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Contributing to Efficiency in Examinations and Diagnoses with the Latest Technology:
application of AI functions in the RF Table System, T-smart PRO

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1. Introduction

Our hospital, established in 1876 as the predecessor of the Saisei Gakusha, has produced many renowned medical scholars, including Hideyo Noguchi. In 2018, we transitioned to a new 12-story hospital with 877 beds and a rooftop heliport. Currently, there are five operational X-ray fluoroscopy systems: two in the radiology department, two in the endoscopy center, and one C-arm RF system. In the fiscal year 2021, the total number of examinations using these systems was 2,945, with nearly ten percent pertaining to orthopedics. One of the fluoroscopy systems in the radiology department, the SONIALVISION G4, capable of Tomosynthesis, was upgraded in May 2022 with the AI-assisted Tomosynthesis reconstruction method T-smart PRO, and we have gradually started to use it for post-operative evaluations of artificial joints.

2. Requirements for Tomosynthesis Imaging

In our hospital, Tomosynthesis imaging is primarily used for patients with artificial joints. Before the introduction of T-smart PRO, the time required from image processing before and after exposure to providing images, as well as the quality of the reconstructed images, largely depended on the technician's experience and skills. Especially in emergency examinations conducted between scheduled ones, rapid provision of images is required. It's crucial to obtain good quality images with minimal artifacts, focusing on the area of interest, such as bone trabeculae and implant junctions, within the limited time available.

3. Introduction to T-smart PRO

T-smart PRO, applying AI functionality*, supports operator tasks in setting parameters and streamlines the Tomosynthesis examination process. The support includes, first, automatic setting of Filter Back Projection parameters based on metal and collimator extraction and separation. Regardless of the size or type of metal, these are automatically extracted and separated. After automatically detecting collimator leaves in the radiographic images and setting the reconstruction processing range, the AI function automatically sets Filter Back Projection parameters according to the size of the extracted metal, creating reconstruction images with minimal metal artifacts.
Next, there's automatic determination of subject thickness and tomographic reconstruction range. If the subject fits within the possible range for tomographic reconstruction, the system automatically determines and sets the appropriate parameters for subject thickness for Filter Back Projection. Additionally, it automatically sets the range for tomographic imaging.

4. Performance Evaluation

We conducted two types of evaluations to assess the time required and image quality for Tomosynthesis imaging creation using T-smart PRO.

4.1 Performance Evaluation 1: Time Required for Tomosynthesis Image Creation

We conducted a simple performance evaluation to see how much difference T-smart PRO makes in the time required for image creation. The evaluation method compared the time from the start of image construction to sending the image to the clinician, using conventional manual parameter adjustments versus T-smart PRO. The subjects were eight general

Editor's Note: *The AI (Artificial Intelligence) technology used in T-smart PRO is not the type that learns and repeats its own learning by themselves.

radiological technologists and one CT technologist, and the evaluation included nine cases: four hip joints, four knee joints, and one lumbar spine.

Evaluation 1 Results:

The time required for image submission using conventional procedures was 7.6 minutes for the hip joint, 10.8 minutes for the knee joint, and 10.2 minutes for the lumbar spine. With T-smart PRO, these times were reduced to 4.18 minutes for the hip joint, 3.46 minutes for the knee joint, and 2.4 minutes for the lumbar spine, resulting in a time difference of 3.42 minutes, 7.34 minutes, and 7.8 minutes, respectively. This suggests that the time required for Tomosynthesis image creation is reduced to half for the hip joint, a third for the knee joint, and a quarter for the lumbar spine, enabling faster image provision to physicians **(Fig.1)**.

Result

[minutes]

	hip joint	knee joint	lumbar spine
conventional procedures	7.6	10.8	10.2
T-smart PRO	**4.18**	**3.46**	**2.4**
Reduction time	**3.42**	**7.34**	**7.8**

Fig.1 Performance Evaluation 1: Time Required for Image Creation

4.2 Performance Evaluation 2: Comparison of Reconstructed Image Quality

We evaluated whether T-smart PRO could produce images with less metal artifact and clearer visibility of bone trabeculae and implant junctions. The observers included three veteran technologists with over 15 years of experience and two junior technologists with less than 10 years. We used reconstructed images created by veteran technologists using traditional procedures, by junior technologists using traditional procedures, and by junior technologists using T-smart PRO. The creators of each image were blinded, and each image was evaluated on three observation points (A, B, C) with a score of 0 to 5. Observation point A was the visibility of bone trabeculae, B was the visibility of the stem junction, and C was the presence of metal artifacts.

