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Short communication

Voluminous fronto-parietal osteomas: Guided resection with patient-specific cutting guides and reconstruction with a 3D printed hydroxyapatite implant

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ABSTRACT

Osteomas are benign, well-differentiated bony tumors characterized by gradual progression, commonly observed within the craniofacial skeleton. This case report aims at describing the successful surgical treatment of giant frontal osteomas thanks to additive manufacturing technologies. The osteomas were located on the external table of the parietal and frontal bones with complete invasion of the anterior wall of the right frontal sinus. Resection was performed with the help of three 3D printed surgical cutting guides to prevent damaging the inter-sinus septum, the right orbital roof and the posterior wall of the frontal sinus. Anterior frontal sinus wall was reconstructed with a 3D printed hydroxyapatite patient-specific implant called MyBone Custom Implant (MBCI). The 3D planning and accuracy of the additive manufacturing tools enabled to obtain good bone contacts. Ossification of the edges of the MBCI is visible on the six-month postoperative scans. The outcome of this reconstruction proved highly satisfactory both in terms of aesthetic results as well as restoring the bone integrity.

1. Introduction

Osteomas are benign, well-differentiated bony tumors characterized by gradual progression, commonly observed within the craniofacial skeleton [1]. Osteomas are predominantly located in the paranasal sinuses and primarily affect the ones of the frontal bone [1,2]. Due to their slow progression, osteomas are often incidentally discovered during routine examinations [3] between the fourth and sixth decades of life, with a higher prevalence in men [2,3]. The etiology of osteomas remains elusive, with proposed origins including developmental, traumatic, infectious, or inflammatory [1,3]. Genetic predispositions, such as Garner's disease—an autosomal dominant condition characterized by the appearance of multiple osteomas—may also play a role [1,4,5].

Usually asymptomatic, these tumors can cause symptoms such as headaches, diplopia, brain abscesses, and even meningitis when they impinge on adjacent organs [2]. In such cases, or when the osteomas cause sinus outflow obstruction, mucocele formation or cosmetic deformity, surgery is recommended [1]. Bone reconstruction may be necessary depending on the resected area [6].

The recent advancements in additive manufacturing technologies provide patient-specific solutions to improve both the resection and the reconstruction of bones. Here, we report a case involving a voluminous (giant) frontoparietal osteoma resection with a series of 3D-printed cutting guides. It was followed by the reconstruction using a 3D-printed porous hydroxyapatite patient-specific implant (PSI).

2. Case presentation

We report a case of a 49-year-old woman who had voluminous frontoparietal osteomas with high aesthetic impact. They had developed progressively since the age of 20 years old, following a car accident. She has no particular medical history, but she is an active smoker (10 cigarettes per day). At the age of 27, she had a first surgery to remove the osteoma who appeared in her right frontoparietal bone. A bi-coronal approach was used to mill the lesions, the anatomopathological examination confirm the presence of osteoma. No reoccurrence was observed

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during the first year.

She was then lost to follow-up until she re-presented herself 22 years later with significant new deformities. She had to wear a cap daily to cover the protuberances and refrained herself from pursuing certain employment opportunities.

2.1. Clinical examination and pre-operative planning

The clinical examination revealed a right frontoparietal deformity, including the upper part of the right orbital rim. The patient reported no pain, oculomotor trouble, diplopia, or sight loss. However, a slight loss of sensitivity in the right supra-orbital nerve territory was noted. The radiological investigation unveiled voluminous osteomas located on the external table of the parietal and frontal bones with complete invasion of the anterior wall of the right frontal sinus (Fig. 1). However, no intracranial invasion was observed and the internal table and the left frontal sinus were intact.

Given the size and location of the osteomas, Gardner's syndrome was suspected but ruled out after a genetic consultation and colonoscopy. Considering the patient's complaints and the major aesthetic impact, a mutual decision was reached to pursue a new surgical resection aiming at restoring skull and face symmetry. Since the complete anterior wall of the right frontal sinus was involved and deformed, it was indicated to remove it entirely to prevent recurrence of the osteomas as far as possible and to obtain the best possible aesthetic result.

