R/F

Experiences Using the SONIALVISION safire Series

– Investigation into Tomosynthesis of the Temporomandibular Joint –

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1. Introduction

Yonago City is located in the extreme west of Tottori Prefecture. It is surrounded by abundant nature: with the Japan Sea to the north; Lake Nakaumi that is registered under the Ramsar Convention to the west; and views of Mt. Daisen, the highest peak in the Chugoku region of western Honshu, to the south. Commerce developed when Yonago was a castle town back in the Edo era. Nowadays, the excellent highway, rail, air and sea links make the town the gateway to the Sanin region. Tottori University Hospital **(Fig. 1)** is located in Yonago City. The hospital offers 35 medical departments with 697 beds and handles an average of approximately 1200 outpatients per day. It is the largest hospital in Tottori Prefecture and offers advanced medial treatments as a core regional hospital.

The hospital used to perform temporomandibular joint tomography (tomography) using a screen-film system on patients with temporomandibular disorders (TMD). However, as the Division of Clinical Radiology shifted toward filmless operation, digitization of tomographic images became an urgent task. In 2009, we updated our R/F table by introducing three new systems incorporating flat panel detectors (FPD). One of these was a SONIALVISION safire series system. As this system incorporates tomosynthesis functions, we investigated switching from tomography to tomosynthesis for TMD patients. This paper describes the process in switching from tomography to tomosynthesis and covers some of our experiences using it.

Fig. 1 Tottori University Hospital

2. SONIALVISION safire Series System

The SONIALVISION safire series system **(Fig. 2)** incorporates a 17 × 17-inch direct-conversion flat panel detector (direct FPD) that offers low exposure dose and high image quality over a wide field of view. Fluoroscopy and radiography are possible across a 198 cm range, which permits fluoroscopy and radiography from head to toe without moving the patient. The tabletop can descend to just 47 cm above the floor, making it extremely easy for the patient to get on and off. In addition to tomosynthesis, other applications available are slot radiography and dual energy subtraction. By means of reference, **Fig. 3** shows a comparison of MTF between the direct FPD in this system and the indirect-conversion FPD (indirect FPD) used in another system that was installed in the hospital at the same time. MTF is calculated from the edge image (raw data) obtained using a 1.0 mm-thick tungsten edge with the tabletop and grid removed.

