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Evaluation of Open Reduction and Internal Fixation of Mandibular Condyle Fracture by Intraoperative Cone-Beam Computed Tomography in a Hybrid Operating Room

Shintaro Sukegawa, DDS, PhD,[*] Masanori Masui, DDS, PhD,[*] Takahiro Kanno, FIBCSOMS-ONC/RECON, PhD,[†] Masayuki Miki, PhD,[‡] Hitoshi Nakamoto, PhD,[‡] and Yoshihiko Furuki, DDS, PhD[*]

Abstract: Condylar fractures are the most common fractures of the mandible, and treatment of mandibular condylar fractures by maxillofacial surgeons is a very important procedure. However, the surgical approaches have anatomical limitations. Therefore, it is difficult to evaluate the reduction achieved in open reduction and internal fixation because of the uncertainty in securing a sufficient operative field. As a potential solution, the authors evaluated the benefits of intraoperative cone-beam computed tomography (CBCT) with high image quality performed in a hybrid operating room. Intraoperative CBCT is easy to perform in a hybrid operating room, and it is possible to quickly evaluate high-quality CT images, including 3D images. Because the state of reduction of mandibular condylar fractures also affects the prognosis of treatment, more precise reduction and fixation should improve prognoses. The use of CBCT in a hybrid operating room also avoids re-operation, and patients benefit from minimum invasive surgery. Intraoperative CBCT is a very useful strategy for evaluation of mandibular condylar fracture surgical treatment.

Key Words: Hybrid room, intraoperative cone-beam computed tomography, mandibular condyle fracture, open reduction and internal fixation

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From the *Division of Oral and Maxillofacial Surgery, Kagawa Prefectural Central Hospital, Takamatsu, Kagawa; †Department of Oral and Maxillofacial Surgery, Shimane University Faculty of Medicine, Shimane; and ‡Division of Radiological Technology, Kagawa Prefectural Central Hospital, Kagawa, Japan.
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Address correspondence and reprint requests to Shintaro Sukegawa, DDS, PhD, Division of Oral and Maxillofacial Surgery, Kagawa Prefectural Central Hospital, 1-2-1, Asahi-machi, Takamatsu, Kagawa 760-8557, Japan; E-mail: gouwan19@gmail.com
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Condylar fractures are the most common fractures of the mandible and can cause dysfunction, such as malocclusion and trismus. Surgical treatment may be needed to provide better occlusion because accurate reduction and rigid fixation allow good anatomical repositioning and immediate function.[1] Compared with the surgical approach and access to other mandible fractures, the approaches and access to mandibular condyle fractures are limited, with a restricted view of the surgical site. In addition, more precise reduction of the fragments is often required. For this reason, it is often impossible to adequately and properly check the reduction in three dimensions. Therefore, inadequate reduction of the mandibular condylar fracture may not be detected.[2]

Intraoperative X-ray examination using a fluoroscopic examination system has had an important role in the surgical treatment of trauma patients for many years. However, because the complicated structures of the facial skeleton and neck overlap in the 2-dimensional X-ray scan, it is difficult to interpret the intraoperative X-ray examination in the head and neck region.[3] Intraoperative 3-dimensional (3D) computed tomography (CT) imaging has gained popularity in craniomaxillofacial surgery in recent years since the first report of the use of intraoperative CT in the management of orbitozygomatic fracture in 1999.[4] This conventional mobile cone-beam CT (CBCT) had been available to perform intraoperative 3D imaging in maxillofacial fracture treatment. With improvements in the technology for facial reconstruction in imaging systems, these CT scanners became more portable and mobile and produced images of relatively higher resolution than that of conventional images.[4,5] However, even with improvements in CT resolution, the resolution has been insufficient for evaluating the precision of reduction of bone fracture lines.

However, because of the global spread of hybrid rooms in recent years, image evaluation during surgery is also changing. A hybrid operating room is a surgical theater that is equipped with advanced medical imaging devices, such as fixed C-arms and angiographic systems. A CT system mounted on a rail can be used in the operation room to support complex surgical procedures, such as intracerebral, spinal, and trauma surgery, and additional imaging information can be obtained intraoperatively.

