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The role of three-dimensional computed tomography in the management of maxillofacial bone fractures

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Abstract

The findings of three-dimensional computed tomography (3DCT) and two-dimensional computed tomography (2DCT) with helical CT scanning were compared for 21 patients with maxillofacial bone fractures. The results of this study suggest that the 3DCT evaluation can be divided into 3 groups. The first group, in which 3DCT is superior to 2DCT, includes severe complicated midface fractures, for example, tripod fractures and complicated maxillary bone fractures. The second group, in which 3DCT is equal to 2DCT, includes simple fractures, for example, nasal bone fractures and isolated zygomatic fractures. In this group, patients and their families could easily understand the nature of the fracture and clinical course shown by 3DCT as compared with conventional X-ray and 2DCT. The third group, in which 3DCT is inferior to 2DCT, includes blowout fractures. Although 3DCT does not provide additional information in blowout fractures, helical scanning permits clear observation of multiplanar images without artifacts arising from metal prostheses by excluding lower slices during image reconstruction. We conclude that 3DCT provides useful information, especially in regard to the extent of complex fracture lines, as in tripod fractures.

KEYWORDS: 3DCT, helical CT, maxillofacial bone fractures, facial bone fractures

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The Role of Three-Dimensional Computed Tomography in the Management of Maxillofacial Bone Fractures

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The findings of three-dimensional computed tomography (3DCT) and two-dimensional computed tomography (2DCT) with helical CT scanning were compared for 21 patients with maxillofacial bone fractures. The results of this study suggest that the 3DCT evaluation can be divided into 3 groups. The first group, in which 3DCT is superior to 2DCT, includes severe complicated midface fractures, for example, tripod fractures and complicated maxillary bone fractures. The second group, in which 3DCT is equal to 2DCT, includes simple fractures, for example, nasal bone fractures and isolated zygomatic fractures. In this group, patients and their families could easily understand the nature of the fracture and clinical course shown by 3DCT as compared with conventional X-ray and 2DCT. The third group, in which 3DCT is inferior to 2DCT, includes blowout fractures. Although 3DCT does not provide additional information in blowout fractures, helical scanning permits clear observation of multiplanar images without artifacts arising from metal prostheses by excluding lower slices during image reconstruction. We conclude that 3DCT provides useful information, especially in regard to the extent of complex fracture lines, as in tripod fractures.

Key words: 3DCT, helical CT, maxillofacial bone fractures, facial bone fractures

Conventional X-rays are commonly used to evaluate maxillofacial bone fractures. Superimposition of bony structures and impaired visualization of underlying fractures due to soft tissue swelling, however, may necessitate further examination. Computed tomography (CT) is known to be a more useful method for the examination of maxillofacial fractures (1-3).

Helical CT is a recently developed technique in which the X-ray tube is rotated continuously as the patient is moved through the gantry, permitting acquisition of a large volume of data which can be used to reconstruct multiple contiguous sections of arbitrary thickness. Newly developed computer software allows three-dimensional imaging of this data (3DCT) generated in a short time. Consequently 3DCT has been used to study a variety of musculoskeletal disorders (4, 5) and cerebrovascular diseases (6).

In this study, we compared 3DCT of maxillofacial bone fractures against conventional two-dimensional computed tomography (2DCT), evaluating the additional diagnostic information provided by 3DCT as compared with 2DCT, and identified the types of fracture that could be visualized by 3DCT.

Materials and Methods

Twenty-one patients with a variety of fractures were included in this study (Table 1). The clinical diagnosis

Table 1 Fractures studied

Type of injury	Number of patients
Tripod fracture	6
Blowout fracture	4
Nasal bone fracture	3
Maxillary bone fracture	3
Zygomatic bone fracture	2
Mandible fracture	3
Total	21

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was made on the basis of physical findings and plain film studies (facial series and panoramic radiography). 2DCT and 3DCT with helical CT scanning were performed using a Toshiba Xvigor scanner. The scanning parameters were set according to the region of interest. The tube voltage employed was 120-135 kV and the tube current was 100-200 mAs. The section thickness was 1-3 mm/second at 1:1 helical pitch, and the table-movement speed was 1-3 mm/rotation/second. From these data, source images of 3DCT were reconstructed at intervals of 0.5-1 mm using the bone algorithm. The bone algorithm was selected because fracture lines are more clearly visualized using this algorithm (Fig. 1). Using the standard algorithm for the head and neck, the bone surface appears smooth, but fracture lines are not clearly depicted. 3DCT imaging was performed using the shaded surface display method at the lowest threshold level at which soft tissues were not visualized. In each case, a period of 20-30 min was required to generate 3D images on Xlink, an independent console connected to the Xvigor scanner. 3DCT required 30-50 seconds for scanning and 10-20 min for 3D reconstruction.