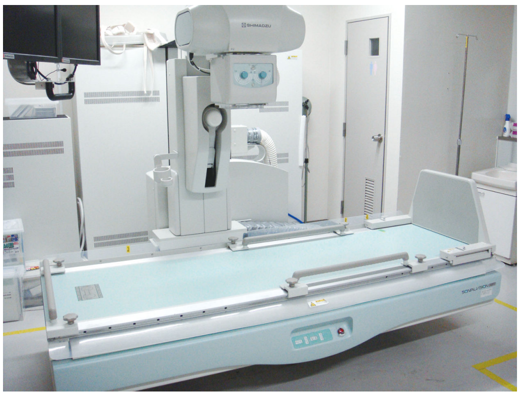


Fig. 2 SONIALVISION safire Series System

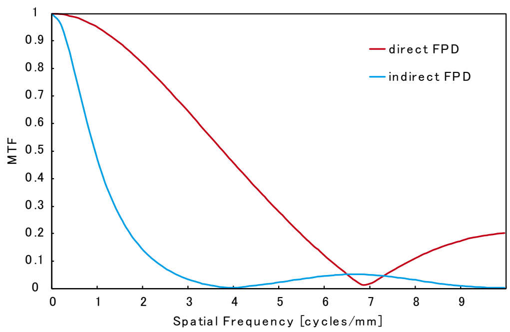


Fig. 3 Comparison of MTF Between Direct FPD and Indirect FPD

3. Tomosynthesis

Tomosynthesis involves moving the X-ray tube and FPD in opposite directions during radiography and swinging the X-ray tube through a certain angle θ to obtain θ units of radiography data. This data is subsequently reconstructed using filtered back projection (FBP) to obtain images on any section. Tomosynthesis is extremely simple to perform using a SONIALVISION safire series system. After positioning, simply use the [SET] button on the main console to move the X-ray tube and then press the Exposure button to complete radiography. Image reconstruction of the required tomographic images is performed after the patient leaves the room but the patient's waiting time is shorter than for tomography that requires film development. Unlike CT, reconstruction on a required section, such as the sagittal section or coronal section, is not possible. However, a single imaging operation (5.0 or 2.5 sec) offers sections from the tabletop to a height of 450 mm above it, and offers short examination time. The tomographic angle (or angular range) θ for the system can be selected as 8, 20, 30, or 40°. However, as tomosynthesis produces less data than CT, artifacts can result due to missing data. Reconstruction filters are available to reduce the artifacts. Reconstruction filters are low-pass filters that cut the high-frequency components that cause artifacts. The reduced frequency band changes according to the projection angle (bandwidth limit). As an example, **Fig. 4** shows three projection angles and the corresponding filter shapes. As the projection angle increases, the filter shape changes to reduce higher-frequency components. Smoothing occurs in the section-height direction when such filters are used in the spatial frequency region to reduce the high-frequency components in the section-height direction before image reconstruction. That is, changing the intensity of the bandwidth limit changes the amount of information (section thickness or slice thickness) contained in a single reconstructed image. The image reconstruction filter Thickness++ that has the highest bandwidth limit produces the thickest section thickness, while the image reconstruction filter Thickness –– that has the lowest bandwidth limit produces the thinnest section thickness. **Table 1** shows the section thickness for each reconstruction filter measured using beads at 40° tomographic angle.

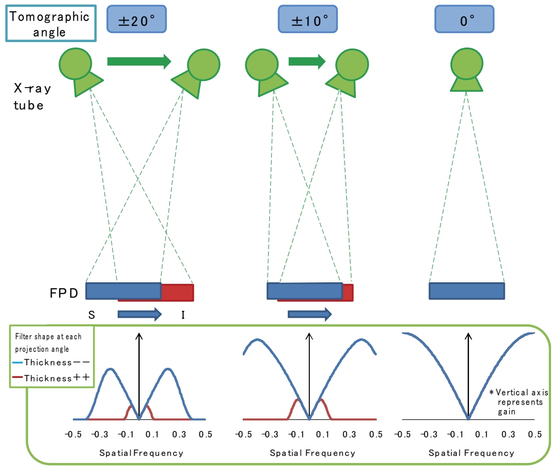


Fig. 4 Changes to Reconstruction Filter Shape at Each Projection Angle

reconstruction filter	section thickness [mm]
Thickness−−	3.72
Thickness−	4.80
Thickness	6.81
Thickness+	8.60
Thickness++	11.29

Table 1 Changes in Section Thickness due to Reconstruction Filter

4. Temporomandibular Joint Tomography by Screen-Film System

We used to perform routine examinations on TMD patients by panoramic radiography and tomography. We performed about 30 examinations per month. **Fig. 5** shows the work flow for tomography.

To obtain lateral images of the temporomandibular joint, radiography was performed with the patient in the prone position and the neck rotated to set the median plane of the head parallel to the tabletop. Left and right images of the temporomandibular joint were taken with the corresponding side of the temporomandibular joint being imaged pressed against the tabletop. At least eight tomographic images were taken from the left and right while opening and closing the mouth. The posture had to be maintained for a long time, which placed a large burden on the patient. As film radiography was used, the film-development time was another factor that increased the examination time.

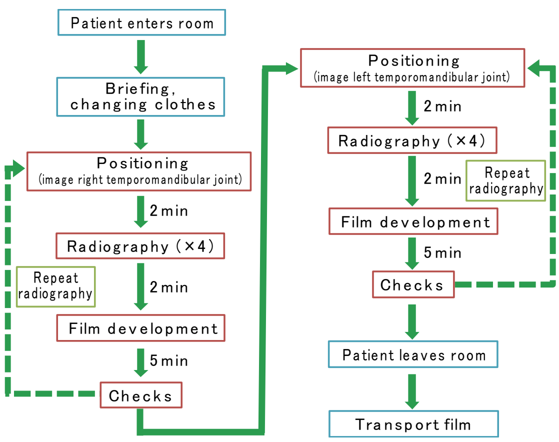


Fig. 5 Work Flow for Tomography

5. Tomosynthesis Imaging of the Temporomandibular Joint

Tomosynthesis imaging of the temporomandibular joint requires the same patient posture as for tomography. However, as the left and right temporomandibular joint images can be reconstructed from one set of radiography data, we thought that the examination could be performed by imaging while opening and closing the mouth just twice. Yet, as so many parameters are required to acquire the images, such as reconstruction filters, the problem of selecting the parameters remains. **Fig. 6** shows reconstructed images using two types of reconstruction filters.

