Oral and Maxillofacial Surgery Cases 3 (2017) 56–60

Contents lists available at ScienceDirect

Oral and Maxillofacial Surgery Cases

journal homepage: www.oralandmaxillofacialsurgerycases.com

Case Report

Intraoperative imaging O-Arm™ in secondary surgical correction of post-traumatic orbital fractures

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ARTICLE INFO

Article history:
Received 20 September 2016
Received in revised form 31 March 2017
Accepted 19 April 2017
Available online 25 April 2017

Keywords:
O-Arm™
Intraoperative imaging
Orbital fractures
Craniofacial deformity reconstruction
Post-traumatic craniofacial fracture

ABSTRACT

Purpose: To determine the safety and efficacy of O-Arm™ intraoperative imaging in maxillofacial surgery of post-traumatic orbital fractures. In order to ensure correct placement of titanium plate, immediately after fixing, viewable, in the axial, sagittal and coronal images.

Methods: The authors evaluated 5 consecutive adult patients with orbital fractures who required a reoperation involving displacement of titanium mesh between January and December 2015. The displacement or incorrect positioning of titanium mesh was detected at post-operative CT scan or clinical neurological findings. Intraoperative O-Arm™ imaging was used for our patients who underwent secondary maxillofacial orbital fracture surgery due to the failure of first surgical approach.

Results: An eyelid incision was performed in order to obtain maximal exposure and minimizing cosmetic defects. Any previous fixation device was skeletonized and removed, any improperly reduced fracture was mobilized, reduced and refixated with 1.5 mm plates, screws and titanium mesh. The intra-operative O-Arm™ imaging technique was used at the end of the procedures. In 4 cases it confirmed the appropriateness of the newly obtained reconstruction, in 1 case a first scan showed a suboptimal result and the devices were correctly repositioned, guided by the O-Arm™ images.

Conclusions: Intraoperative O-Arm™ assisted craniofacial reconstruction surgery improves the assessment of neurovascular structure decompression, skeletal fragment identification, fixation procedures and for the correct re-establishment of facial symmetry in orbital floor fractures.

1. Introduction

Orbital floor fractures are the most frequently injured areas in maxillofacial trauma and the major events involved are motor (80.9%) or sport accidents (14.2%), and direct pounding on the face (4.76%) [9].

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http://dx.doi.org/10.1016/j.omsc.2017.04.002

Diplopia, enophthalmos and blindness are the most common complications of orbital trauma and midface reconstruction and may become permanent if not treated [4]. Management of craniofacial injuries requires careful preoperative planning. It is also common practice for many neurosurgeons to obtain postoperative imaging to ensure the correct placement of the titanium plate. Therefore, computed tomography (CT) has become the gold standard for the diagnosis and radiological follow-up of maxillofacial injuries. Especially as, until now, it has only been possible to monitor the alignment of orbital floor fractures postoperatively with a CT examination with coronal sectioning. An incorrect positioning may require further surgical procedures or, eventually, cause damage to critical neurovascular structures. Intraoperative imaging allows the realization of a multidimensional anatomic map that provides, in cranial and spinal procedures, a guide for surgical decision making.

In recent years, the use of an intraoperative 3D anatomic imaging system: O-Arm™ (Medtronic Sofamor Danek, Memphis, TN, USA) has spread in spinal surgery [8]. The O-Arm™ is a full-rotation, multidimensional imaging system. It is a mobile CT scanner designed for intraoperative use, providing standard fluoroscopic images and 3-D volumetric CT scans. The O-Arm™ is compatible with conventional surgical tables, it allows for immediate real-time image guidance with multi-planar higher image resolution views. Although it is well described with regard to spine surgery, the use of the O-Arm™ in cranial surgical patients has been less commonly reported.

Careful understanding of the complex anatomy and relationship in craniofacial fractures and pathology is difficult with two-dimensional (2-D) imaging (for example, plain radiographs), on the other hand, three-dimensional (3-D) imaging modalities such as CT scans and MRI have become routine in the pre- and postoperative evaluation of craniofacial disorder.

The purpose of this study was to define the safety and efficacy of O-Arm™ imaging in cranial surgical patients with complex craniofacial post-traumatic deformities in which the first surgical approach failed.

2. Material and methods

We studied 5 adult patients with orbital fractures who consecutively required a re-operation due to displacement of the titanium mesh between January and December 2015. They underwent maxillofacial surgery using intraoperative O-Arm™ imaging and we have illustrated 2 of those cases in detail.