MyBone Custom implant (MBCI) (Cerhum SA, Liège, Belgium), which is a made of porous hydroxyapatite was chosen for the reconstruction. Detailed digital workflow and additive manufacturing processes associated with this patient-specific implant are described elsewhere [7,8].

Additionally, three patient-specific cutting guides (3D-CUT, 3D-Side, Mont-Saint-Guibert, Belgium) were manufactured in polyamide with a selective laser sintering technology (EOS, Krailing, Germany) (Fig. 2A). The primary resection guide was planned to cut through the anterior wall of the right frontal sinus while avoiding damage to the different sinus walls (inter-sinus wall, orbital roof and posterior wall) (Fig. 2B). A secondary guide based upon the osteomas was planned to indicate precisely the lateral resection to be performed in addition to the primary resection guide for the correct positioning of the implant. The tertiary guide indicated the implant positioning and the resection depth required for an ideal implant fit (Fig. 2A). To ensure precise positioning of the secondary and tertiary guides, a lateral part fitting the right orbit lateral wall, an area without osteomas that can be used as a reference, was added. MBCI was designed to reconstruct the anterior frontal sinus wall (Fig. 2C) and to be secured with two plates.

2.2. Surgical procedure

The surgery was performed in September 2023 under general anesthesia, utilizing the pre-existing bi-coronal scar for access. A first detachment into Merckel's space was performed, followed by a subperiosteal dissection of the first osteoma down to the upper orbital rim (Fig. 3A). The two supraorbital nerves were then liberated. The lateral wall of the right orbit was also freed, to serve as a reference for the implant positioning guide. The primary cutting guide was then positioned over the right frontal osteoma (Fig. 3B). A cylinder was present on this guide indicating the milling axis to accurately direct the resection of the frontal sinus anterior wall without risking reaching the inter-sinus septum and the frontal sinus posterior wall. The sinus was opened using a drill and the mucosa was completely removed to minimize the risk of postoperative mucocele formation (Fig. 3C). Subsequently, the secondary guide was used to indicate precisely the area to resect and, accurately shaping it to conform to the specifications of the MBCI (Fig. 3D). The lateral part of the guide, positioned on the lateral wall of the right orbit, was an important feature making sure the guide was in the correct position. Bone drilling was performed, starting from the middle and progressively reaching the edges of the marked area (Fig. 3E and F).

The tertiary guide, matching the shape of the MBCI, was employed to verify the adequacy of the resection and ensure proper fit of the MBCI within the bone (Fig. 4A). The symmetrical and smooth craniofacial surface was achieved by meticulously shaping the bone with a burr (Fig. 4B). Lastly, the MBCI was positioned and secured with two X-