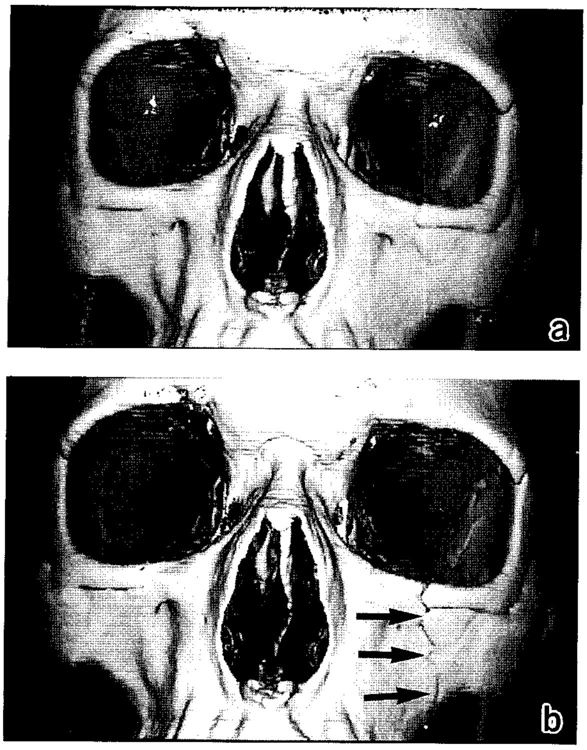


Fig. 1 Three-dimensional computed tomography (3DCT) of tripod fracture reconstructed using two algorithms.
a: standard algorithm; **b**: bone algorithm.
The bone surface appears smooth when the standard algorithm for the head and neck is used, but the fracture line is not clearly depicted. The fracture line is more clearly visualized using the bone algorithm (arrows).

Results

In each case, we compared 3DCT with 2DCT (the same data was used to generate both 3DCT and 2DCT images) and assessed each method with regard to their ability to visualize the fracture, extent of the fracture, and displacement of the fracture using a simple scoring system (Table 2).

Tripod fracture. Fracture detection by 3DCT was superior to that by 2DCT, and the extent and displacement of the fracture were better demonstrated by 3DCT (Fig. 2). In particular, a horizontal fracture line of the zygomaticomaxillary complex that could not be detected by 2DCT was clearly visible by 3DCT. Also, 3DCT clearly revealed the extent of the fracture line from the anterolateral wall to the posterior wall of the maxillary sinus, which was not easily recognized on 2DCT images. However, in one case, a minor horizontal fracture line of

Table 2 Cumulative scores of each fracture type assessed by comparison between three-dimensional and two-dimensional computed tomography (2DCT and 3DCT)

Type of fracture	Detection of fracture	Determination of fracture extent	Determination of fracture displacement	Total
Tripod fracture	1	4	2	7
Browout fracture	−2	−1	−3	−6
Nasal bone fracture	0	0	1	1
Maxillary bone fracture	0	1	1	2
Zygomatic bone fracture	0	0	0	0
Mandible fracture	0	1	0	1

Score: +1: 3DCT superior to 2DCT, 0: 3DCT equal to 2DCT, −1: 3DCT inferior to 2DCT.