A single surgical team, including neurosurgeon and maxillo-facial surgeon, performed all surgeries. Patients included in the study agreed to use intraoperative imaging and surgical procedure simultaneously. Patient demographics, operative details, complications related to titanium plate placement, additional surgeries, and perioperative outcome were evaluated and compared with cases that underwent a conventional postoperative radiological follow-up after maxillofacial reconstruction. The scanning time with the O-Arm™ Imaging system was about 13 s (normal definition) with the head protocol: 120 kVp (kilovolts peak), varying mA (milliamperes), 1 rotation, 391 pulses of 10 ms each (beam-on time 3.91 s per acquisition) [2].

3. Surgical technique

After intubation and under general anesthesia, a Mayfield frame was positioned and the patient was placed in a supine position. A swinging eyelid incision (transconjunctival with lateral canthotomy) was performed to obtain maximal exposure while minimizing cosmetic defects. Wide underperiosteal dissection of the lateral wall, the floor and the medial wall of the fractured orbit and zygoma was carried out. Any previous fixation device was skeletonized and removed. Then, any improperly reduced fracture of the lower and/or lateral rim was mobilized, reduced and fixated using 1.5mm plates and screws. Then all fractures involving the orbit were managed. In detail, the herniated orbital content was reduced and the walls reconstructed with titanium mesh.

4. Illustrative cases

4.1. Case 1

A 37-year-old male with diplopia presented displacement of the left orbital titanium mesh. CT scan of the facial bone confirmed plate malpositioning. The patient had required surgical treatment for correction of the post-traumatic orbital left fracture three years earlier. The intra-operative O-Arm™ imaging technique was used and assisted us during all surgical procedure steps. Intraoperatively, we visualized (Fig. 1a,b,c) and removed the implants placed previously, then we repaired the walls of the orbit and confirmed the correct restoration of orbital structures (Fig. 2a,b,c). Pre-, intra- and post-operative (Fig. 3a,b,c) pictures were compared, indicating the correct placement of new titanium mesh and the clinical correction of diplopia was achieved.

4.2. Case 2

A 30-year-old female sustained a high-speed traffic accident injury 4 years earlier. She had been treated for a complex left orbital fracture elsewhere (Fig. 4a,b,c). Two years after the first operation, she underwent surgical removal of orbital mesh, as a CT scan follow-up had shown displacement of the plates and screws fixed in the orbital floor. When she came to our

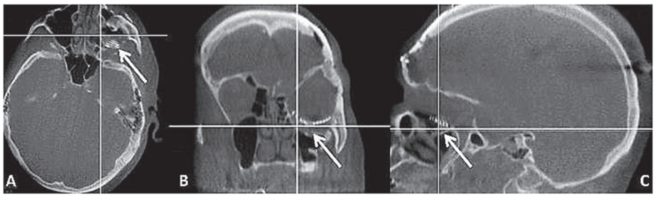

Fig. 1. First intra-operative O-Arm scan imaging. White arrows show in axial (A), coronal (B) and sagittal (C) plane orbital mesh displacement.

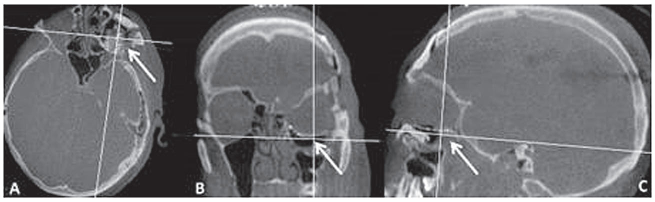

Fig. 2. Second O Arm intra-operative scan. White arrows show titanium mesh in axial (A), coronal (B), and sagittal (C) plane and correct orbital plate reconstruction.

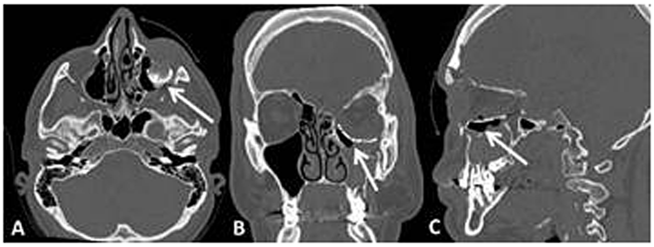

Fig. 3. Post-operative follow-up CT scan. White arrows show correct placement of new titanium mesh in axial (A), coronal (B), and sagittal (C) plane.

attention, she presented ocular dystopia and enophtalmos. Intraoperatively, we removed all of the devices placed previously, reduced the orbital content and restored wall integrity by means of titanium meshes. A first O-Arm™ Scan (Fig. 5) showed a suboptimal result both of the rim reduction and in terms of mesh positioning.

