3D C-arm-based Imaging Opens New Potentials

A collaboration with the Oral and Maxillofacial Surgery Department of the University Medical Center Hamburg-Eppendorf has extended the spectrum of indications for three-dimensional reconstructions with the intraoperative aid of an isocentric C-arm imaging system.

By Max Heiland, MD, DMD, PhD

Intraoperative imaging using fluoroscopy is well integrated into many orthopedic and general trauma surgical procedures. In 2001, Siemens Medical Solutions introduced SIREMOBIL® Iso-C³, a C-arm imaging system that is able to immediately reconstruct a 3D DICOM data set based on single fluoroscopic exposures obtained during surgery, thereby broadening the spectrum of available intraoperative imaging modalities. As would be expected, this advance was first employed in the medical specialties that regularly use fluoroscopy [1, 2]. Even Siemens Medical Solutions, the system developer, did not foresee its potential in the facial skeleton region, and consequently, the head and neck were not included in the original scope of approved applications.

Facial Skeleton as an Approved Application

Extending the SIREMOBIL Iso-C³ approval to include the facial skeleton application was the direct result of an event that occurred in December 2001. A fluoroscopic system acquired in 1987 was still installed but not in use at the Oral and Maxillofacial Surgery Department of the University Medical Center Hamburg-Eppendorf. After the clinic entered the field of computer-assisted surgery with the aid of an intraoperative navigation system from BrainLAB, Inc., Professor Rainer Schmelzle, MD, head of the department, decided to revitalize fluoroscopy and focus on navigation possibilities with intra-
operative-acquired data. One of the first SIREMOBIL Iso-C® data sets contained images showing the upper cervical spine. The great potential of the modality was immediately obvious, and making the system available for facial skeleton imaging became the challenge. Two principles were influential in creating the solution: cone-beam computed tomography (CBCT) and digital volume tomography (DVT). The latter is well known in dentomaxillofacial imaging.

Scanners for Dentists
In 1997, a dedicated facial skeleton DVT scanner that can be used by dentists without the necessity of a supporting radiological staff was introduced. Since then, CBCT has become increasingly more popular in dentomaxillofacial imaging and, at present, a variety of different dedicated scanners is available, with the newer systems designed similar to panoramic units. As a result, CBCT had proven its capability as a sufficient visualization tool for very thin facial bones as early as 2001 [3]. In addition, several reports have been published by numerous groups and organizations documenting the useful application of CT during the open reduction of mid-facial fractures [4-6].

Integration of 3D C-arm-based Imaging in the Operative Workflow in Maxillofacial Surgery
After using the SIREMOBIL Iso-C® in clinical maxillofacial surgery the first time [9, 10], the clinic’s purchase of an additional system was approved by the Deutsche Forschungsgemeinschaft early in 2005. After obtaining the ARCADIS Orbic 3D, the successor of the SIREMOBIL Iso-C®, the clinic had performed 118 intraoperative examinations during the first four months of the system’s availability [Fig. 1]. This rate was due to a continuing high volume of intraoperative applications and not influenced by enthusiasm for the imaging system. The intraoperative use of the system is shown in Figure 2. A scan is usually performed at the end of the operation, keeping the sterile conditions of the surgical field. However, a similar sterile dressing of the system is not necessary in maxillofacial surgery. Positioning, data acquisition, and generating individual multiplanar reconstructions require a maximum of six minutes. This necessitates a corresponding prolongation of the general anesthesia. The intraoperative use of 3D C-arm-based imaging, especially in the following circumstances, is of enormous value:

* Alderson-Rando phantoms are human skeleton phantoms consisting of isocyanate rubber used for detailed mappings of dose distribution with ionizing irradiation.
• after open reduction of midfacial fractures, since not all fracture sites are exposed and controlled by direct vision;
• after open reduction of mandibular fractures, because the lingual cortex is generally not explored due to the danger of an increased gap after osteosynthesis;
• after complex bony reconstructions (e.g., microsurgical tissue transfer) with patients that are transferred to the ICU postoperatively and not available for conventional radiographs [Fig. 3];
• children with different indications for preoperative CT scans, which usually require sedation or general anesthesia in the radiology department, may now be substituted with intra-operative scans immediately before surgery;
• handicapped or demented patients with obvious indications for surgical treatment in general anesthesia (e.g., dental surgery), with whom sufficient preoperative radiographs are not possible.

Furthermore, the clinic has obtained additional experience with intraoperative navigation in 3D C-arm data sets – even in the facial skeleton. However, at present, this application remains a challenge, as there is no sufficient software available. Additionally, the indications for navigation with 3D C-arm data sets are limited in maxillofacial surgery (e.g., removal of foreign bodies). This will result in a subsequent rise in the importance of intraoperative updates of preoperatively acquired DICOM data obtained with other modalities. Ultimately, it will yield dramatic changes in the workflow of preoperative imaging, virtual preoperative planning, and fusion with an intraoperative acquired data set to control the surgical result immediately, thus revealing the option of revision during the same procedure [Fig. 4].

Conclusion

Although other specialties are used to check the surgical result by intraoperative 2D or 3D fluoroscopy for a longer time, 3D C-arm-based imaging for intraoperative visualization of the facial skeleton is now available. Its implementation in the OR has changed the intraoperative workflow by improving patient safety and care.

Author: Max Heiland, MD, DMD, PhD, has been the acting senior physician of the Oral and Maxillofacial Surgery Department at the University Medical Center Hamburg-Eppendorf, Germany, since 2005. His experience in the department began in 1998. His current focus is on 3D imaging of the facial skeleton and the development of intraoperative navigation systems in maxillofacial surgery.

References