For each observation point, five evaluation areas were set on the reconstructed image. A score of 1 was given for visible bone trabeculae and 0 for poor sharpness or visibility, with a maximum of 5 points. For artifacts, a score of 0 was given if metal undershoot was visible, and 1 if not. This unique scaling method was used according to the observation points, as shown in **Fig.2**. Although displayed as a single image in this publication, the actual evaluation was conducted on continuous tomographic reconstruction images.

Evaluation 2 Results:

For images created by veterans without T-smart PRO, the scores were A: 4.2, B: 4.0, C: 4.16. For images created by junior technologists without T-smart PRO, the scores were A: 3.3, B: 3.37, C: 4.16. For images created by junior technologists using T-smart PRO, the scores were A: 4.1, B: 4.0, C: 4.26. The scores of images created by veterans and those created by junior technologists using T-smart PRO were nearly equal for A, B, and C.

These results suggest that using T-smart PRO allows even less experienced technologists to create images with clear visibility of bone trabeculae and implant junctions, and minimal artifacts. While individual preferences and minor adjustments may be necessary, it's suggested that images of a similar quality to those created by veterans can be produced **(Fig.3)**.

・Observation Point A visibility of trabecular bone
・Observation Point B visibility of the stem junction
・Observation Point C Few metal artifacts

veteran technologists (over 15 years of experience) | junior technologists (less than 10 years) | T-smart PRO

Fig.2 Performance Evaluation 2: Observation Points of Reconstructed Images

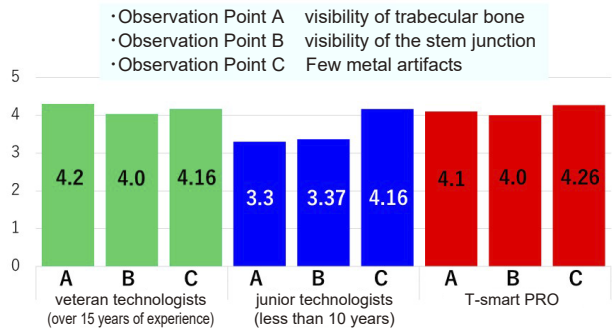

Fig.3 Performance Evaluation 2: Comparison of Reconstructed Image Quality

5. Case Presentations

Case 1:

This is an image from a patient who underwent artificial hip joint replacement surgery for bilateral osteoarthritis of the hip joints and is a postoperative two-week follow-up image. Using the oblique reslice display function in T-smart PRO, a reconstructed image along the stem was created. The stem junction, bone trabeculae near the pelvic cup, and bone trabeculae near the screws, which were difficult to discern in pre- and postoperative photographs, are visible **(Fig.4)**.

Case 2:

A patient who underwent artificial joint replacement for right hip joint necrosis and later treatment for necrotizing fasciitis. The implant was removed and fixed with a cement spacer mold, and this image is pre-replacement surgery. The cement spacer mold, a temporary implant filled with bone cement until a proper artificial hip replacement, is recognized by T-smart PRO's automatic detection feature, reducing metal artifacts **(Fig.5)**.

Case 3:

An image from a patient with bilateral osteoarthritis of the knee, who underwent artificial knee joint replacement surgery, taken during a three-week postoperative follow-up. The implant junction and surrounding bone trabeculae, which were hard to distinguish in general X-rays, are visible **(Fig.6a)**. The same patient was also imaged in a standing position on using a tilting table function. Tomographic imaging is possible even in a standing position, and T-smart PRO functioned without issues, allowing reconstruction image creation. The advantage of this RF table system is that tomography can be performed in both lying and standing positions without moving the patient to another room **(Fig.6b)**.

