

# Experiences with Slot Radiography Using SONIALVISION safire17

## — Applications to Limb Lengthening Surgery of the Lower Limbs —



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### 1. Introduction

This hospital was established in September 1971, and is currently a university hospital comprising two basement levels and 19 aboveground floors (**Fig. 1**). With its attached critical care center and general perinatal medical center as well as its 23 medical departments offering 1154 beds, it contributes to regional health services and functions as an advanced treatment hospital. The hospital handles an average of 1800 to 1900 outpatients and the Department of Radiology performs an average of 600 to 800 radiographic examinations each day. Approximately 65 % of these are performed by the general radiography department. Due to the focus of the orthopedics department on bone treatment, the general radiography department frequently performs bone radiography, in particular long view radiography, on some 20 to 30 cases per day.

In May 2009, the hospital relocated based on the concept of hospital IT and began totally filmless operation. We then faced the problem of how to digitize the conventional long view radiography film images.

This hospital previously performed two types of long view radiography: normal overview radiography and a method known as slit scanograms. Slit scanograms are taken on a long film by collimating the X-rays with an approximately 2 mm slit. The images are taken using a long exposure time while moving the subject in the craniocaudal direction. This method results in low operation efficiency and a high exposure dose to the technologist and patient alike. To exploit the introduction of digitization to overcome these problems, we switched to slot radiography using a Shimadzu SONIALVISION safire17 Digital R/F System. This paper reports on our experiences using slot radiography with the Shimadzu SONIALVISION safire17, in particular for limb lengthening surgery on the lower limbs, and on the clinical utility of this radiography.



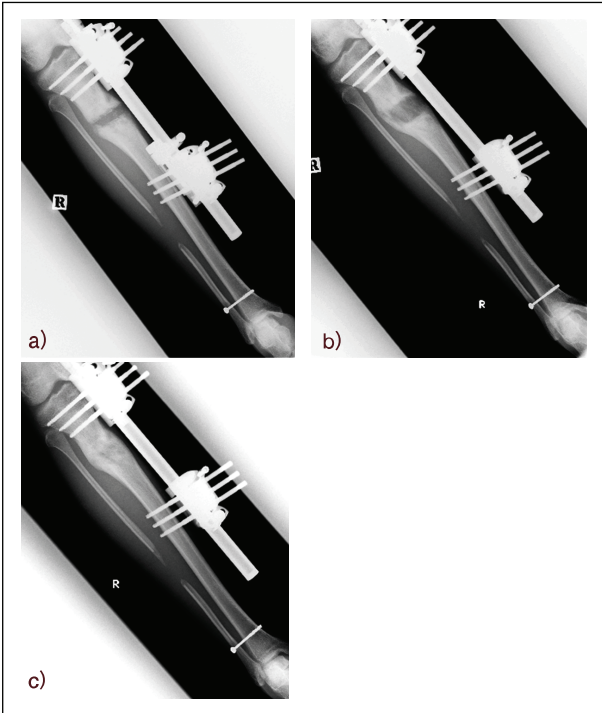
Fig. 1 Teikyo University Hospital

### 2. Requirement for Slot Radiography

This hospital commonly performs bone treatments on limbs using the Ilizarov method.

Bone lengthening surgery by the Ilizarov method is applied in cases of bone defect or bone deformation due to congenital disease or trauma or after bone resection due to malignant tumor or osteomyelitis. The principle of the Ilizarov method is to apply continual tensile stress to increase the amount of tissue through distraction histogenesis. This method exploits the body's mechanism for healing broken bones. As a bone fracture heals, callus forms at the fracture site and increases in volume to create bone tissue. During limb lengthening surgery using the Ilizarov method, the joint between artificially resected bone surfaces is gradually pulled apart to form callus and is then fixed at the optimal length, as shown in **Fig. 2**. This creates bone tissue at the joint site, resulting in extension of the bone. The fixator holding the extension site can be used to apply bending or twisting to lengthen the bone. It can therefore straighten bones that are deformed due to an accident or malformation. In practice, the procedure involves adjusting the fixator by about one millimeter per day. **Fig. 2** shows the progression of callus formation at the extension site in the tibia.

Therefore, the X-ray images for limb lengthening surgery must be able to visualize the callus formation process and permit accurate length measurements. Consequently, normal long view radiography is unsuitable for observing the progress of bone lengthening surgery, as the image magnification is not constant and the image distortion due to body thickness effects increases as the distance from the center point of the X-ray beam to the measurement point increases. Greater accuracy is required, especially during the period when a fixator is applied to lengthen a bone in millimeter increments. For the reasons above, due to its low image distortion and low magnification in the craniocaudal direction, we use slot radiography at this hospital to measure the extension distance during the lengthening process and to measure the difference in length of the left and right legs for diagnosis.