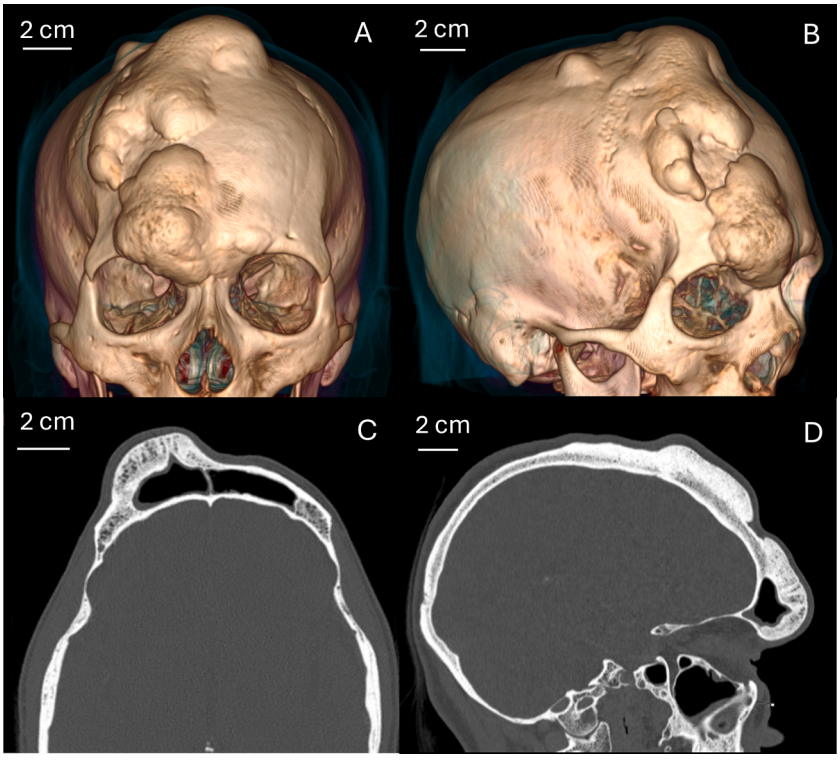

Fig. 1. Pre-operative views of the patient. (A) 3D reconstruction front view and (B) side view; (C) and (D) CT-scan axial view and sagittal view respectively.

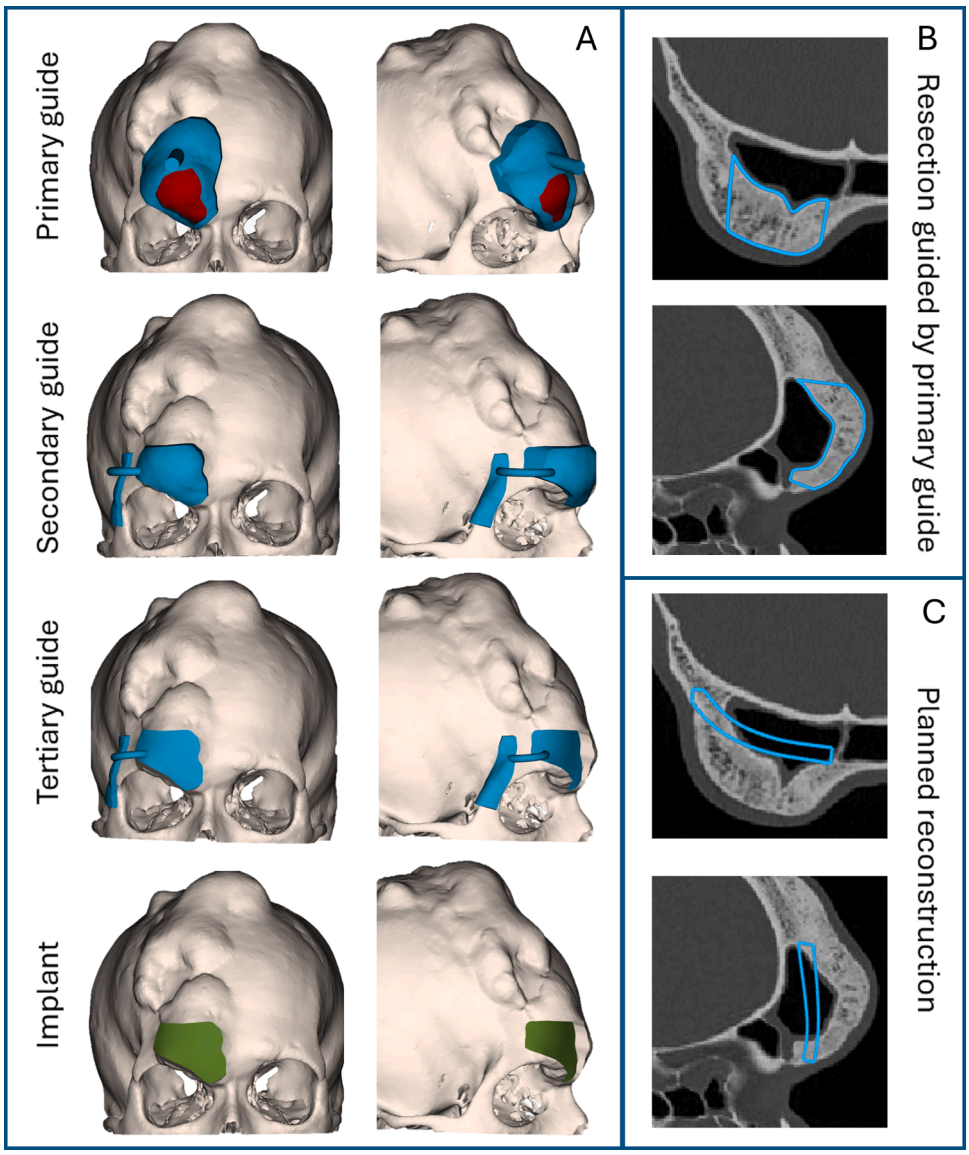

Fig. 2. Preoperative planning – (A) 3D representation of the 3 cutting guides and the implant design (B) Axial and sagittal views of the guide resection; (C) Axial and sagittal views of the planned reconstruction.