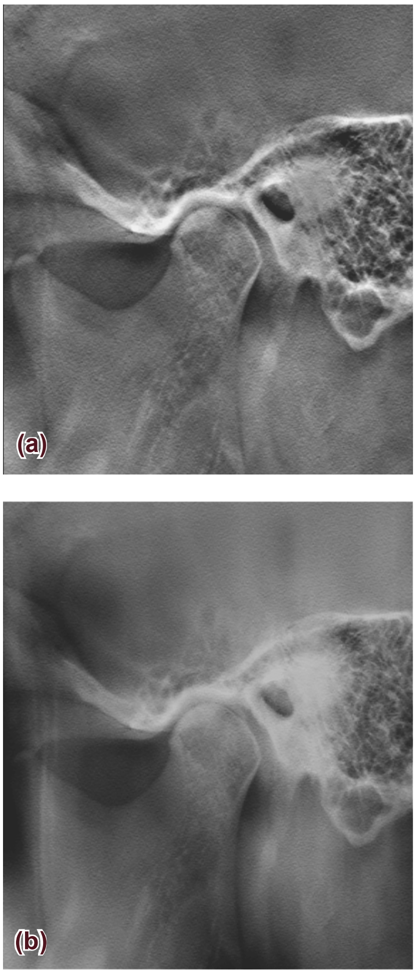


Fig. 6 Differences in Reconstructed Images due to Reconstruction Filter
(a) Thickness ++
(b) Thickness ++ (Metal)

6. Equipment

- R/F Table: SHIMADZU SONIALVISION safire Series
- Tomography system: SHIMADZU SFC-110 (Screen-Film)
- Head phantom: ARL-XR100
- Observation monitor: TOTOKU CCL254i2 (2M, color)
- Film: Kodak INSIGHT (14 × 14 inch)
- Dosimeter: Radcal 9015 (10 × 5-6)

7. Methodology

7.1 Investigated Items

We investigated the items in **Table 2** to determine the optimal radiography conditions and reconstruction conditions.

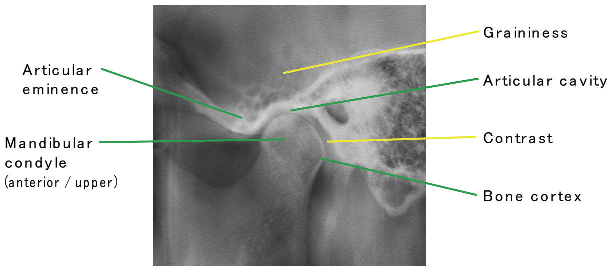
Investigated Items	Compared Parameter
Radiography Tomographic angle	20, 30, 40°
Reconstruction filter	Thickness++, Thickness-- and Thickness++ (Metal)*, Thickness-- (Contrast)*
Difference in left/right image quality	Left/right temporomandibular joint images reconstructed from the same image data
Slice pitch	1.0, 3.0, 5.0 mm
Comparison with conventional method	Tomography, Tomosynthesis

* Thickness++ (Metal) is Thickness++ with a DC filter. Thickness-- (Contrast) is Thickness-- with a DC filter.
A DC filter leaves the direct-current (DC) components and achieves higher image contrast than a normal filter.

Table 2 Investigated Items

7.2 Evaluation Items

The evaluation items for visual evaluation of tomographic images of the temporomandibular joint were determined through consultation with oral surgeons, based on the diagnostic criteria for TMD. Six dental and oral surgeons (with between 10 and 29 years' experience) participated in the visual evaluations. **Fig. 7** shows the evaluation positions that were determined. Graininess and contrast were added to the evaluation items as physical indicators. Items mainly observed around bones are denoted as "bone objects" and the physical indicators as "physical objects." Scores were applied to each evaluation item and the evaluation was based on the scores obtained.



*Graininess was evaluated at an area of uniform density on the temporal bone. Contrast was a comparison between the mandibular condyle and articular cavity.

Fig. 7 Evaluation Positions

7.3 Evaluation by Phantom

The items above were visually evaluated in tomosynthesis and tomographic images of a head phantom.

7.4 Evaluation Using Volunteers

Visual evaluation was performed on tomosynthesis and tomographic images of healthy volunteers. 20

volunteers participated: 14 males, 6 females, aged from 23 to 55
The evaluation of the phantom images and volunteer images was approved by the Tottori University Hospital Ethics Committee.

