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Usefulness of Tomosynthesis for Orthopedics


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1. Introduction

The Chiba Central Medical Center was established as Kasori Hospital in 1987, in the northwest part of Chiba prefecture, as a general hospital with 150 beds. However, to become a more advanced medical institution, a second phase of construction occurred in 1998. Currently, we have grown to become a central hospital for Chiba city, with 272 beds and 26 medical departments. From the beginning, we focused on developing advanced medical capabilities, such as single-photon emission computed tomography (SPECT) and MRI, so in 2004, the hospital name was changed to the Chiba Central Medical Center. At the same time, we introduced an electronic medical patient record system and PACS to switch to digital imaging and migrate to a paperless/filmless operation. Then in September 2010, we introduced the Shimadzu SONIALVISION safire system, equipped with tomosynthesis, which can be used not only for orthopedics, but also a variety of other fields, such as gastrointestinal radiography and venography of lower extremities. The word tomosynthesis combines the words "tomography" and the Greek-origin word "synthesis" and refers to new digital tomography technology that combines computed tomography with digital image processing.

Current radiographic diagnostic imaging is the culmination of developments and improvements to various diagnostic imaging technologies such as CT and MRI. However, in the field of orthopedic surgery, there are still many cases that are difficult to diagnose with such systems. If often occurs that key target points are not represented accurately in cross sectional images and are overlooked due to artifacts from metal implants, complicated anatomical shapes of bones, and so on. Furthermore, previous diagnostic imaging equipment was not suited to capturing changes resulting from posture or dynamic factors. The most significant feature of tomosynthesis is its ability to reconstruct a cross sectional image of any desired coronal plane (or sagittal plane for lateral positions) by simply acquiring 36 or 74 images from a single scan parallel to the table, with the patient in any position, and then digitally processing the images. This means it can render minor dislocations, fractures, callus formation, fusing, or synostosis in joints, which are difficult to capture in general radiography images, with minimal effects from metal implant artifacts. This article describes tomosynthesis and how this system has been useful in orthopedic surgery.

2. Tomosynthesis Basics and Characteristics

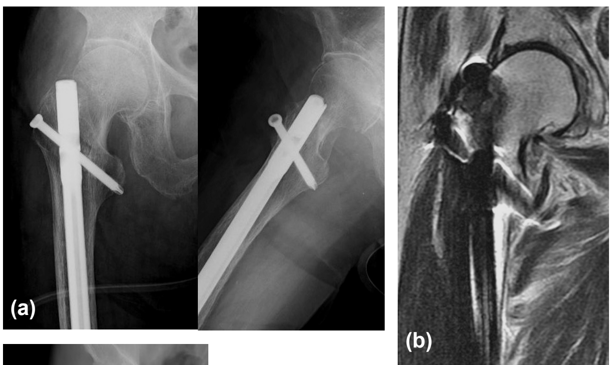
There are two methods used in tomosynthesis to reconstruct images. One is the shift-and-add (SA) method, which shifts the pixels in proportion to the movement between cross section slices. The other is the filtered back projection (FBP) method, which is based on CT reconstruction methods and includes a process to reduce artifacts by adjusting the reconstruction function. The SONIALVISION safire series also features a distortion and halation-free direct-conversion FPD with a 17-inch effective height and width and a wide dynamic range. Consequently, fluoroscopy images can be rendered in high definition. The major characteristics of tomosynthesis using the SONIALVISION safire series are as follows. (1) The FBP method results in cross sections with fewer artifacts in the direction of the imaging chain movement than the SA method, but the effective slice thickness is thicker. (2) Less affected by metal artifacts than CT or MRI. (3) The direct-conversion FPD provides high contrast and high resolution, which results in high resolution cross section images. (4) Radiation exposure dose is about twice the level of conventional orthopedic radiography, but about 1/10 the dose of CT. (5) Tomography is possible with patients in any posture, such as standing, supine, or oblique, or with dynamic loading. Therefore, patients do not need to keep the posture or be restrained for as long, which significantly reduces any discomfort. (6) Images can be examined easily on the monitor. In this way, tomosynthesis provides a unique method of tomography that uses different reconstruction methods than general radiography, CT, or MRI. Therefore, it allows obtaining a wide range of detailed information not previously available. Depending on the disease and pathology, adding tomosynthesis to CT, MRI, or other examination methods can provide more precise diagnoses.

3. Usefulness of Tomosynthesis for Orthopedics

At our hospital, tomosynthesis is mainly used in the orthopedics department and has been helpful for confirming diagnoses or determining treatment protocols. Tomosynthesis by FBP reconstruction is useful for diagnostics because it shows trabeculae clearly, image quality can be adjusted or images reconstructed depending on diagnostic purposes using a workstation. In addition, exposure dose that is lower than CT improves safety for patients and medical personnel. In orthopedics, supplementing fluoroscopy of the spine with functional radiography using tomosynthesis, especially for spinal disease, can help identify dynamic factors contributing to pathology. It is also very useful when artifacts from an implant make it difficult to determine the presence of bone fractures or synostosis. The following are clinical examples where tomosynthesis was especially useful in orthopedics.

