



# Intraoperative imaging and navigation with mobile cone-beam CT in maxillofacial surgery

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## Abstract

**Introduction** Intraoperative mobile Cone-Beam Computed Tomography (CBCT) trends to develop for the management of complex facial fractures. It allows a real-time imaging and surgical navigation.

**Aim** Through the presentation of two clinical cases, we aimed at presenting the procedure of intra-operative CBCT and new applications in maxillofacial surgery.

**Results** A young patient with extended orbito-frontal fibrous dysplasia, and a child with the recurrence of a temporomandibular joint ankylosis secondary to mastoïditis, were operated using an intra-operative imaging control. In both cases, the intraoperative CBCT increased precision and safety of the bone resection. No surgical complication was noted and a good healing was obtained.

**Conclusion** Intraoperative CBCT raises the problems of radiation exposure and increased operating time. However, it represents a useful imaging tool and a navigation system in complex situations as osseous dysplasia and surgery of the temporo-mandibular joint.

**Keywords** Intraoperative · Cone-beam computed tomography · Neuronavigation · Maxillofacial surgery

## Introduction

Intraoperative computed tomography (CT) has been used for many years in orthopaedic, spine [1] and neurosurgery [2] to increase safety and accuracy of the surgical procedures. More recently, some authors described the use of intraoperative imaging in zygomaticomaxillary complex (ZMC) fractures, showing a high rate of intra-operative revision of the bone reduction and fixation [3–6]. Because of the increase of the operative time, the cost and the radiation exposure with such technology, its use in every facial fracture seems inappropriate [7].

Most of navigation systems rely on information from intraoperative images [8]. Various intraoperative imaging devices have been described including ultrasonography, fluoroscopy and spiral CT [5]. Exposing to lower radiation, and having the same size as C-arm fluoroscope with mobile capability, the

intraoperative cone-beam CT (CBCT) tends to replace the conventional CT [4, 5, 8, 9].

Intraoperative navigation was shown to be useful in complex reconstruction of the orbits, the cranium and the temporomandibular joint (TMJ) [10]. Mobile CBCT offers a promising alternative for intraoperative imaging and navigation [8]. Through the presentation of two clinical cases, we aimed at presenting the procedure of intra-operative CBCT and new potential applications in maxillofacial surgery. Due to the retrospective nature of this study, it was granted in writing an exemption of ethics committee by the Nantes University Hospital.

## Case report number 1

A 22-year-old patient was referred for a left fronto-orbital fibrous dysplasia. He complained his forehead and orbit aspects. The clinical examination revealed an orbital asymmetry and a left frontal bump, without any visual attempts (Fig. 1). The craniofacial CT scan showed a left ethmoido-fronto-sphenoidal extended fibrous dysplasia with exophthalmia (Fig. 1). The bone scintigraphy revealed a monostotic disease, and the histopathologic examination on a surgical biopsy confirmed the diagnosis.

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**Fig. 1** Patient number 1 presenting with a left fronto-orbital dysplasia. Facial photographs in a frontal view (a), and a profile view (b), showing the frontal bump and the vertical orbital dystopia in intra-operative time. Intra-operative axial CBCT section showing the left fronto-orbital fibrous dysplasia (c)



A combined approach was decided to remove this bone dysplasia, through the use of preformed cutting guides, and the CBCT intraoperative navigation. The head of the patient was immobilised in a carbon Mayfield head support, and a referential arm was placed near the head and oriented towards the navigation system receiver. A two-dimensional (2D) acquisition was first realised to locate the good position for the device. A bicoronal incision was carried out to expose the fibrous dysplasia from the frontal bone to the supra-orbital edge (Fig. 2), while a subciliary approach allowed to control the orbital floor. An intra-operative three-dimensional (3D) acquisition with the O-arm CBCT system (O-Arm® surgical imaging, Medtronic, Louisville, USA) was carried out, allowing the intra-operative navigation (Fig. 2), and better accuracy of bone resection close to orbital walls and skull base. The postoperative examination and CBCT acquisition revealed a good bone resection (Fig. 3). The healing 6 weeks after surgery was uneventful and the long-term follow-up revealed an acceptable surgical outcome.