The purpose of this study was to intraoperatively evaluate treatment of a mandibular condylar fracture by using high-precision CBCT in a hybrid operating room.

CLINICAL CASE

Our patient was a 69-year-old Japanese female. The patient had fallen down the stairs and was injured. She had consulted at another hospital with an orthopedic surgeon who noted a radius and ulnar fracture that had been initially treated by a family doctor. She underwent open reduction and internal fixation (ORIF) for her

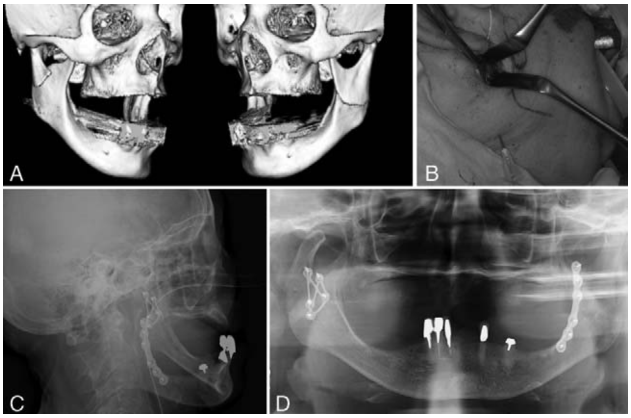

FIGURE 1. 3D-CT showing the right subcondylar and left ramus obsolete fracture. Right subcondylar fracture was performed by using a retromandibular approach. Reduction and fixation in a small surgical field of view are required. Evaluation of reduction of mandibular condylar fracture with intraoperative plain X-P. Obtaining an accurate diagnosis is difficult. The X-ray imaging evaluation the day after the operation shows dislocation of the right temporomandibular joint and the error in the reduction to the anatomical position.

radius and ulnar fracture 10 days after the injury. After surgery, because of the continuation of mandibular pain, diagnosis of mandibular fracture was made by imaging examination. For this reason, she was introduced to our hospital on the day 28 after the injury. Plain X-ray and CT imaging revealed a right subcondylar mandibular fracture and left ramus fracture (Fig. 1A). She had an edentulous jaw in the maxilla and only three remaining teeth. To repair these fractures, we performed ORIF with the patient under general anesthesia on day 35 after the injury. A retromandibular approach was used to treat the right subcondylar fracture (Fig. 1B), and an intraoral approach was used to treat the left ramus fracture. Thereafter, the bone fragment was reduced at the central occlusion position and fixed with titanium plates. After ORIF, intraoperative plain X-ray imaging confirmed the reduction of the temporomandibular joint; therefore, the operation was completed (Fig. 1C). However, panoramic X-ray imaging on the day after the operation revealed dislocation of the right temporomandibular joint and an anatomical positional error in the reduction (Fig. 1D). To reliably perform a correct anatomical reduction and fixation of the condylar fracture segment, we planned to re-operate in a hybrid operating

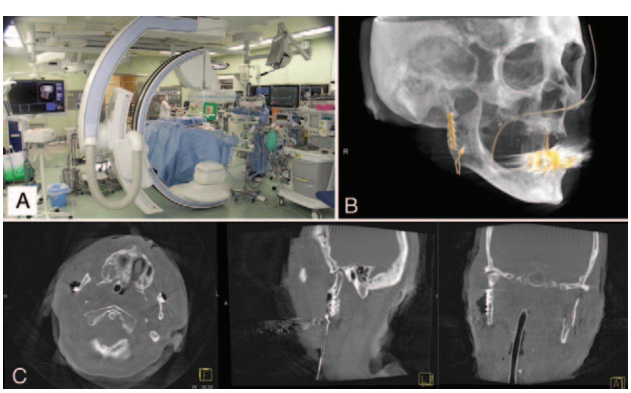

FIGURE 2. Intraoperative CT in the hybrid operating room after open reduction and internal fixation of mandibular condylar fracture. Intraoperative 3D imaging constructed from intraoperative CT imaging in a hybrid operating room. It is possible to confirm the continuity of cortical bone and the position/angle of the reduction of fracture fragments easily and accurately by evaluating the high-quality images.