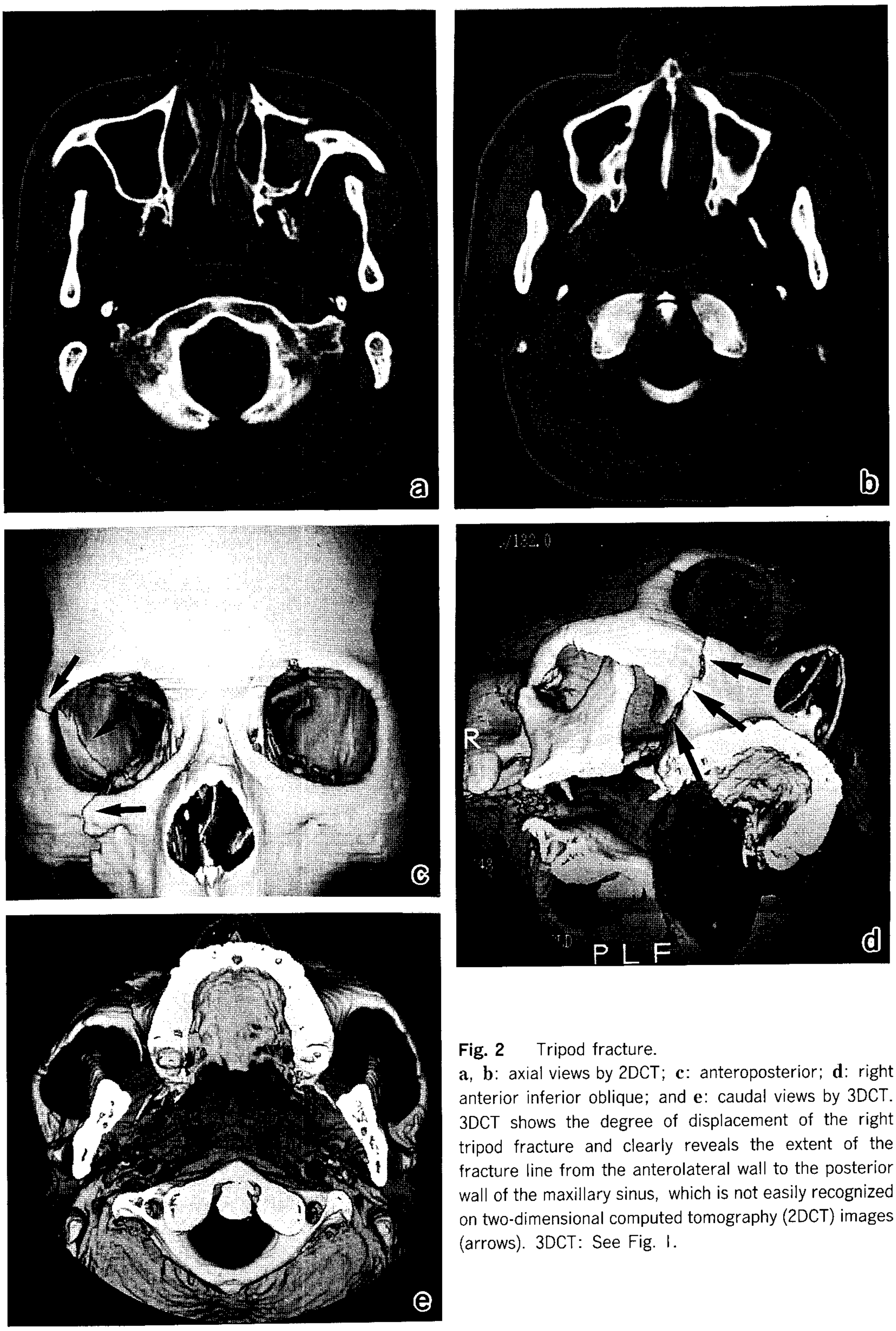
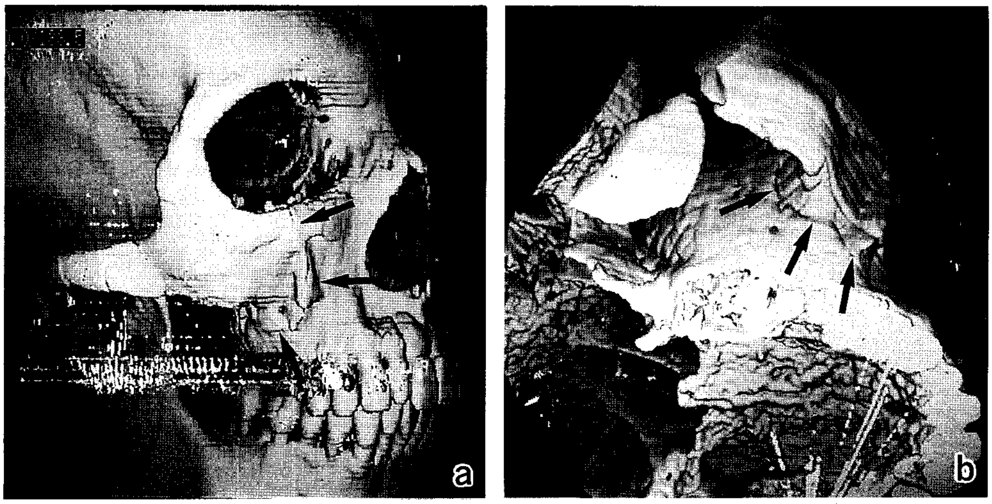