shaped titanium plates (Osteomed, Saint-Ouen-l'Aumône, France), two lateral screws (Ø2 mm, 6 mm) and two medial screws (Ø2 mm, 4 mm) (Fig. 4C and D). In order to ensure optimal healing and minimize post-operative complications, two aspirating drains were placed, and the wound was closed with two layers of sutures.

2.3. Outcome and follow-up

One day after the surgery, radiological investigations revealed optimal implant positioning and confirmed the integrity of the frontal sinus walls (Fig. 5 [A-D]). Due to considerable improvement, the patient was discharged from the hospital on the second postoperative day and follow-up consultations were conducted at 1, 3, 6 and 12 months post-op. The 6-month post op CT scan demonstrated ossification of the MBCI on the edges and the absence of osteoma recurrence (Fig. 5E and Fig. 5F). This findings were further confirmed by the one-year post-operative CT scan.

Clinically, frontal and parietal symmetry was satisfactory (Fig. 6). Even if the patient reported experiencing mild pain and discomfort after the surgery, she expressed contentment with the outcome, discontinued the use of head covering, and gained the confidence to pursue employment opportunities that she had not previously dared to.

3. Discussion

Similarly to approximately 30 % of the cases, the osteomas reported in this case report are associated with history of head trauma. Bleeding or swelling under the periosteum, coupled with muscle tension that raises the periosteum in the cranial area, can initiate an osteogenic response, potentially resulting in the development of tumors. [2]

This patient was lost to follow-up, and the osteomas had growth already extensively once she presented herself again. Surgical intervention was necessary due to the significant aesthetic concerns and reconstructive surgery was necessary in addition to the resection due to the involvement of the right frontal sinus. Similarly to others [6,9] a bi-coronal approach was preferred. It is, in fact, advised in case of voluminous tumors to have a good exposition while keeping a discrete scar if the patient is hairy [9].

For the resection, the use of cutting guides allowed to preserve the inter-sinus wall, the orbital roof and the sinus posterior wall, and to obtain a resection adapted to the planned PSI and to ensure good bone contacts.