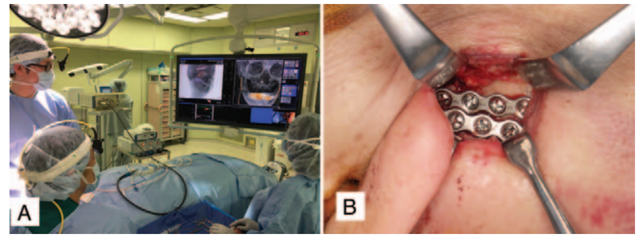

FIGURE 3. Surgery with intraoperatively checking CT data. Minimally invasive surgery without enlarging the incision line.

room, which enables intraoperative evaluation of high-precision images. After checking the central occlusion position by intraoperative maxillomandibular fixation, the fracture segment was provisionally fixed with a titanium plate. We performed intraoperative CBCT imaging in that state. The scanning time of the Artis Zee C-arm real time imaging system (Siemens AG, Forchheim, Germany) was approximately 5 seconds (normal definition) when using the head protocol that consisted of 1 rotational acquisition of 70 kVp, varying 3 mA, and the minimal time for a single scan consisting of 133 projection images in 5 seconds (Fig. 2). The radiation exposure dose of approximately 0.45 mSv was considered as effective dose. The intraoperative CBCT imaging time was 8 minutes including the preparation time. Exposure could be avoided while performing intraoperative CBCT, because remote control was performed from outside the operating room. After confirming good reduction of the subcondylar position, internal fixation was performed by using 2 miniplates (Fig. 3).

Postoperative X-ray imaging revealed reduction of the subcondylar segment with good positioning and restoration of the mandibular ramus height. After surgery, her mandibular movement was good. Mandibular deviation and temporomandibular joint pain were not evident when she opened her mouth.

DISCUSSION

Condylar fractures account for 18% to 45% of all mandibular fractures and are the most common fractures of the mandible.[5,6] Therefore, treatment of mandibular condylar fractures is a very important procedure for maxillofacial surgeons. ORIF in condylar fracture is considered as the gold standard for both condylar base and neck fractures.[7] Although ORIF may be recommended for condylar fractures in adult and in children with mixed dentition, this recommendation requires further investigation.[8] Therefore, as our surgical treatment indication, we selected condylar fractures in the neck and the base. Mandibular condylar fractures are treated using various surgical approaches, including intraoral and extraoral approaches,[9] such as retromandibular transparotid,[10] peri-angular,[11] and submandibular.[12] However, the surgical approaches used to treat condylar fractures have anatomical limitations. Consequently, it is difficult to evaluate the reduction after ORIF because of the uncertainty in securing a sufficient operative field. Insufficient reduction of condylar fractures may lead to less satisfactory results and an increased incidence of complications.[2,13,14]

Intraoperative image assessment has been proposed as an adjuvant solution to this limitation. For intraoperative evaluation of treatment for mandibular condylar fracture, fluoroscopy[15] and mCBCT[2] have been reported in addition to plain X-ray imaging. In our case, although we evaluated reduction of mandibular condylar fracture using intraoperative plain X-P, we were unable to make an accurate diagnosis. It is almost impossible to perform plain X-P evaluation of the temporomandibular joint evaluation. The fluoroscopic system is flexible, maneuverable, and can be easily positioned. In addition, it can be operated without a radiology technologist and is widely available in trauma centers and several hospitals.[15] Consequently, the fluoroscopic technique is routinely used in orthopedic surgery. However, unfortunately, it is very difficult to evaluate 2D X-ray images because of the fine structures and overlap with other anatomical structures.[16] Although certain sites (eg, single-line subcondylar fracture) can be evaluated by selecting a specific direction of the X-rays,[15] it is impossible to evaluate complicated fractures; therefore, this strategy may not necessarily be clinically useful.