Fig. 2 Tripod fracture.
a, **b**: axial views by 2DCT; **c**: anteroposterior; **d**: right anterior inferior oblique; and **e**: caudal views by 3DCT. 3DCT shows the degree of displacement of the right tripod fracture and clearly reveals the extent of the fracture line from the anterolateral wall to the posterior wall of the maxillary sinus, which is not easily recognized on two-dimensional computed tomography (2DCT) images (arrows). 3DCT: See Fig. 1.



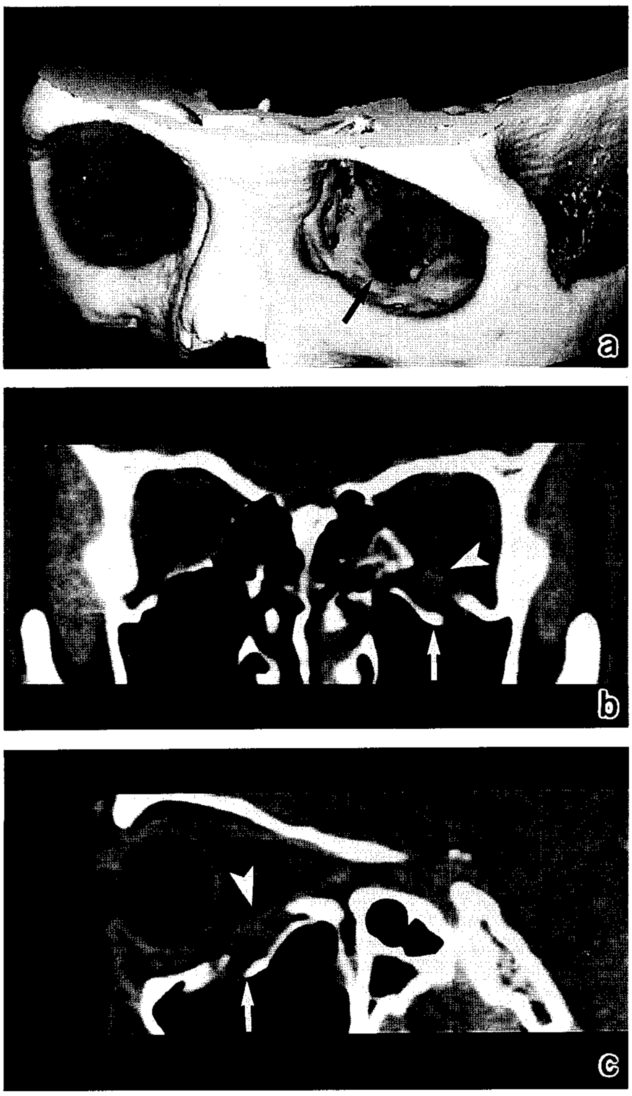


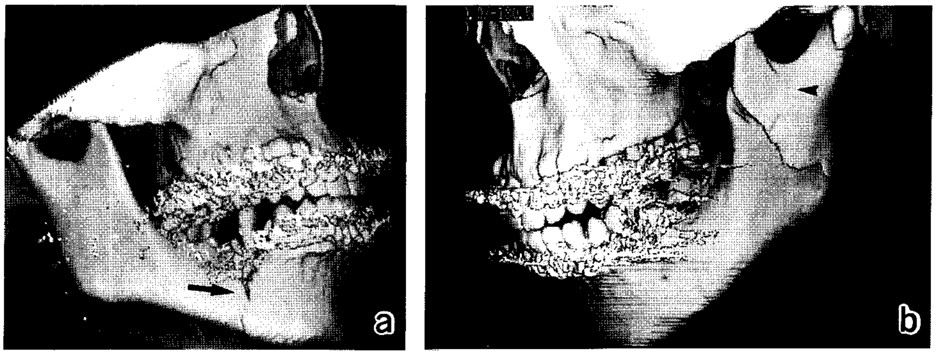
Fig. 3 Tripod fracture.
a: Left anterior oblique view; **b**: Right anterior inferior oblique view by 3DCT. 3DCT clearly reveals the extent of the fracture line from the anterolateral wall to the posterior wall of the maxillary sinus (arrows), which is not easily recognized on 2DCT images. However, the horizontal fracture line of the frontal process of the zygomatic bone identified at surgery is not visualized. 3DCT, 2DCT: See Figs 1, 2.