**Fig. 2** Process of Callus Formation During Limb Lengthening Surgery  
 a) Cut the shorter bone surgically  
 b) Extend that portion by fixing device  
 c) Callus will form between the bone

### 3. Distortion in Long View Radiography and Slot Radiography Images

The geometrical arrangement in **Fig. 3** was determined based on consideration of the distance accuracy of slot radiography images and normal long view radiography images by CR.

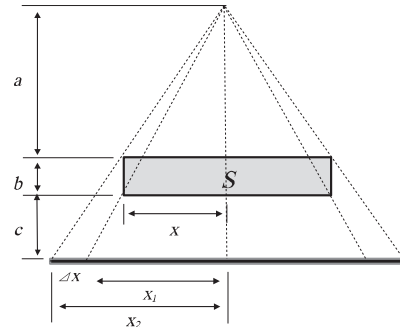
At a distance  $x$  from the center of a thick object  $S$ , the position of the projected image of the upper edge on the light-receiving surface is given by

$$x_2 = \frac{a+b+c}{b+c} \cdot x$$

and the position of the projected image of the lower edge is given by

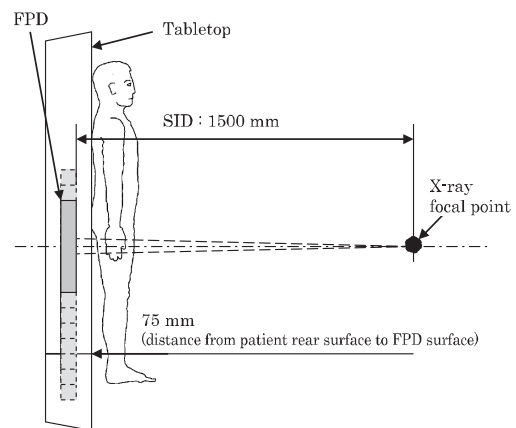
$$x_1 = \frac{a+b+c}{c} \cdot x$$

If  $\Delta x$  denotes the magnitude of image distortion of the object at position  $x$  on the light-receiving surface, then  $\Delta x$  is given by  $\Delta x = x_2 - x_1$ .

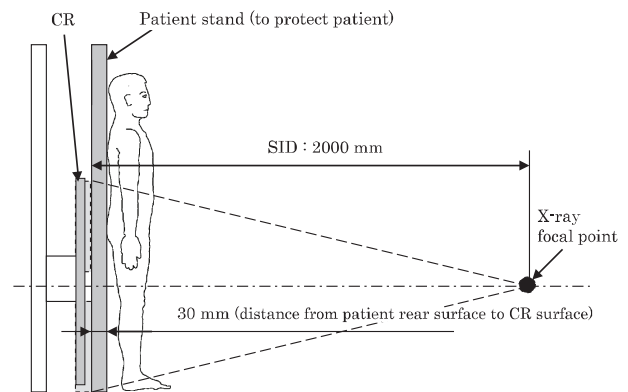


**Fig. 3** Image Distortion During Radiography of a Thick Object

The geometrical arrangements of long view radiography and slot radiography were set as shown in **Fig. 4**. **Fig. 5** and **Fig. 6** show the image distortion calculated for each case.



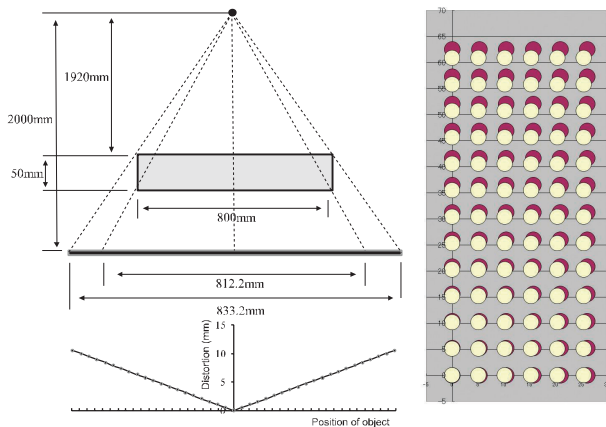
Dimensions for Slot Radiography (SONIALVISION safire17)