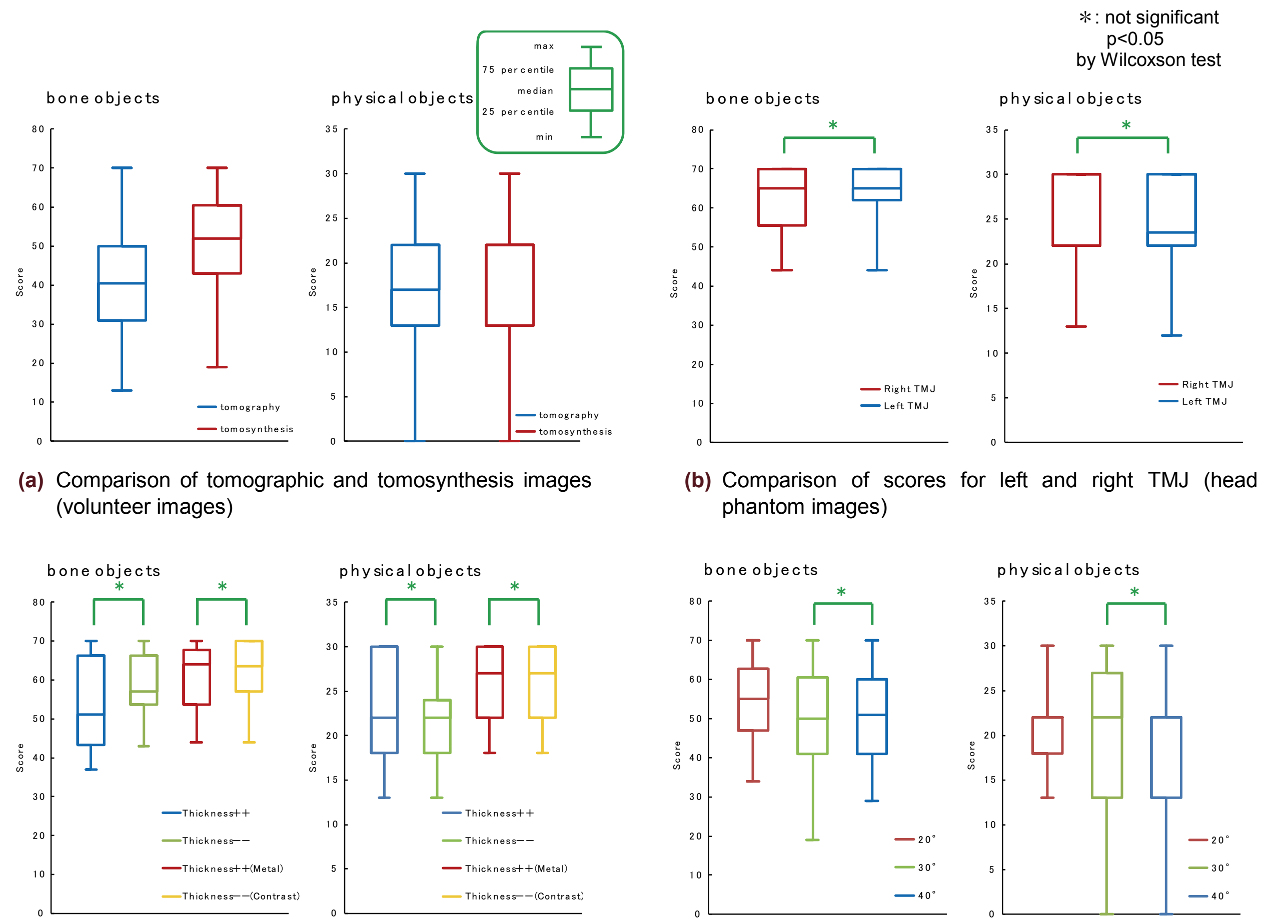
8. Results and Discussions

8.1 Comparison of Tomographic and Tomosynthesis Images

Fig. 8 (a) shows the results of visual evaluations of the tomographic and tomosynthesis images taken of the volunteers. The * marks in **Fig. 8 (a)** to **(d)** indicate no significant differences in the score between the parameters. The tomosynthesis images of the volunteers achieved significantly higher scores than the tomographic images. This confirms that tomosynthesis enhanced the visibility.