Fig. 4 (Left) Blowout fracture.
a: Left anterior superior oblique view by 3DCT; **b**: Coronal image of multiplanar reconstruction by 2DCT; **c**: Sagittal image of multiplanar reconstruction by 2DCT. No findings are added to those of 2DCT. However, helical scanning permits observation from many viewpoints without artifacts arising from artificial dentures by excluding lower slices during image reconstruction. (Blowout fracture: arrows, inferior rectus muscle: arrowheads). 3DCT, 2DCT: See Figs 1, 2.

the frontal process of the zygomatic bone identified at surgery was not visualized by 3DCT (Fig. 3).

Blowout fracture. Due to the presence of "pseudoforamina", *i.e.*, artifactual defects in thin bone commonly involving the inferior and medial orbital walls, fracture detection, extent and displacement by 3DCT were either equal or inferior to 2DCT. In three cases, displacement visualization of the fractured medial orbital walls by 3DCT was inferior to 2DCT. In only one case, displacement visualization of the fractured inferior orbital walls was equal to that by 2DCT (Fig. 4).

Nasal bone fracture. 3DCT was equal to 2DCT in detection of fractures and determining their extent, and superior in determining their displacement. Patients and their families could easily understand the condition of the nasal bone beneath local swelling on 3DCT images.



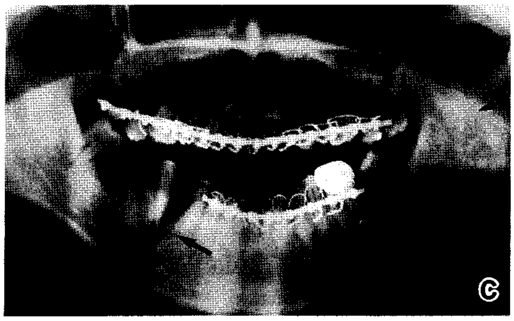


Fig. 5 Mandible fracture.
a: Left and **b**: right anterior oblique views by 3DCT. **c**: Panoramic radiography. With regard to fracture of the right body of the mandible, 3DCT shows the relationship with the alveolar bone, although this finding can be identified even by panoramic radiography (arrow). In addition, the fracture of the left coronoid process is less evident on 3DCT, and this finding is visualized less clearly than on panoramic radiography (arrowheads). 3DCT: See Fig. 1.

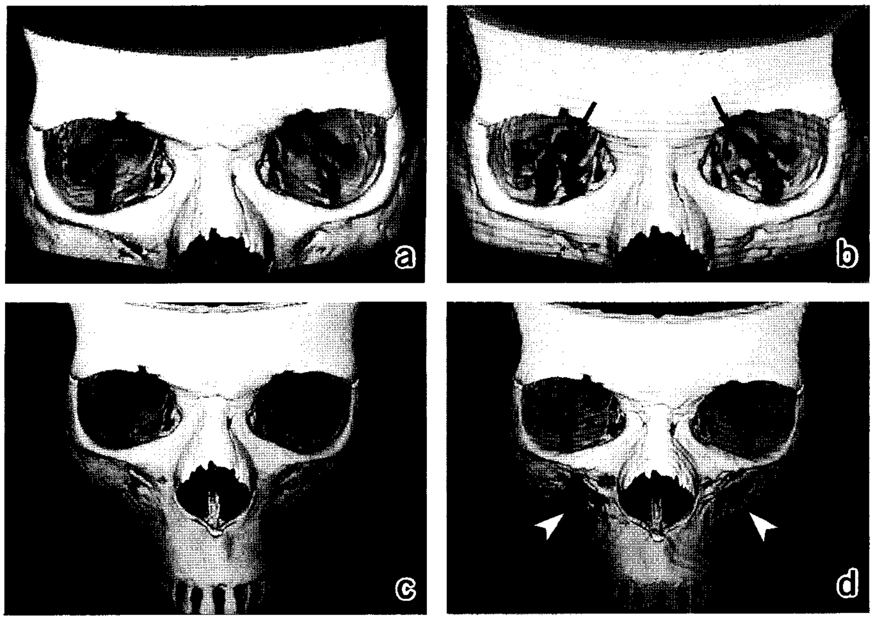


Fig. 6 3DCT of cranial bone preparation
a: Axial helical scanning with 1 mm section thickness
b: Axial helical scanning with 3 mm section thickness
c: Coronal helical scanning with 1 mm section thickness
d: Coronal helical scanning with 3 mm section thickness
Errors due to detection of bone defects (pseudoforamina) of the inferior orbital wall (arrows) are lessened by reducing the section thickness. Although coronal scanning is improved, a bone defect is seen in the anterior wall of the maxillary sinus (arrowheads).
3DCT: See Fig. 1.