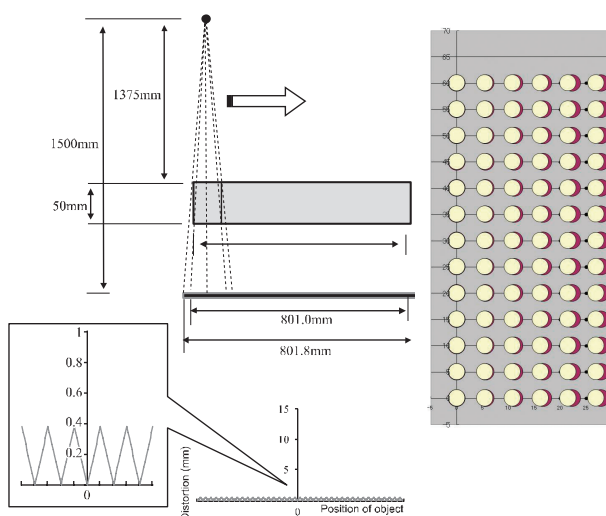
Dimensions for Long View Radiography (CR)

**Fig. 4** Geometrical Arrangements of Long View Radiography (CR) and Slot Radiography

These results indicate that the top edge and bottom edge of an 800 mm object in a long view radiography image appear at 833.2 mm and 812.3 mm in the craniocaudal direction, respectively, due to the effects of the geometrical arrangement. In addition, calculations for 10 mm cylindrical objects arranged at 50 mm intervals indicate that image distortion occurs in the craniocaudal and lateral directions, as shown in **Fig. 5**. It is apparent that the positions of the objects are displaced due to the change in magnification as the distances of the cylinders from the center increase. Therefore, when the distances between objects are measured using different positional relationships, the measured distances differ due to displacement even if the spacing between the objects is actually constant. It is also necessary to consider the effects of image distortion when setting the reference for distance measurement.



**Fig. 5** Image Distortion for Long View Radiography (CR)



**Fig. 6** Image Distortion for Slot Radiography (HQ mode)

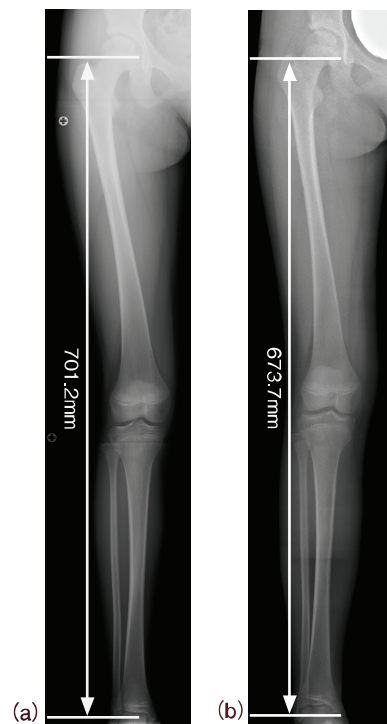
Conversely, the top and bottom surfaces of an 800 mm object in a slot radiography image are enlarged to 801.8 mm and 801.0 mm, respectively, at maximum in the craniocaudal direction, as shown in **Fig. 6**. As slot radiography involves taking

images while moving the imaging chain, calculations for 10 mm cylindrical objects arranged at 50 mm intervals indicate that image distortion does not exceed approximately 0.4 mm in the craniocaudal direction. However, as the SID is shorter than for long view radiography, the distortion and positional displacement are larger in the lateral direction than for long view radiography.

Consequently slot radiography is effective for measuring the extension distance in the craniocaudal direction during the limb lengthening process and for measuring the difference in length between the left and right legs during diagnosis, for which millimeter accuracy is required.

**Fig. 7** shows long view radiography and slot radiography images for the same patient.

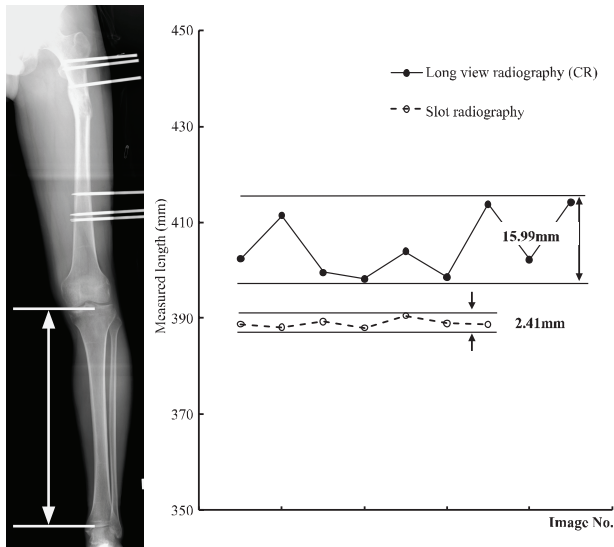
In **Fig. 7**, a discrepancy of approximately 30 mm occurs between the lengths measured from the center of the femoral head to the ankle joint in the long view radiography and slot radiography images.