Conversely, intraoperative CT evaluation using mCBCT provides extremely useful information for the treatment of maxillofacial injuries. These complex facial structures can be effectively visualized using the 3D mode of CBCT. In fact, CT allows non-error visualization of the osteosynthesis area of the mandible fractures in three dimensions and produces substantially more information than that of conventional X-ray images.[17] The beneficial effect on the efficacy of intraoperative CBCT in the treatment of maxillofacial fracture was first reported in a study of zygomaticomaxillary complex fractures.[18] Following this, the utility of this system was further demonstrated and shown to provide relatively high image quality intraoperatively.[2,17,19] Although mCBCT is a far superior evaluation method than plain X-ray, image quality remains an important issue. On evaluation of intraoperative mCBCT, Klatt and colleagues have stated that images obtained following mandibular fracture reduction were of high quality.[2,17] However, to achieve the image quality shown in their research paper, the operator needed skill and experience to confirm the continuity of the cortical bone of the mandible in the correct position. Pohlenz et al have hypothesized that intraoperative mCBCT may enable repositioning in the condylar process.[16] In conventional mCBCT, it is possible to evaluate certain degree of reduction of mandibular condylar fractures; however, it is difficult to evaluate the rotation and angle of the bone fragments following reduction.

On the other hand, the advantages of this system compared with regular 3D-CT in a hybrid operating room are the higher image quality and larger field of view.[20] Needless to say, intraoperative CBCT imaging is convenient because the CT is installed in the hybrid operating room. Additionally, intraoperative CBCT imaging does not require additional CT imaging after surgery that is routinely performed if intraoperative CBCT has not been performed. This is a great advantage considering the weaker general condition of patients after surgery. The C-arm type CT installed in hybrid operating rooms is the most recent advance in CT and offers the option of skull imaging with high geometric accuracy in all spatial planes as well as 3D reconstruction at high resolution. CT imaging systems in hybrid operating rooms that can reliably provide clinically useful image quality are very useful.

Obtaining intraoperative CBCT images of high-quality does not require routine postoperative CT imaging, can avoid the need for frequent CT imaging. Further, in intraoperative CBCT system, even lower exposure could be realized using flat-detector. In the research paper that compared the craniofacial CT exposure in conventional multislice CT under the same imaging conditions, the radiation exposure dose for this type of treatment was approximately 1.4 mSv.[21] The radiation exposure dose for conventional craniofacial multislice CT at our facility protocol was approximately 1.2 mSv. These exposure doses are very high compared with that in CBCT (0.45 mSv). The influence of radiation exposure caused by CBCT imaging on children is a crucial issue. Because certain studies have demonstrated its influence on carcinogenesis,[22,23] whereas others have not,[24,25] the topic remains debatable. In any case, it is important to reduce exposure. Appropriately selecting according to the purpose during surgery and combining postoperative CT imaging could effectively reduce radiation exposure. Consequently, avoiding CT imaging following surgery contributes to reduction of medical expenses. In fact, intraoperative CT imaging has been reported to be cost effectiveness,[26] and similar effects can be expected in the oral surgical field. During intraoperative CBCT imaging, exposure can be avoided as it was performed remotely from outside the operating room. Therefore, surgeons and surgical staff do not have to worry about radiation exposure. This is important from the point of view of the medical environment.

In recent years, hybrid operating rooms have been established worldwide. However, because it is highly useful in other clinical medical departments,[27,28] it may not be an environment that can always be used in facial surgery. Klatt et al have suggested that a compromise between intraoperative CBCT control of every condylar process fracture and no intraoperative CBCT could be to use intraoperative CBCT only for grossly dislocated fractures that require CT control.[2] An obsolete or edentulous mandibular condylar fracture, as in the present case, without a reference point for bone reduction as a mark during surgery is an extremely difficult challenge. For such situations, intraoperative CBCT imaging in a hybrid room is the most useful approach because they require more accurate intraoperative diagnosis. Intraoperative CBCT is unnecessary for all mandibular fractures; however, it is very useful for difficult cases and is expected to be utilized in maxillofacial surgery treatment.

CONCLUSION

This is the first report of the use of intraoperative CBCT in mandibular condylar fracture treatment in a hybrid operating room. The availability of CT during surgery enabled immediate monitoring of the reduction of condylar process fractures of the mandible in all 3 planes. Maxillofacial surgeons can evaluate the results directly during the operation by reviewing high-quality images, and this strategy is very useful for treating mandibular condylar fractures, which require high-precision surgery because of the insufficient field of view during surgery.

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Celebrations at night.