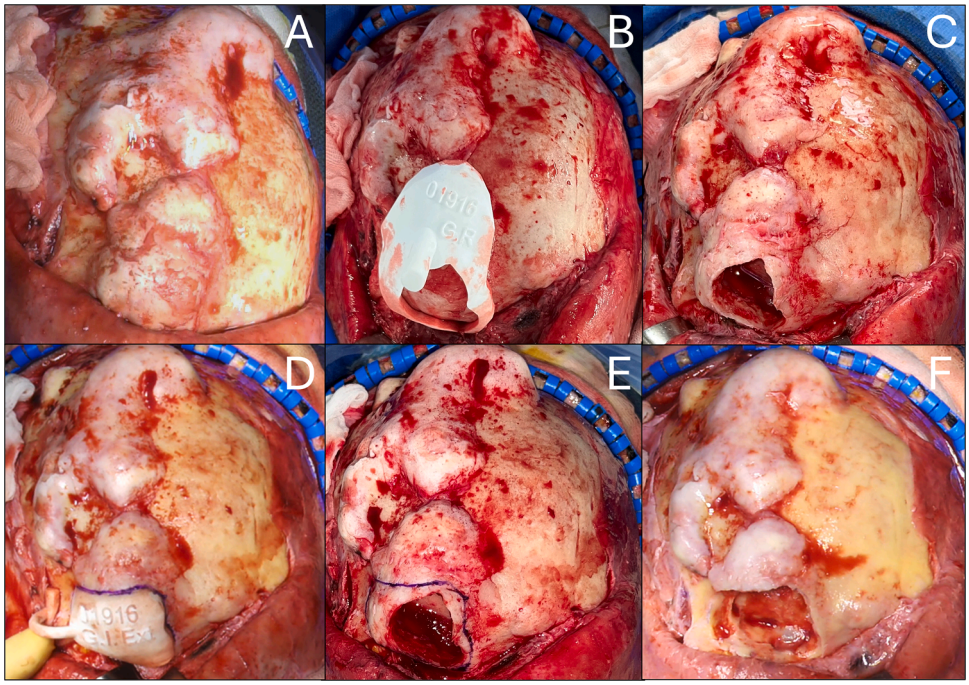

Fig. 3. Intraoperative photographs – (A) Preoperative situation; (B) Primary cutting guide positioned over the right frontal osteoma; (C) Situation after the resection with the primary cutting guide; (D) Secondary cutting guide positioned over the right frontal osteoma; (E) Delineation of the area to resect (F) Situation after the resection with the secondary cutting guide.

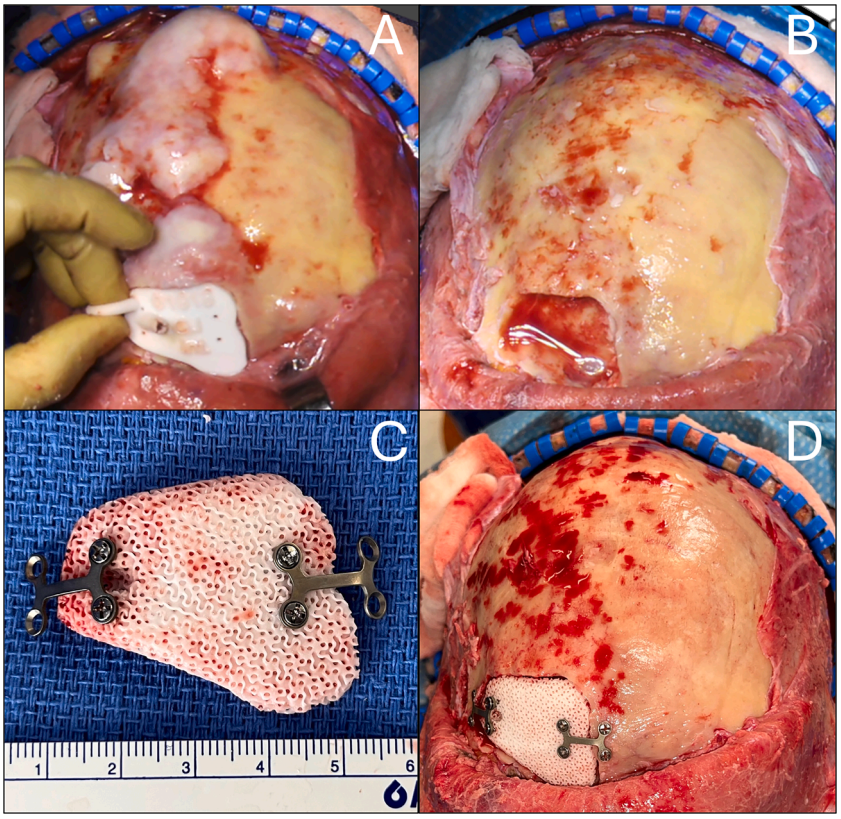

Fig. 4. Intraoperative photographs – (A) Resection size verification with tertiary cutting guide; (B) Situation after removal of all the osteomas; (C) MyBone Custom Implant with the osteosynthesis material; (D) Reconstruction of the right frontal sinus with MBCI.

In order to have an accurate excision, it was decided to first perform the resection of the right frontal sinus and secondly to drill the osteomas covering the external table of the parietal and frontal bones where no cranial invasion was present. The contrary was not possible since the cutting guides could only be planned based on the pre-operative anatomical situation. Third and last, the frontal sinus was