8.2 Radiography Conditions for Tomosynthesis

Head phantom images were taken by tomosynthesis and left and right images of the temporomandibular joint (TMJ) reconstructed from the same data were evaluated **(Fig. 8 (b))**. We expected the significant difference in height above the tabletop of the left and right TMJ to affect the image quality, but no differences were observed in the scores. Therefore, it was determined that satisfactory diagnosis is possible using reconstructed images of the left and right TMJ from data acquired by an imaging operation with the temporomandibular joint on one side pressed against the tabletop. **Fig. 8 (c)** shows the evaluation results using the same image data when the reconstruction filter is changed. Thickness ++ (Metal) and Thickness – – (Contrast) yielded significantly higher scores than Thickness ++ and Thickness – –. The evaluations using a head phantom indicate no difference in score due to changing the tomographic angle during radiography.
The evaluations of tomographic angle using volunteer images are shown in **Fig. 8 (d)**. In the volunteer images, the score at 20° tomographic angle was significantly higher than other angles. Examining the head phantom images reveals no differences in score due to the tomographic angle. We believe this occurs because the increased section thickness at 20° tomographic angle makes the deterioration due to artifacts and graininess less distinct, despite the different conditions such as the individual body types of the volunteers and the various ways of viewing the TMJ. Comparison of the Thickness ++ (Metal) and Thickness – – (Contrast) reconstruction



(a) Comparison of tomographic and tomosynthesis images (volunteer images)

(b) Comparison of scores for left and right TMJ (head phantom images)

(c) Comparison of scores for different reconstruction filters (head phantom images)

(d) Comparison of scores according to tomographic angle (volunteer images)

Fig. 8

filters confirmed no difference between the scores. These two filters apply a DC component to achieve higher contrast than a normal filter. Therefore, both filters achieved a good score, with no difference between the scores.

9. Summary

From the results of the visual evaluations, our hospital determined the radiography conditions in **Table 3** for tomosynthesis imaging of the TMJ and image output. Due to the time required for data transfer to the supplied workstation and image reconstruction, we decided to use a 9-inch field of view. Using 200 % magnification during image reconstruction alleviated the burden on the interpreting doctors. In addition, the WW and WL values used by observers to adjust the images during evaluation are recorded so that they are then used as reference values to adjust the density of images transferred to the server, which makes image adjustment simpler for the interpreting doctors.
The Thickness –– (Contrast) reconstruction filter results in a thinner section thickness that may cause deterioration in graininess. Therefore, we selected Thickness ++ (Metal) for clinical applications. **Fig. 9** shows the work flow for tomosynthesis imaging of the TMJ. The introduction of tomosynthesis more than halved the examination times compared to tomography. This reduces the burden on the patient in holding a posture as well. Confirmation by X-ray fluoroscopy after positioning virtually eliminates the need for re-imaging. Tomosynthesis imaging of the TMJ therefore results in one-tenth the X-ray exposure dose of tomography.

Imaging Parameters

Tomographic angle	20°	
Slice height	Nose height	Parameters for automatic reconstruction
Slice width	140 mm	
Slice pitch	10 mm	
Exposure dose	75 kV, 2.5 mAs, 12 msec	

Reconstruction Parameters

Reconstruction filter	Thickness ++ (Metal)
Slice height	TMJ height selected from automatically reconstructed image
Slice pitch	3.0 mm
Magnification	200 %

Table 3 (Red items were current investigation items)

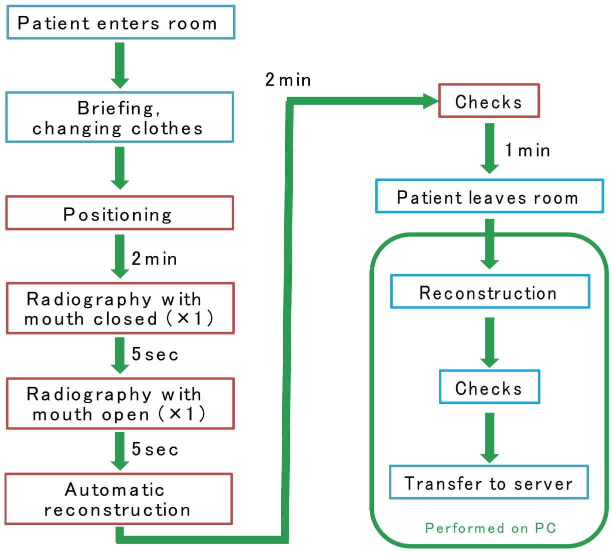


Fig. 9 Work Flow for Tomosynthesis Imaging

10. Conclusions

This paper described results of our investigations into tomosynthesis imaging of the temporomandibular joint. Tomosynthesis is a simple and extremely convenient tool that acquires a lot of information. However, due to the large number of parameters for imaging and reconstruction, introducing tomosynthesis requires consultations with specialist doctors. At this hospital, we plan to investigate the application of tomosynthesis to other body positions in the future.