Guided by O-Arm™ images, we then repositioned the devices correctly. A new O-Arm™ scan showed a good result (Fig. 6).

5. Results

We studied 5 adult patients (Table 1), 3 male and 2 female, with median age 30.4 (range 18–41). We used intraoperative O-Arm™ imaging for all cases to verify the correct placement of titanium mesh in orbital fracture reconstruction. In 4 cases, the first surgical result was good. In one case, we had to perform a new placement of orbital titanium mesh, due to unsatisfactory reconstruction at intraoperative imaging (Case 2). We did not observe any complications, except for a transient exophthalmos.

Moreover, all post-traumatic patients in our series, underwent CT scan follow-up, which is the practice in our department. The intraoperative O-Arm™ imaging and the postoperative conventional CT scan of the 5 patients in our series were compared and the radiological results were similar.

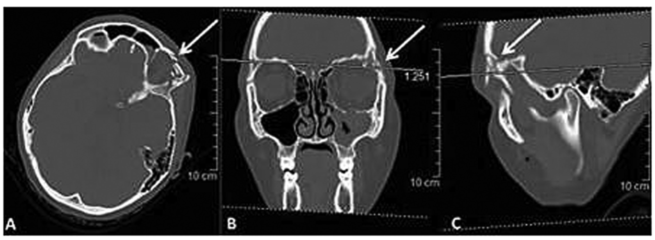

Fig. 4. Pre-operative CT scan. White arrows show complex orbital fracture in axial (A), coronal (B), and sagittal (C) plane.

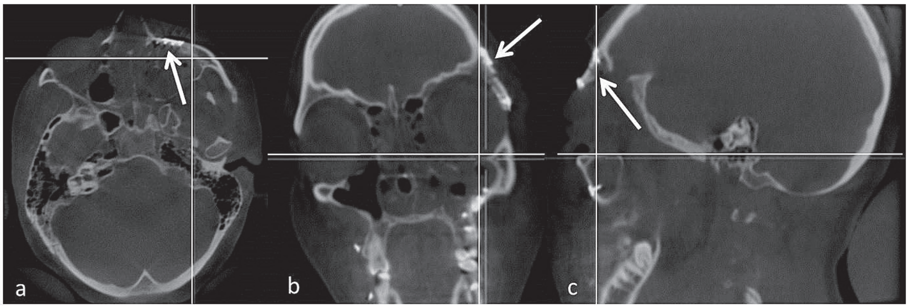

Fig. 5. First intra-operative O-Arm scan imaging. White arrows show in axial (A), coronal (B) and sagittal (C) plane inaccurate positioning orbital mesh.

Fig. 6. Second O Arm intra-operative scan. White arrows show titanium mesh in axial (A), coronal (B), and sagittal (C) plane and careful orbital plate reconstruction.

Table 1
Summery of surgical, radiological and clinical data of case series.

N. Pz	Age	Sex	Orbital Fracture	Pre-operative Symptoms	Complications	Post-operative Symptoms	Post operative Ct scan/O Arm
1	37	M	Left	diplopia	*N*	N	Y
2	30	F	Left	enophtalmos	*N*	N	Y
3	26	M	Right	visual loss	*N*	N	Y
4	41	F	Left	diplopia	*Y*	Transient exophthalmos	Y
5	18	M	Right	subcutaneous emphysema	*N*	N	Y

6. Discussion

Raza et al., reported results from a cadaveric study obtained comparing the 3D skull base bone from O-Arm™ images and cadaveric dissection [5]. The authors noted high matching anatomical data extracted from the O-Arm™. The O-Arm™ entails less radiation than conventional CT scans, it requires a very short acquisition time and is easy to use. The O-Arm™ allows the identification of osseous structures, or structures hyper- or hypodense to the parenchyma, such as ventricular catheters or cerebrospinal fluid spaces. As reported in an economic study analyzing the cost-effectiveness of the intraoperative CT scan (used for lumbar fixation), the use of the O-Arm system seems to suggest an economic advantage, when it is used to perform a minimum of 154 surgical interventions per year in a period of 8 years.