Maxillary bone fracture and zygomatic bone fracture. Although 3DCT did not provide additional information in localized simple fractures such as isolated zygomatic bone fractures, the extent and displacement of more complex fractures were better demonstrated by 3DCT.

Mandible fracture. 3DCT was equal to 2DCT in detection of fractures and determining their displacement. Although the extent of the fracture was better demonstrated by 3DCT, the relationship between the fracture line in the mandible and the alveolar bone, which identifiable even by panoramic radiography, could not always be detected by 3DCT (Fig. 5).

Additionally, we tried a simple experiment concerning the pseudoforamina. Fig. 6 shows the images of a cranial bone preparation generated by axial and coronal helical scanning with 1 mm and 3 mm section thicknesses. Visualization errors due to bone defects (pseudoforamina) of the inferior orbital wall were improved by reducing the section thickness. Using coronal helical scanning, pseudoforamina of the inferior orbital wall, as well as the horizontal fracture line, can be eliminated, but one should keep in mind that this technique also showed pseudoforamina of the frontal wall of the maxillary sinus.

Discussion

A number of authors have advocated the use of CT as a diagnostic tool for the evaluation of the facial bones because of its improved visualization of the complex bony anatomy of the head and neck (1-3). There have also been several reports describing the use of 3DCT for diagnosing facial bone injuries (4, 7, 8). The extent of the fracture line can not only be readily assessed but a suggestion of the mechanism of injury can be obtained, reducing operating time and decreasing the likelihood of unforeseen difficulties arising during surgery (5, 9-12).

The results of the present study suggest that 3DCT evaluation can be divided into 3 groups. The first group, in which 3DCT is superior to 2DCT, includes severe complicated midface fractures, including tripod fractures and complicated maxillary bone fractures. In particular, the extent of the fracture line from the anterolateral wall to the posterior wall of the maxillary sinus, which is not easily recognized on 2DCT, is clearly seen on 3DCT. This information is very important before surgery, permitting the surgeons to plan the entire surgical procedure, including the selection of optimal fixation devices. The second group, in which 3DCT is equal to 2DCT, includes simple fractures like nasal bone fractures and isolated zygomatic fractures. In this group, 3DCT does not provide additional information. However, patients and their families can easily understand the nature of the fracture and clinical course by viewing 3DCT images as compared with conventional X-ray and 2DCT images. Thus, 3DCT can make a valuable contribution to clinical management. The third group, in which 3DCT is inferior to 2DCT, includes blowout fractures. Due to the presence of "pseudoforamina", *i.e.*, artifactual defects in thin bone commonly involving the inferior and medial orbital walls, fractures at these sites could not be detected. However, from a clinical point of view, although 3DCT does not provide additional information in blowout fractures, helical scanning permits clear observation of multiplanar images (sagittal, coronal and oblique) without artifacts arising from metal prostheses by excluding lower slices during image reconstruction. Also multiplanar images clearly reveals the important imformation concerning the relationship between the extrinsic eye muscles and displacement of the fracture.

The main problems with 3DCT are those involving pseudoforamina and unreliable demonstration of minor fracture lines due to partial volume effects (9, 13). These problems can be overcome by using thinner sections, a lower table-movement speed, and the bone algorithm (Figs. 1, 6). The coronal helical scanning method also overcomes visualization of pseudoforamina of the superior and inferior orbital wall.

The disadvantage of 3DCT employing thinner sections and a lower table-movement speed, is an increase in radiation dosage. For these reasons, we have recently started using a 1-mm/second section thickness and a 3-mm/rotation/second table-movement speed and tried to select the proper field of view of 3DCT.

In conclusion, we believe that 3DCT provides useful diagnostic information, especially in regard to the extent of complex fracture lines, as in tripod fractures. Thus, 3DCT can make a valuable contribution to the clinical management of patients with severe facial fractures.

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