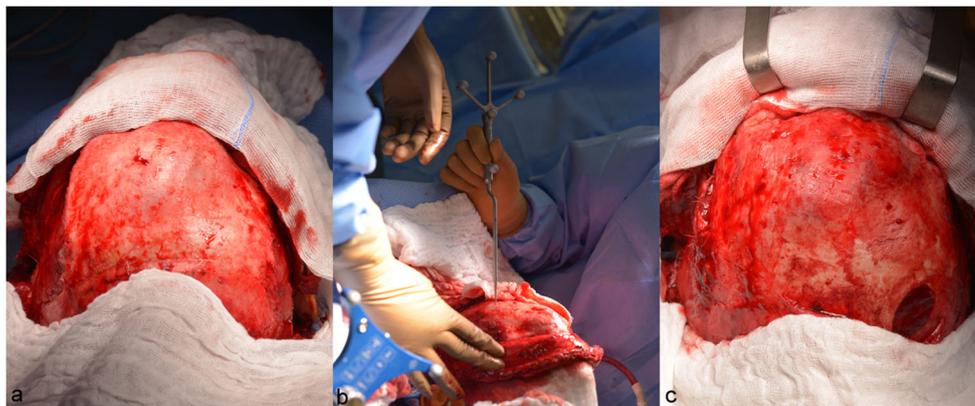
## Case report number 2

A child of 5 years of age was addressed for the recurrence of a left TMJ ankylosis secondary to an advanced

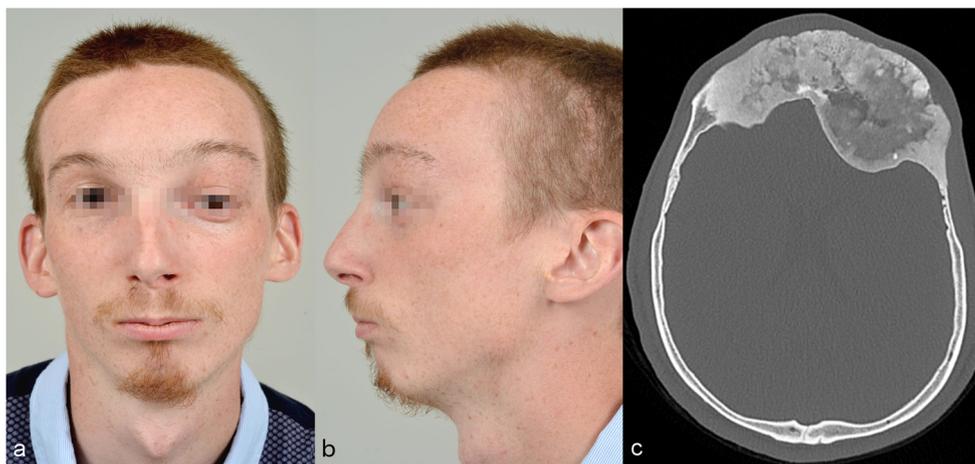
otomastoiditis in childhood. The clinical examination revealed a 4-mm mouth opening with obliquity of the occlusal plane, secondary to the maxillomandibular growth problem. This patient was already given an ankylosis block resection, and a simultaneous reconstruction of the left TMJ with a chondro-costal graft 1 year before. The intra-operative CBCT confirmed the recurrence of the complete left TMJ ankylosis (Fig. 4).

A new surgical resection was decided with no immediate reconstruction of the ramus, and a delayed costochondral grafting. A left pre-tragien incision was achieved to reach the TMJ block. An intra-operative O-arm acquisition was made to calibrate the device around the area of interest (Fig. 5). A left pre-tragien incision was achieved to reach the TMJ block. Then, the bony block was resected starting at the inferior border of the planed resection area, with the help of a navigated styler. The O-arm allowed a better surgical precision and safety during the bone resection (Fig. 5). The pathologic bone was completely resected from the superior part of the glenoid cavity to the mandibular lingula with no intra-operative complication. The mouth opening was immediately improved in postoperative time, and the CBCT confirmed a complete resection of the TMJ ankylosis (Fig. 6).

**Fig. 2** Intra-operative pictures of the bone resection in patient number 1. Exposition of the frontal bump after bi-coronal approach (a). Use of the navigation styler to estimate the depth of the bone resection (b). Frontal bone after bone removal and modelling (c)



**Fig. 3** Postoperative pictures of patient number 1 in frontal (a) and profile (b) views showing the correction of the frontal pump and a partial correction of the eye dystopia. Axial CBCT section showing the frontal bone remodelling after surgery (c)



