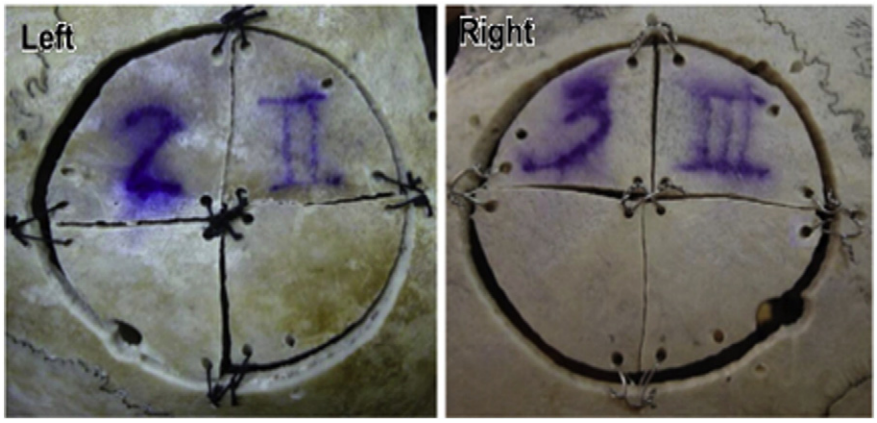

Fig. 2. Cranial flap fixation technique (left: suture, right: wire) [8].