Short Communication

Long-term results of porous hydroxyapatite bilateral cranioplasty: an 8-year radiological follow-up

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SUMMARY: *Bilateral decompressions in a 16-year-old boy were reconstructed using custom-made porous hydroxyapatite implants. Long-term follow-up of this biomimetic and osteoconductive material was evaluated at different time point to assess osteointegration at bone–implant margins. CT scans were performed at 10 days, 58 months and 93 months after cranioplasty. and used to furnish tissue density measurements along the bone/implant interface. Hounsfield graphs were plotted to assess tissue density, and therefore osteointegration, at the bone/implant margins at all three time points. Improved osteointegration over time is evident on both CT scans and Hounsfield graphs. Measured density was always above the bone threshold, even at implant/bone edges. The interface showed no interruption or evidence of fibrous tissue, and no apparent resorption of the implant was evident from radiological measurements. Long-term follow-up of porous hydroxyapatite implant confirmed good osteointegration of the biomimetic prosthesis with the receiving bone. Hydroxyapatite should therefore be considered an ideal implant material in terms of mid–long term functional recovery.*

KEY WORDS: *Cranioplasty, Hydroxyapatite, Long-term effect, Osteointegration.*

INTRODUCTION

The primary objective of cranioplasty is to obtain a durable, stable, and acceptable reconstruction(8). However, the outcome of cranial bone reconstruction is thought to be dependent not only on surgical skills, the quality of adjacent soft tissues, and the size and location of the bone defect, but also the choice of implant. Regarding the latter, despite much research, there is still no clear consensus regarding the most appropriate reconstruction materials(9).

Although alloplastic materials are biocompatibile, and provide good primary stability, their long-term effects are seldom investigated, and we cannot rule out adverse reactions developing after many years. In fact, Gautschi et al.(3) described a case of hypersensitivity to PMMA after cranioplasty that led to implant removal.

Calcium phosphate ceramics and cements are also highly biocompatible, and have a very similar structure and chemical composition to that of the mineral phase of bone. Presumably as a result of this likeness, calcium phosphates seem to be remodelled like normal bone through a cell-mediated process. Their ability to act as a synthetic osteoconductive scaffold after implantation in natural bone makes them one of the best implant options.

Hydroxyapatite is one of the forms of calcium phosphate most commonly used for clinical applications. Although it is known to be non-resorbable over time, long-term follow-up of HA cranioplasty implants is seldom reported in the literature, as the majority of complication arise within the first year after implantation.

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LIST OF ACRONYMS AND ABBREVIATIONS: **CT** = Computed Tomography; **HA** = HydroxyApatite; **HU** = Hounsfield Unit; **PMMA** = PolyMethyl-MethAcrylate.

AIMS

Long-term radiological follow-up of a patient successfully implanted with porous HA prosthesis almost 8 years prior to the time of writing was performed to assess any signs of resorption and/or osteointegration at the prosthesis/receiving cranial bone interface over time.

MATERIALS AND METHODS

Surgical procedures. The implants were placed according to the procedure recommended by the manufacturer, and as described by Staffa et al.[7].

CT scans, bone density measurement and osteointegration analysis. Post-operative CT scans were performed at different time points after cranioplasty to evaluate implant positioning and margin adhesion. Bone density in the immediate vicinity of the implant was evaluated using Mimics Innovation Suite v17.0 Medical (Materialise, Belgium) and Hounsfield units, which describe the density of the CT image at a specific point. The Hounsfield density scale corresponds to different levels of beam attenuation, and ranges from -1,000 (air) to +3,000 (dense bone), thereby enabling the quantitative differentiation of tissues in the region (i.e., muscle, 35-70 HU; fibrous tissue, 60-90 HU, cartilage, 80-130 HU; bone 150-1800 HU)[4], with cranial bone presenting the highest cancellous bone density[6]. Density measurements across the bone-implant interface at the various time-points were performed twice to provide a mean.