**Fig. 7** Comparison of Long View Radiography (CR) and Slot Radiography Clinical Images  
(a) Long View Radiography (CR) (b) Slot Radiography

**Fig. 8** shows the actual follow-up of a case using long view radiography and slot radiography. The measurement results for the length of the white arrow in the photograph are shown in the diagram. A large discrepancy up to 16 mm occurs in the values measured by long view radiography. This results from different rates of magnification due to differences in positioning during radiography. The discrepancy in slot radiography measured values is small, up to about 2.4 mm max. We use positioning sponges to keep the target long bones parallel to

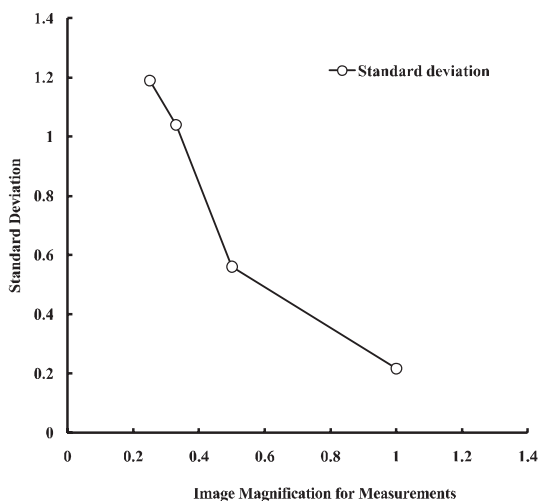
the diagnostic table during long view radiography or slot radiography, and create notes for each patient to enhance the positioning repeatability, but the degree of error shown in **Fig. 8** occurs with long view radiography. However, performing slot radiography according to notes kept for each individual patient produces highly reproducible measurement images.



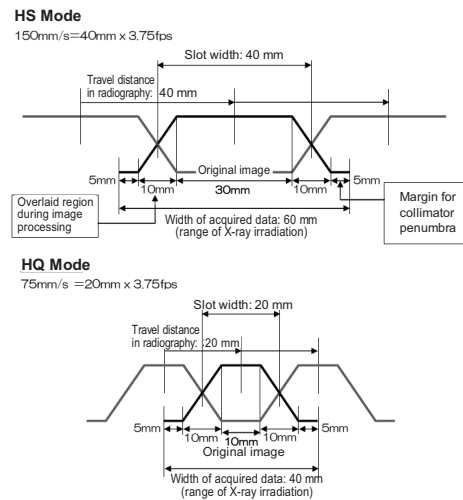
**Fig. 8** Discrepancies in Measured Values for Long View Radiography (CR) and Slot Radiography

However, the image magnification is important when measuring distances on images. As shown in **Fig. 9**, the variation in 20 measured values at the same location is significantly affected by the image magnification. This point must also be taken into consideration when measuring distances.

As shown in **Fig. 10**, two radiography modes are used for slot radiography: HS mode and HQ mode. Care is required, as the image distortion differs according to the radiography mode used.

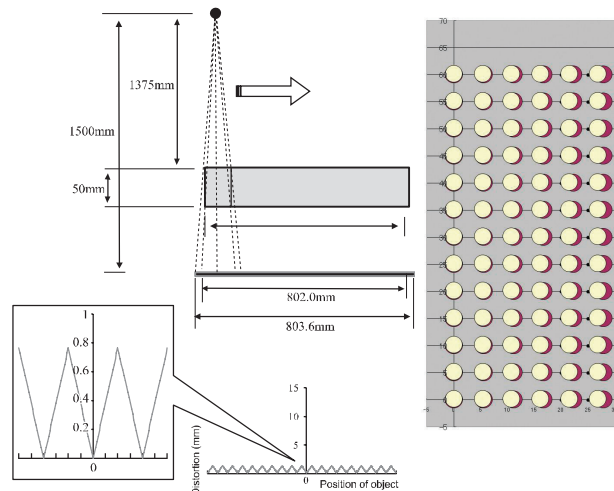


**Fig. 9** Variation in Measured Values Due to Image Magnification Used for Measurement



**Fig. 10** Slot Radiography Modes

**Fig. 11** shows the results of distortion calculations for images taken in the HS mode using the calculation model shown in **Fig. 6**. It results in up to two times the distortion in the HQ mode.