Fig.4 Case 1: Postoperative Follow-up Image 2 Weeks after Artificial Hip Joint Replacement
a) Frontal view
b) Lateral view near the stem
c) Lateral view near the cup

Fig5 Case 2: Image during Cement Spacer Mold Fixation before Artificial Hip Joint Replacement Surgery

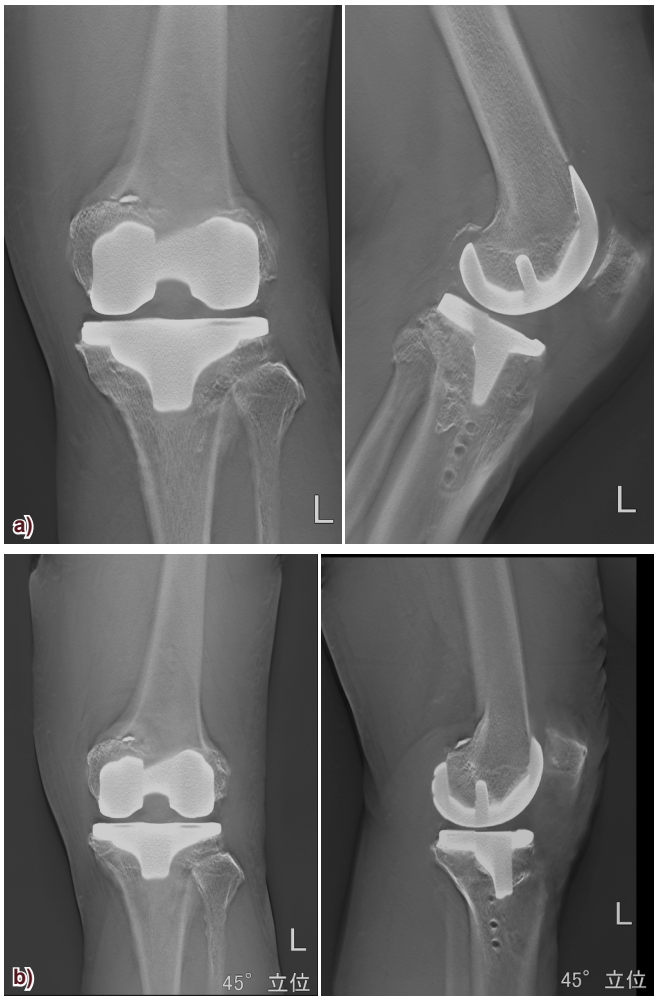

Fig.6 Case 3: Postoperative Follow-up Image 3 Weeks after Artificial Knee Joint Replacement Surgery
a) Lying position **b)** 45° Standing position

Case 4:

An image from a patient who underwent wire fixation surgery for a patella fracture, taken before wire removal to assess bone fusion. Even when the area of interest, such as a patella with a wire, is located at the edge, T-smart PRO detects the entire knee for reconstruction. Even if the reconstruction range is too broad, it can be easily adjusted by entering the reconstruction range values **(Fig.7)**.

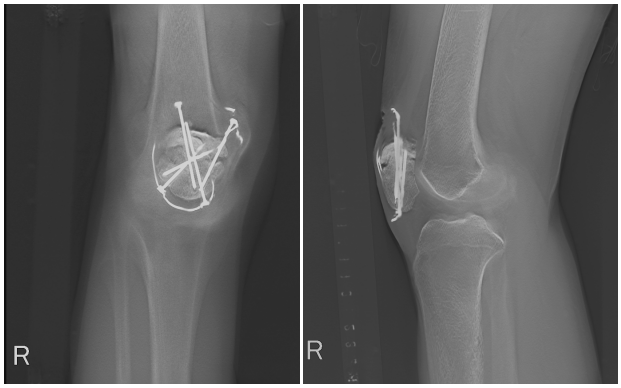

Fig.7 Case 4: Pre-Wire Removal Image for Bone Fusion Evaluation in Patella Fracture

Case 5:

An image for evaluating bone necrosis in a patient with necrosis of the femoral condyle before artificial joint replacement surgery, under the same radiographic conditions as Case 3. Using T-smart PRO in the lateral view of this case. about a fifth of the region of interest was recognized as out of reconstruction range. This case was adjusted in the same way as Case 4 to create a reconstruction image **(Fig.8)**.