**Discussion**

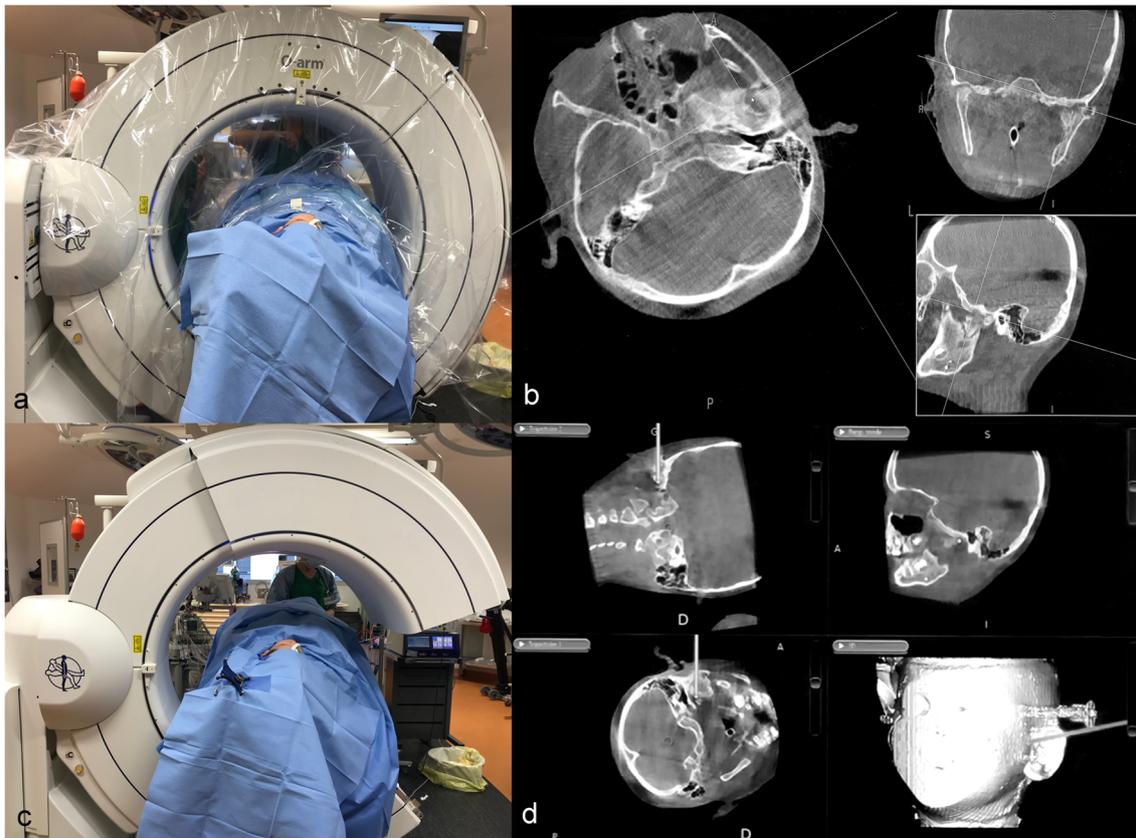
The O-arm cone-beam CT is a mobile CT imaging device allowing a 3D acquisition of facial skeleton and a real-time tracking system. It combines high-resolution fluoroscopy, conventional radiology and live 2D or 3D informations. The intra-operative navigation allows the surgeon to follow the real-time position of a pointer, a surgical drill or an anatomic structure with increased precision. In the light of the literature, various applications have been described in craniofacial surgery, particularly regarding the surgery of the orbite and the skull base. In maxillofacial traumatology, radiological imaging is routinely performed postoperatively to assess the bone reduction [5]. However a suboptimal radiological and then clinical outcome rarely leads to a second surgical intervention to avoid the morbidity of a second look [11]. The use of an intraoperative CT was showed to increase the rate of intra-operative revision of the reduction and/or fixation in orbital and ZMC fractures [5, 12, 13], reaching 26% in complex facial fractures [14]. The computer-assisted navigation helps the craniofacial surgeon in assessing position, pro-

jection and symmetry of the facial skeleton in complex cases, including TMJ ankylosis and fibrous dysplasia [3]. However, most of the navigation systems rely on data from intra-operative images, and can be the source of potential errors since the systems do not take account for anatomical deformation during surgery [8]. Furthermore, these systems require a surface matching for referencing patient to the system, leading to potential errors. That is why intraoperative imaging, particularly the mobile CBCT devices, may be beneficial by improving surgical precision and safety for the patient. We report the use of the O-arm cone-beam CT imaging and navigation in the bone resection of facial fibrous dysplasia and TMJ ankylosis. To our knowledge, that is the first report of the use of such technology in these indications.