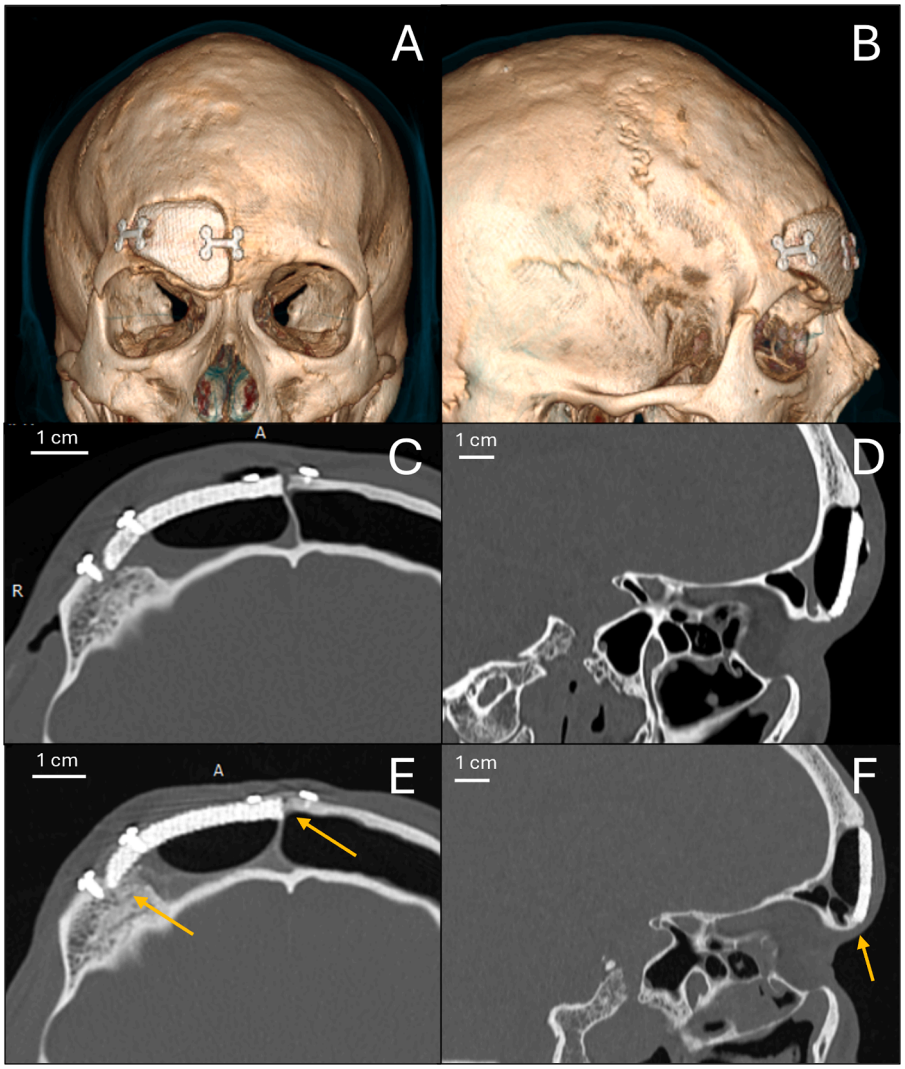

Fig. 5. Postoperative follow-up – (A) & (B) 3D frontal and side views of the postoperative situation.; (C) & (D) 1-day post-operative CT scan, axial and sagittal views respectively; (E) & (F) 6-month post-operative CT scan, axial and sagittal views respectively; arrows are pointing to the osteointegration signs.

reconstructed with PSI once the drilling was complete to avoid damaging the MBCI.

Since the inter-sinus septum and the frontal sinus posterior wall were intact, the resection technique described by Fanchette et al. [9] was not adequate to keep them intact. Guidance of the resection depth was necessary. To the best of our knowledge, it is the first time such cutting guide sequence has been presented.

With regards to the reconstruction, autologous parietal bone is the gold standard technique for frontal bone but it rarely delivers good aesthetic results, especially when addressing complex bone shapes, such as those near the periorbital area [6]. Therefore a PSI was preferred. Titanium PSI was discarded due to the risk of osteoma recurrence, in such case the titanium would hinder its excision. Hydroxyapatite PSI on the other hand can be removed similarly to bone in case of osteoma recurrence and already showed good results for frontal sinus reconstruction [6].

In particular, MBCI has already demonstrated efficacy in various craniomaxillofacial applications in promoting osteointegration and achieving good aesthetic results [7,8,10].