Case 1

An open reduction fixation technique was used to install an intramedullary rod in an 84 year old female with a trochanteric fracture of the right hip. After surgery, she was able to walk and was discharged, but fell again at home and was brought back by ambulance. She complained of pain in the treated hip, so a conventional X-ray was taken **(Fig. 1 (a))**, but no bone fractures were evident. Therefore, since we could not determine if it was refractured, we obtained an MRI image **(Fig. 1 (b))**. Nevertheless, due the metal artifact, we still could not determine whether or not there was a fracture, so we used tomosynthesis, which clearly showed a fracture and resulted in diagnosing a refracture **(Fig. 1 (c))**.

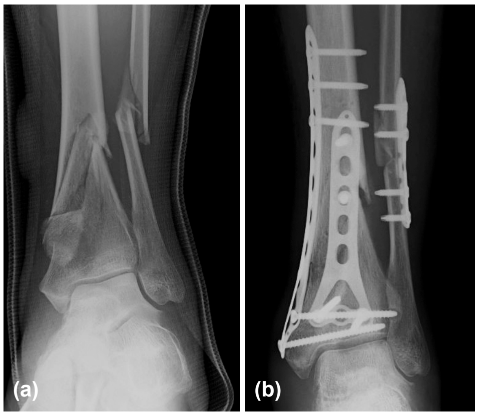


(a) | (b)
(c)

Fig. 1 (a) Refracture of the trochanter is not clear
(b) MRI: Fracture cannot be determined due to artifacts
(c) Tomosynthesis clearly shows refracture line

Case 2

This patient was a 67 year old female with a comminuted fracture of the left ankle **(Fig. 2 (a))**. A plate and screws were installed using an open reduction fixation technique. After the procedure, we observed the progress for three months with no loading, planning to start loading after confirming callus formation. However, plain radiography image after three months revealed a complicated break with multiple fractures and the presence of the implant made it difficult to determine if bone callus was forming **(Fig. 2 (b))**. Therefore, tomosynthesis was used. As a result, callus formation was confirmed about 38 mm from the pretibial surface, so loading was started **(Fig. 2 (c))**.



(a) | (b)
(c)

Fig. 2 (a) Comminuted fracture of the left ankle
(b) Callus formation is not clear in a plain radiography image three months after surgery
(c) Tomosynthesis revealed callus formation 38 mm from pretibial surface

Case 3

This case is an 80 year old female with L4 degenerative spondylolisthesis. A titanium pedicle screw and rod and a PEEK cage was used for a

TLIF procedure between two vertebrae **(Fig. 3 (a))**. Three months after surgery, a CT scan was performed to confirm the synostosis status, but determination was not possible due to artifacts from the PEEK cage **(Fig. 3 (b))**. With tomosynthesis, there were no artifact effects, so the synostosis status could be determined **(Fig. 3 (c))**.

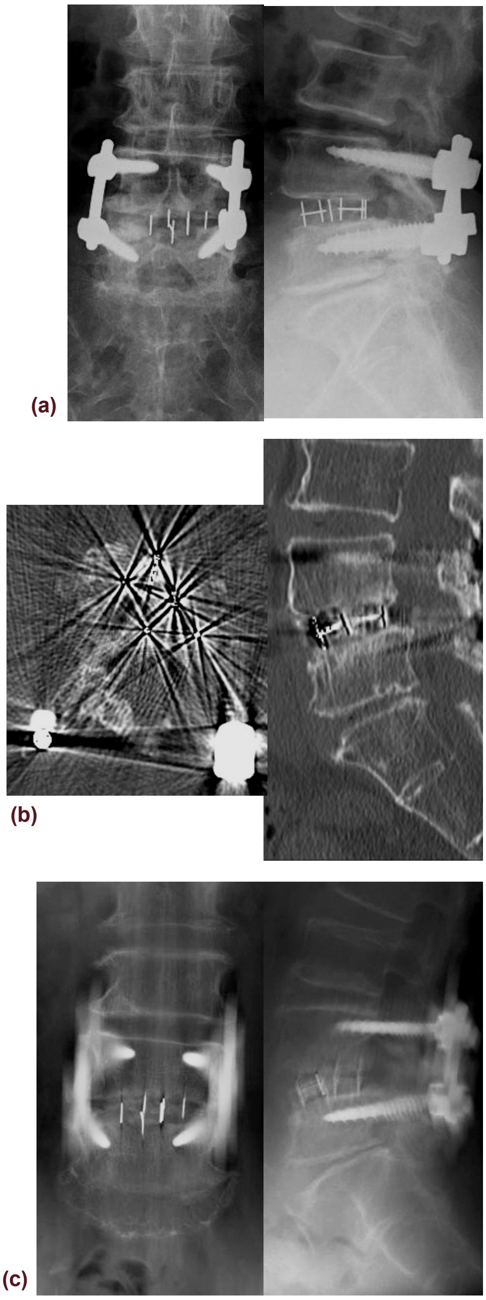


Fig. 3 (a) TLIF performed using PEEK cage
(b) Due to artifacts, synostosis status could not be determined using CT
(c) Tomosynthesis was unaffected by artifacts and allowed determination of synostosis at any slice

Case 4

For this 22 year old male with atlantoaxial subluxation, occipital cervical fixation was performed with instrumentation and a bone graft from the patient. Three months after surgery, posterior synostosis was confirmed using tomosynthesis images **(Fig. 4)**, so external fixation was terminated.