Clinical case. A 16-year-old boy underwent cranial bilateral fronto-parieto-temporal decompression after severe head injury, due to a car accident, in 2006 (Figure 1A). Three months later the skull was surgically reconstructed using two custom-made HA implants (*CustomBone Service, Fin-Ceramica Faenza S.p.A*). Clinical and radiological follow-up was performed from 2007 to 2014.

RESULTS

Radiologic evaluation (positioning, Hounsfield values at bone-implant margin). 10 days after surgery, a clinical and radiographical assessment of the patient's condition and the implant position was performed (Figure 1B). Subsequent scans, at 58 months (Figure 1C) and 93 months (Figure 1D) after cranioplasty, confirmed that the implants remained correctly positioned over time. The entire perimeter of the prosthesis remained perfectly adhered to the host bone, and both internal and external prosthesis profiles were correctly aligned; this becomes more evident over time, in particular at 93-month follow-up (Figure 1D and 2 A-B).

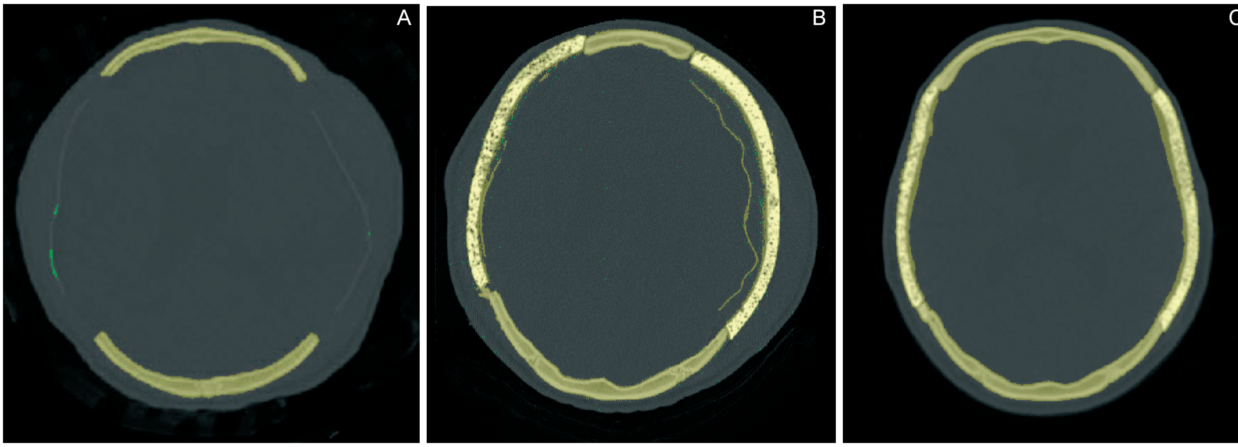
Hounsfield values of cranial bone ranged from 200 to 1,200 HU (Figure 2D), while HU, and therefore density, values for hydroxyapatite were far higher (> 3,000 HU, see red and blue arrows in Figure 2C-D). We excluded the formation of fibrous tissue (range 60-90 HU) at the interface since values were always above bone threshold (Figure 2C-D). No macroscopic resorption of the implant was apparent on the scans.

DISCUSSION

8-year radiological follow-up showed the increasing osteointegration of both implants with the receiving cranial bone. Bone healing appeared more homogeneous over time, with no interruption or defect. Indeed, HA is the mineral form of calcium apatite that is the main component of bones, and, as demonstrated by different authors[1,2,5], new bone formation within the prosthesis is a peculiar characteristic of porous HA implants. Although bone regeneration and healing times have not been precisely defined as yet, it is clear from our results that osteointegration of such implants continues to improve over time. The osteoconductivity of HA ensures physical and mechanical integration with the surrounding bone, promoting functional recovery in the mid-to-long term.

CONCLUSIONS

Porous HA appears to be recognized as "self" by the organism, making it an ideal implant material for a lifelong approach to regenerative medicine.