An additional benefit of using the O-Arm system is the possibility of not needing to perform a CT scan in the pre-surgical phase and a CT scan or an X-ray in the postsurgical phase. This would positively affect the imaging department by shortening the waiting lists for the performance of CT and/or X-ray examinations. If the use of the O-Arm is part of the daily surgical practice of a department for different procedures, its supplementary use in maxillofacial surgery should be a way to improve the surgical outcome, reducing the number of post-operative CT examinations and the cost-effectiveness of the scan itself. So, analyzing economic aspects, we suggest advantageous to consider intraoperative imaging system, verifying the precise placement of the titanium mesh and to correct them during the same surgical procedure if necessary. This intraoperative imaging approach decreases the second procedure rate and permits the reduction of any potential medical and legal risks [1].

Conventionally, definitive information regarding the results of the surgical reduction of fractured bone fragments is produced by postoperative X-ray control. Notwithstanding, obtaining the intraoperative images, the revision rate may be reduced drastically, avoiding additional surgical procedures. In fact, an incorrect fragment reduction often requires further surgical procedures and general anesthesia.

A late literature review of 2014 [10], focused on the intraoperative imaging effects on facial symmetry subsequent to a cranio-maxillo-facial fracture reduction, examining the frequency of additional reduction of the zygoma and orbital floor following intraoperative imaging. The additional reduction rate was 18% (14 patients of 76 included) in zygoma fractures and the revision rate in orbital floor following intraoperative imaging was 9% (7 patients of 80 examined). The review suggested that the information obtained from intraoperative imaging is useful for the surgical management of cranio maxillo facial fractures. Singh et al., confirmed that the use of intraoperative CT scans might improve the accuracy of craniofacial fracture corrections and decrease the rate of potential additional surgeries, particularly in complex maxillofacial traumas [7]. With advances in science and technology, the development of computer-assisted preoperative planning soft-ware has made three-dimensional (3D) observation and simulation of skull base surgeries possible. The computer-designed results can be applied during the operation by a process of navigation or intraoperative assistance. Intraoperative imaging plays an integral role in maxillofacial reconstruction in order to allow real-time image acquisition and perform intraoperative revisions for the mal-reduction or mal-positioning of implants. The secondary correction of post-traumatic craniofacial deformity requires detailed preoperative clinical and radiological planning [3]. The main objectives of craniofacial reconstruction are functional integrity and a good aesthetic result, where possible. Intraoperative imaging with O-Arm™ improves both clinical and radiological outcomes. During the surgical procedure, intraoperative O-Arm™ allows the verification of correct plate placement and assesses the proper modeling angle, so as to reduce the reoperation rate. Intraoperative CT monitoring is considered a useful surgical aid in secondary correction surgery. Its advantage is the immediate monitoring of the surgical reduction, especially in orbital floor fractures where vascular and nervous structures are involved. We want to stress that the quality of imaging with the intraoperative O-Arm™ is sufficient to evaluate the surgical outcome with a low radiation dose, possibly replacing a conventional post-operative bone window CT scan. Shaye DA reported that performing intraoperative CT scans during maxillofacial surgery adds approximately 14.5 minutes per case, therefore, the use of intraoperative CT imaging should be considered in maxillofacial reconstructive surgery [6]. The use of intraoperative imaging in cranio-maxillofacial fracture repairs involves a prolonged operating time, but allows a reduction in retreatment rate and postoperative imaging exams for each patient. Due to the brief observation period and the small case series in this study, it is not possible to assess the long-term outcome for patients treated with this method. This would require a prospective, randomized study with a control group. Despite the limited number of patients in this study, we believe the use of O-Arm™ imaging is sufficient for peri-operative cases of post-traumatic orbital fractures where there is no intra-cerebral damage or fractures, which would usually be studied with pre-and post-operative standard CT brain scans.

Conclusions

The intraoperative use of O-Arm™ allows a reduction in complications, improves clinical and radiological outcomes, and decreases the reoperation rate. Indications for spinal surgery are widely reported. Intraoperative O-Arm™ assisted cranio-facial reconstruction surgery improves the assessment of the neurovascular structure decompression, the identification of the skeletal fragments, renders the fixation procedures safer and, in the end, aids the correct re-establishment of facial symmetry in orbital floor fractures.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

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