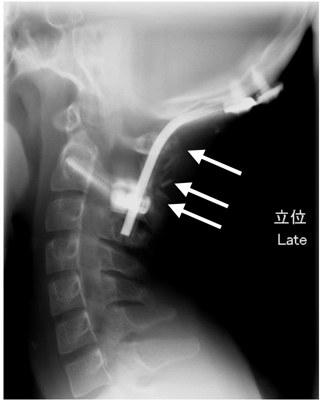
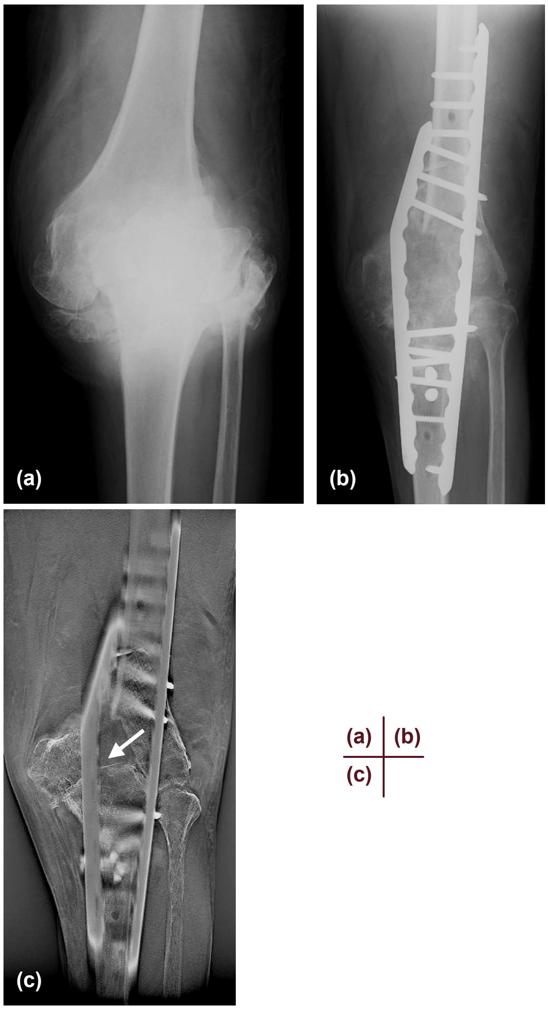


Fig. 4 Synostosis determined by tomosynthesis three months after occipital cervical fixation

Case 5

This is a 65 year old male with Charcot's joint in the left knee **(Fig. 5 (a))**. His non-painful walking disability caused by knee instability was treated by fixation of the joint. A plain radiography image taken three months after surgery **(Fig. 5 (b))** seemed to show synostosis, but confirmation by tomosynthesis showed air voids remaining in the posterior tibial malleolar and still no synostosis **(Fig. 5 (c))**, so we decided to start loading.



(a) | (b)
(c)

Fig. 5 (a) Charcot's joint in the left knee
(b) A plain radiography image three months after surgery appeared to show synostosis
(c) Tomosynthesis showed voids in posterior tibial malleolar which precluded synostosis determination

4. Summary

Tomosynthesis enables clearly observing bone fractures, callus formation, fusing, synostosis status, and bone and joint structures via cross sectional images, which are difficult to render using general radiography. Undershoot artifacts can appear near metal implants in the body, but tomosynthesis is much less vulnerable to effects from artifacts than CT or MRI and can provide high definition images. In addition, tomosynthesis permits acquiring images with patients in any posture, can be used in combination with functional imaging, and allows acquiring images with the affected area secured by corsets or casts, with no burden on the patient, which makes it an especially useful examination method for orthopedic surgery. On the other hand, obtaining stable image quality requires readjusting X-ray and reconstruction parameters for each patient. In addition, the large amount of data it generates has caused problems with having to wait for images to download to the electronic medical record when examining an outpatient. In terms of image quality, default settings for each patient are not necessarily optimal. Obtaining good images requires changing individual tomography parameters using a workstation, then reconstructing images again. In the future, I hope Shimadzu considers providing image quality at least as good as CR systems and increase the speed of transferring images to the image server in the hospital.

Reference Documentation

1) Masanari Taniguchi, Utility of Tomosynthesis in the Orthopaedic Surgery at the Sumitomo Hospital, Rad Fan Vol. 9 No. 1, 2011
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3) Shouta Miura, Clinical Experience Using the SONIALVISION safire II – Utility of Tomosynthesis in Orthopedic Surgery, MEDICAL NOW No. 65, 2009