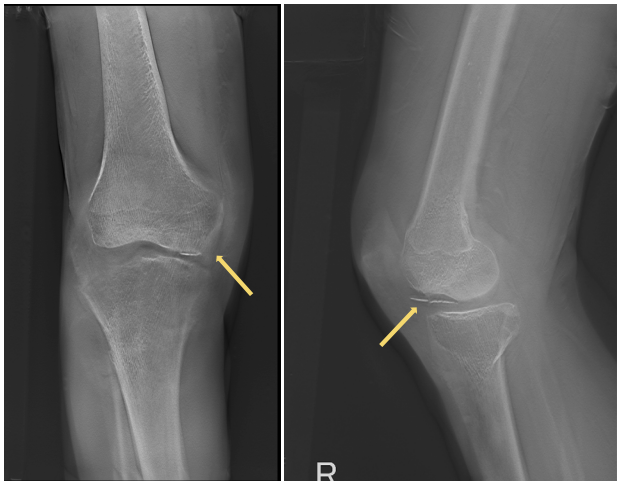

Fig.8 Case 5: Pre-Artificial Joint Replacement Image for Evaluation of Necrosis of the Femoral Condyle

Case 6:

A patient with lumbar spinal stenosis underwent a laminectomy at L5 followed by posterior fixation and bone grafting from L4 to S1. This image was taken immediately after performing S1 spinal myelography and right S1 nerve root myeloblock with SONIALVISION G4. The contrast medium near the right S1 sacral foramen and screws, although very thin, is visible. Bone trabeculae and the boundary with artificial bone are discernible. Furthermore, the metal artifacts are minimal, allowing clear visibility of the screws to their tips **(Fig.9)**.

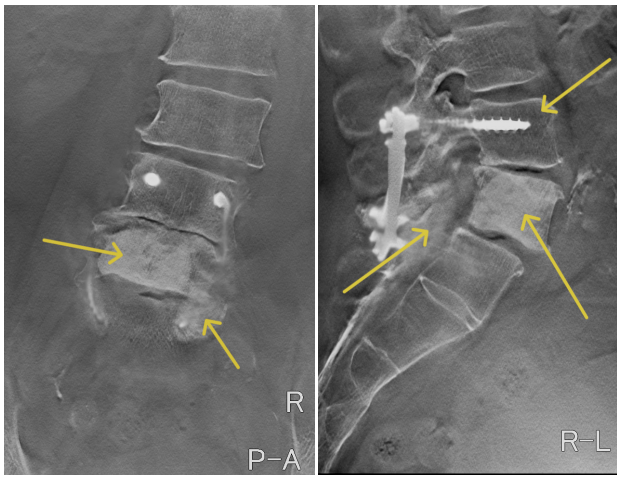

Fig.9 Case 6: Image Immediately after Myeloblock Following Posterior Fixation from L4 to S1 and Bone Grafting

6. Comments from Orthopedic Surgeons

Regarding the reconstructed images from T-smart PRO, orthopedic surgeons commented that the images were clear and allowed for precise observation of bone healing, comparable in quality to CT images. There was a request for additional dedicated examination slots for tomographic imaging. Additionally, comments mentioned its low cost and patient-friendliness. The surgeons requested that we technologists create images with anterior angulation adjustments similar to CT MPR images, construct images along the implant, and construct images that can evaluate loosening of the cup in the pelvic area.

7. Conclusion

With T-smart PRO, metal and collimator extraction and separation, as well as automatic determination of subject thickness and tomographic reconstruction range, have reduced the time-consuming tasks and image quality adjustments before and after exposure, decreasing the time required for Tomosynthesis examinations. Moreover, it has enabled providing images with clear visibility of bone trabeculae and implant junctions, and fewer artifacts, independent of the Technologist's experience or skills. Furthermore, the improved throughput has shortened the time to provide images to doctors, suggesting that T-smart PRO contributes to improving the workflow of Tomosynthesis examinations.

This study was a preliminary performance evaluation. In the future, we plan to conduct further validations, including physical experiments, to optimize exposure conditions and explore the potential and limitations of T-smart PRO's automatic determination features. Regarding image evaluation, we aim to continue collaborating with clinicians to increase the number of cases and observers for more detailed observational evaluations.

8. Acknowledgements

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