The mobile CBCT imaging raises the problem of the radiation generated, by adding a CT imaging to the intra-operative and postoperative imaging routinely achieved. Some authors argue for lower radiation exposure than conventional CT scan, and that the risk should be weighted against a persistent malreduction or malpositioning [5, 15]. It also increases the

**Fig. 4** Intra-operative craniofacial CBCT in patient number 2. Frontal reconstruction (a), and three-dimensional reconstruction (b) revealing a recurrence of a complete left TMJ ankylosis after costochondral graft





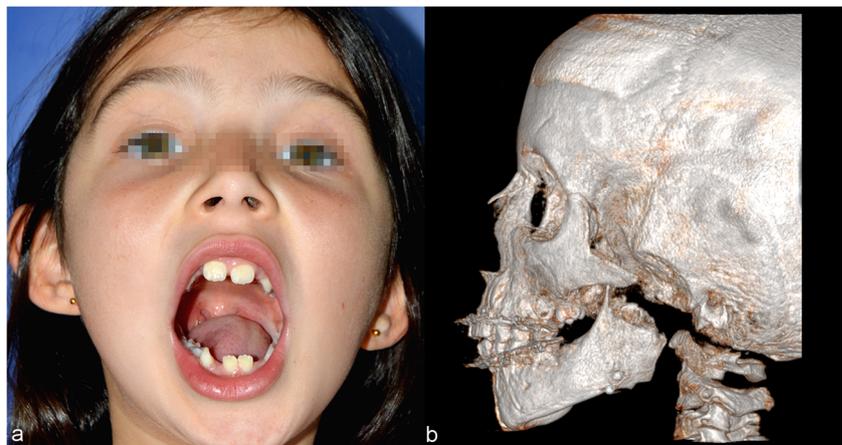
**Fig. 5** Intra-operative pictures of the use of the O-arm system. Intra-operative acquisition (a) and the multiplanar reconstruction are centred around the area of interest (b). Then, the equipment is removed from the surgical site (c), and the use of a stylus allows the computer-assisted navigation (d)

operative time from 28 to 65 min [6, 12, 13, 16], due to the patient draping, the CBCT positioning, acquisition and data processing [15]. The intraoperative CBCT imaging presents the advantage of a low level of metal artefact, which is particularly interesting in the dental area, but it does not allow the visualisation of the facial soft-tissues [9, 14]. Surgery in the mandible is constrained by the difficulty to navigate a mobile structure by using a computer-assisted system; the use of an intermaxillary fixation, an occlusal splint or special sensors mounted on the mandible, could help the navigation [3].

Finally, in our experience, the cranial sensor placed at the top of the head can interfere with the surgical procedure in the fronto-temporal region. All the advantages and inconvenients of the intraoperative CBCT are listed in Table 1.

With respect to the ALARA (as low as reasonably achievable) principle of radioprotection, mobile intraoperative CBCT can be proposed in complex cases of facial fractures, bone tumours particularly regarding the orbite and the skull base, and TMJ surgery. Further studies are needed to provide outcome data and cost-benefit analyses for intraoperative

**Fig. 6** Postoperative craniofacial CBCT in patient number 2. Frontal reconstruction (a) and three-dimensional reconstruction (b) showing the complete resection of the ankylosis block on both mandibular and skull base sides



**Table 1** Summary of advantages and inconvenients of the O-arm CBCT in maxillofacial surgery

Advantages	Inconvenients
Intraoperative precision	Radiation generated
Prevent surgical errors in reduction	Increased operating time
Prevent secondary procedure	No visualisation of the soft tissues
Low level of metal artefacts	Splint required for mandibular navigation
Substitute to the postoperative imaging	Increased costs
Update current information about bone anatomy during surgery	Antenna placed at the top of the head interfering with the surgical procedure

CBCT for these specific indications in maxillofacial surgery. The use of preformed cutting guides in maxillofacial sphere represents a good alternative in securizing the bone resection and in increasing accuracy during osteotomy [17, 18]. It is a reliable technique in mandibular bone resection, but it is still an expensive process and it does not allow a surgical navigation. Furthermore, the advent of surface CBCT would help maxillofacial surgeons to navigate the soft parts more objectively [19].

**Conclusion**

The intra-operative CBCT represents a useful imaging tool and navigation system in bone resection of craniofacial fibrous dysplasia and surgery of the temporomandibular joint.

**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** Due to the retrospective nature of this study, it was granted in writing an exemption of ethics committee by the Nantes University Hospital.

**Informed consent** Informed consent was obtained from patients (and legal guardian) included in this study.

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