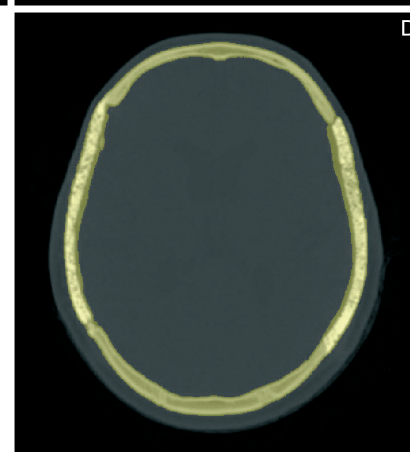
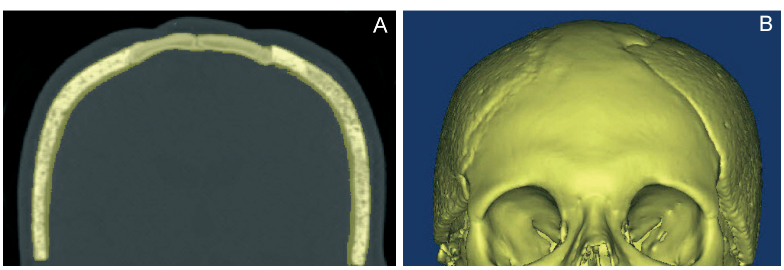


Figure 1. Post-operative radiological evaluation after cranioplasty. CT scans of a 16-year-old boy with bilateral cranial lacunae in the fronto-parieto-temporal bones after decompressive craniectomy (A). CT 10 days after cranioplasty with porous hydroxy-apatite implants shows good implant position and osteointegration (B), which persist 58 months (C) and 93 months later (D).



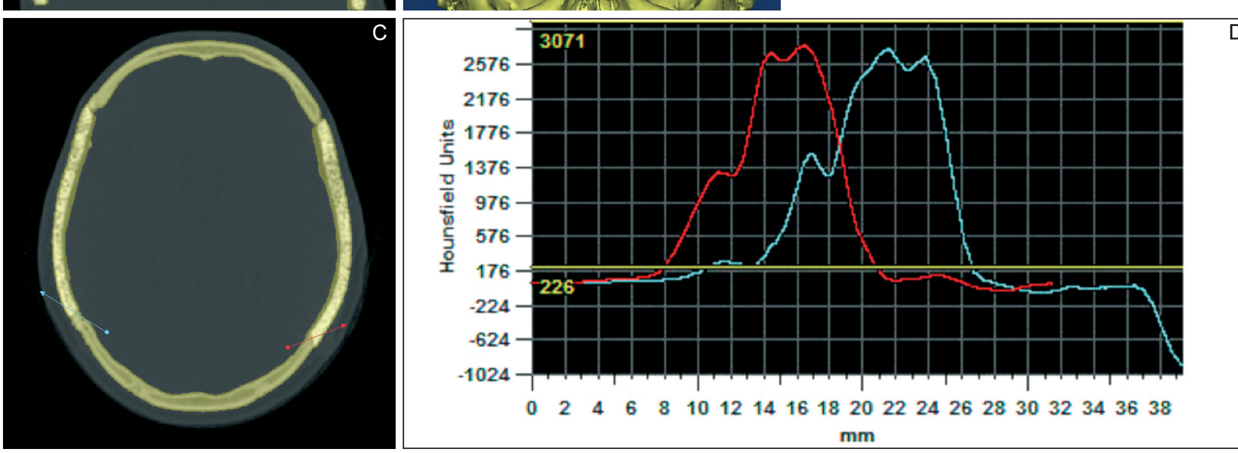


Figure 2. Long-term follow-up radiological evaluation (A, B) and Hounsfield bone density graph (C, D) 93 months after cranioplasty. CT scans taken 93 months after cranioplasty show excellent cranial repair achieved using porous hydroxyapatite implants (A) in all three dimensions (B). Osteointegration at the bone/implant margins (red and blue arrows) (C) is confirmed by Hounsfield unit values, which are invariably above bone threshold (400–1000 HU), with no interruption even at the interface (D).

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