**Fig. 11** Image Distortion with Slot Radiography (HS mode)

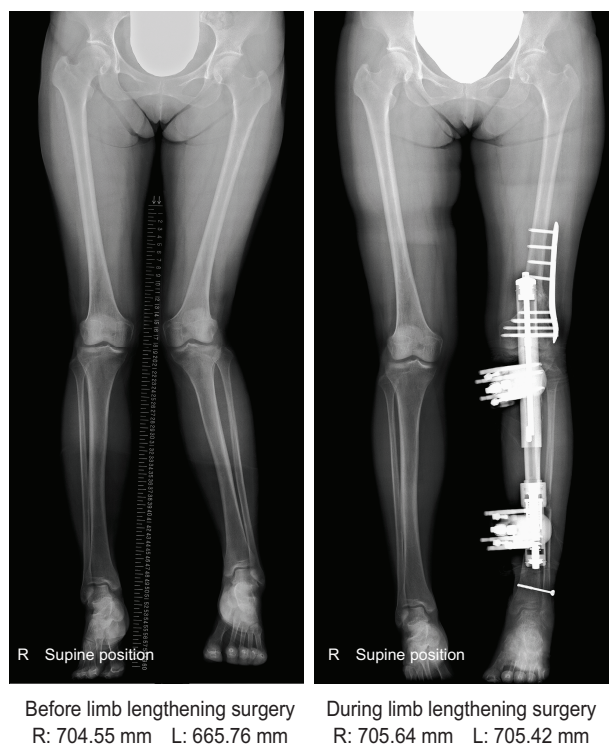
## 4. Slot Radiography Clinical Cases

As shown above, slot radiography produces images suitable for distance measurements due to the extremely low image magnification and image distortion. In addition, highly reproducible images can be produced by using positioning sponges during radiography to keep the target long bones parallel to the diagnostic table according to notes created for each patient. This method is effective for the evaluation of limb lengthening surgery and helps to enhance measurement accuracy.

**Fig. 12** shows slot radiography images of a patient before and during limb lengthening surgery. In this case, the 39 mm difference in leg length prior to surgery was virtually eliminated. It also corrected the degeneration of the left leg. A 39 mm difference in leg length not only impairs walking but



places a load on the lumbar spine and other organs that significantly impairs the everyday life of the patient. Remedying such a problem is extremely beneficial to the patient.



**Fig. 12** Slot Radiography Images of Limb Lengthening Surgery

As shown above, slot radiography offers properties that are extremely well suited to measuring distances. Consequently, at this hospital we use slot radiography images for all distance measurements for limb lengthening surgery, especially on the lower limbs. Also, the alignment of the legs must be observed in a standing position. However, as slot radiography does not require distance accuracy in observing the alignment of the legs in a standing position, to save the effort of fixing the patient, we currently use long view radiography by CR or auto-stitching radiography by the newly introduced Shimadzu RADspeed safire digital general radiography system with a flat-panel detector.

Moreover, as the slot radiography images are intended for length measurements, evaluation of the trabecular bone is not required. That is, as all that is required is to specify the reference point for the measurement on the image, we perform radiography in the HQ mode using approximately one-half the manufacturer's recommended X-ray dose, due to considerations of the X-ray exposure dose.

## 5. Conclusions

Conventionally, slit scanograms using long film required moving the patient in the craniocaudal direction and the technologist had to move the diagnostic table at a constant speed. Therefore, concerns about operator X-ray exposure, personnel required to ensure patient safety, patient X-ray exposure due to long radiography periods, and restrictions due to system standards placed limitations on the radiography. However, the introduction of slot radiography resolved many of these problems to permit more accurate treatment. Even so, some remaining issues related to obtaining more accurate measurement images require future investigation, including the patient X-ray exposure dose, radiography positioning, radiography conditions, and methods for measuring distances on the workstation used for image observations. Due to the difficulty in quantifying the callus formation process at the extension position, future investigations are required into how to quantify this process and perform observations.

Shimadzu has striven to apply digital R/F systems, which were previously used mostly for gastrointestinal observations, to more diverse examinations by introducing new systems such as the SONIALVISION safire17. In today's environment where efficient system operation is demanded, additional functions such as slot radiography are extremely valuable and we anticipate even higher levels of creativity and cooperation from the manufacturer in the future.

Finally, we wish to express our gratitude to Professor & Chairman Takashi Matsushita, M.D. and Nobuyuki Takenaka, M.D. of the Department of Orthopaedic Surgery, Teikyo University School of Medicine, and to Professor & Chairman Shigeru Furui, M.D. of the Department of Radiology, Teikyo University School of Medicine, for their valuable cooperation and advice during the creation of this paper.

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