The post-operative follow-up is encouraging. Already after 6 months, the edges the hydroxyapatite PSI have ossified, while others do not report any post-operative scan describing the evolution of the reconstruction [6,9].

As expressed by Verbist *et al.* [10], hydroxyapatite custom-made implants are recommended for the reconstruction and aesthetic enhancement of anatomical structures. Hydroxyapatite resembles the natural chemical composition of bone, ensuring excellent biocompatibility. Additionally, its osteoconduction, osteointegration and vascularization capabilities make it an ideal candidate for repairing bone defects [6,8]. While hydroxyapatite is sometimes qualified as brittle and attached with suture threads by others [6], MBCI can be tightly fixed with screws as demonstrated in this case and elsewhere [7,10].

4. Conclusion

Our work demonstrated that thanks to good preoperative planning and the use of PSI, many cases that were not treated due to their surgical complexity can be treated. This case report aims at describing an effective surgical procedure to treat extensive frontoparietal osteomas with additive manufacturing technologies and patient-specific solutions. The meticulous pre-operative 3D planning and the application of a series of cutting guides reduced the surgical risks associated with this procedure. Additionally, while the aesthetic implications of this case were significant, the reconstruction of the frontal bone using a 3D-printed hydroxyapatite patient-specific implant proved highly satisfactory both in terms of aesthetic results and restoring the bone integrity and allowed the patient to regain a normal life.

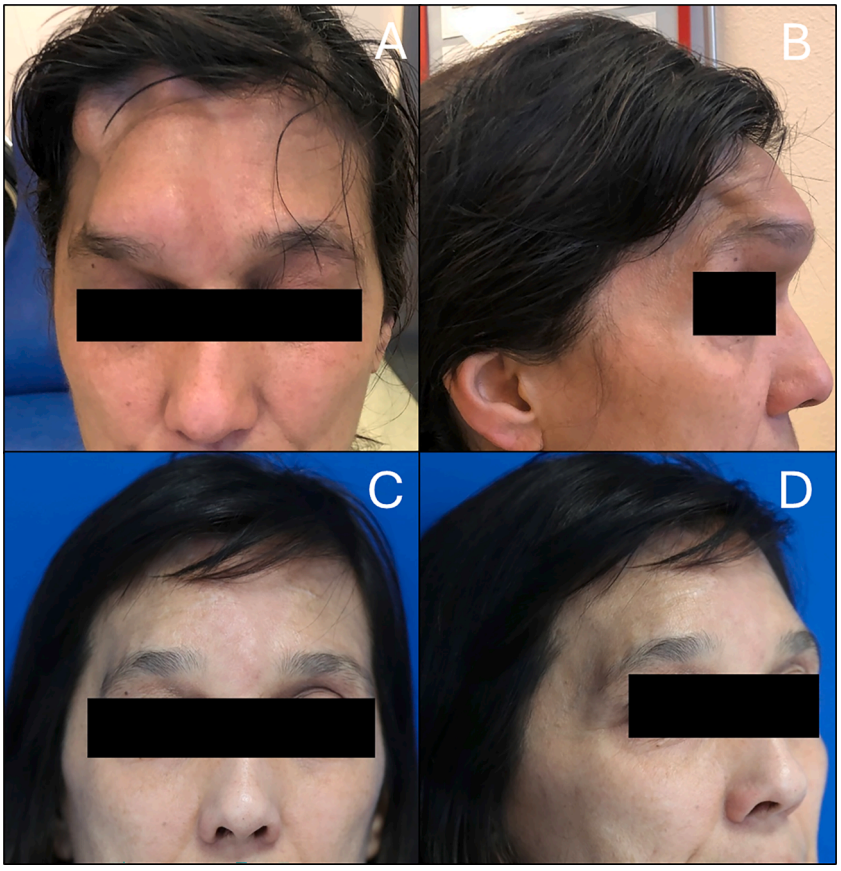

Fig. 6. (A) & (B) Pre-operative photographs, frontal and side views; (C) & (D) Post-operative photographs, frontal and side views.

Patient consent

Written informed consent was obtained from the patient for her anonymized information and images to be published in this article.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: FH and EC are CERHUM employees. The other authors have no conflict of interest.

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