



# Hanging radiograph in idiopathic scoliosis patients: significance as a preoperative stress X-ray

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**Background:** Before corrective surgery for idiopathic scoliosis, the stress X-rays are indispensable to collect information regarding the reducibility of deformity, deciding fusion levels, and categorizing curve types and so on. The hanging radiograph has not been conducted preoperatively so far as known. The objective of this study was to investigate retrospectively the significance of the hanging radiograph for prediction of the curve correction with surgical procedure by comparing with the side-bending and the traction radiographs.

**Methods:** The subjects enrolled in current study were 22 cases of idiopathic scoliosis who performed posterior instrumentation and fusion by ISOLA method between 2008 and 2014. They included 2 males and 20 females, with a mean age of 16 years and 8 months. The type of curves by Lenke classification were type 1 in 20 cases, type 2 in 1 case, and type 3 in 1 case. We investigated the correction rates of main thoracic curves in side-bending, traction, and hanging positions and compared them with that after surgery. In addition, correction indices were also calculated and compared among these stress X-rays.

**Results:** The correction rate after surgery was 65.9% that was statistically higher than those in side-bending (44.2%), traction (46.6%), and hanging (22.1%) positions. There were statistical correlations between the correction rates after surgery and in side-bending position ( $R=0.73$ ) and those after surgery and in traction position ( $R=0.57$ ). However, there was no statistical correlation between the correction rates after surgery and in hanging position ( $R=-0.01$ ). With regard to the correction indices, that in hanging position (3.67) was statistically higher than those in side-bending (1.51) and traction (1.45) positions.

**Conclusions:** The correction rates in side-bending and traction positions seem to be useful to estimate the amount of curve correction before surgery. Whereas, that in hanging position did not have any significance as preoperative evaluation.

**Keywords:** Idiopathic scoliosis; hanging radiograph; spinal flexibility; surgical treatment; preoperative evaluation

Submitted Jul 25, 2021. Accepted for publication Sep 03, 2021.

doi: 10.21037/jss-21-74

View this article at: <https://dx.doi.org/10.21037/jss-21-74>

## Introduction

Before corrective surgery for idiopathic scoliosis, stress X-rays are indispensable to collect information regarding the reducibility of deformity, deciding fusion levels, and categorizing curve types and so on. Various types of stress

X-rays to evaluate the spinal flexibility in patients with scoliosis have been reported in the past (1-16).

In previous report, the hanging radiograph was utilized in evaluating the spinal flexibility in patients with idiopathic scoliosis scheduled Osaka Medical College (OMC)

brace treatment (17). The side-bending and the traction radiographs are usually performed and seem to be useful to estimate the amount of curve correction before surgery, however, the hanging radiograph has not been conducted preoperatively so far as known.

The objective of this study was to investigate retrospectively the significance of the hanging radiograph for prediction of the curve correction with surgical procedure by comparing with the side-bending and the traction radiographs.

We present the following article in accordance with the STROBE reporting checklist (available at <https://dx.doi.org/10.21037/jss-21-74>).

## Methods

The subjects enrolled in this study were 22 cases of idiopathic scoliosis who performed posterior instrumentation and fusion by ISOLA method between 2008 and 2014. They included 2 males and 20 females, ranging in age from 11 years 5 months to 28 years 7 months, with a mean age of 16 years and 8 months. The curve types by Lenke classification were type 1 in 20 cases, type 2 in 1 case, and type 3 in 1 case. All these patients were preoperatively evaluated the flexibility of curves by the side-bending, the traction, and the hanging radiographs under the supervision of the first author on the same day.

The side-bending radiograph was completed with the patient voluntarily bending maximally while in a supine position. The traction radiograph was obtained through applying maximally tolerable manual distraction force by the first author to stretch the spine using a standard cervical traction halter with a second individual holding the patient's ankles in a supine position. The hanging radiograph was taken in position that the patient was hanging onto the bar, stretching the back, and touching the toes lightly to the floor not to sway the body after instructed exerting greatly to stretch the back as much as possible (*Figure 1*) (17).

We investigated the correction rates of main thoracic curves in side-bending, traction, and hanging positions and compared them with the correction rates after surgery that were collected within 3 months postoperatively. In addition, correction indices were also calculated and compared among these stress X-rays.

Cobb angles were manually measured on main thoracic curves using the standard technique. Correction rates and correction indices were calculated using the following formulas.

$$\text{Correction rate (surgery)} = \frac{(\text{preoperative Cobb angle} - \text{postoperative Cobb angle})}{\text{preoperative Cobb angle}} \times 100\% \quad [1]$$

$$\text{Correction rate (stress position)} = \frac{(\text{preoperative Cobb angle} - \text{Cobb angle in stress position})}{\text{preoperative Cobb angle}} \times 100\% \quad [2]$$

$$\text{Correction index} = \frac{\text{correction rate with surgery}}{\text{correction rate with surgery position}} \quad [3]$$

Statistical analysis was performed using two-tailed paired *t*-test and Pearson's correlation coefficient. A P value of <0.05 was considered to be statistically significant.

We obtained written informed consent from the patients and their guardians for publication of this report and any accompanying images. Further, all procedures performed in this study were in accordance with the Helsinki declaration (as revised in 2013).

This research has been approved by the IRB of the authors' affiliated institution (IRB No. 30-07).

## Results

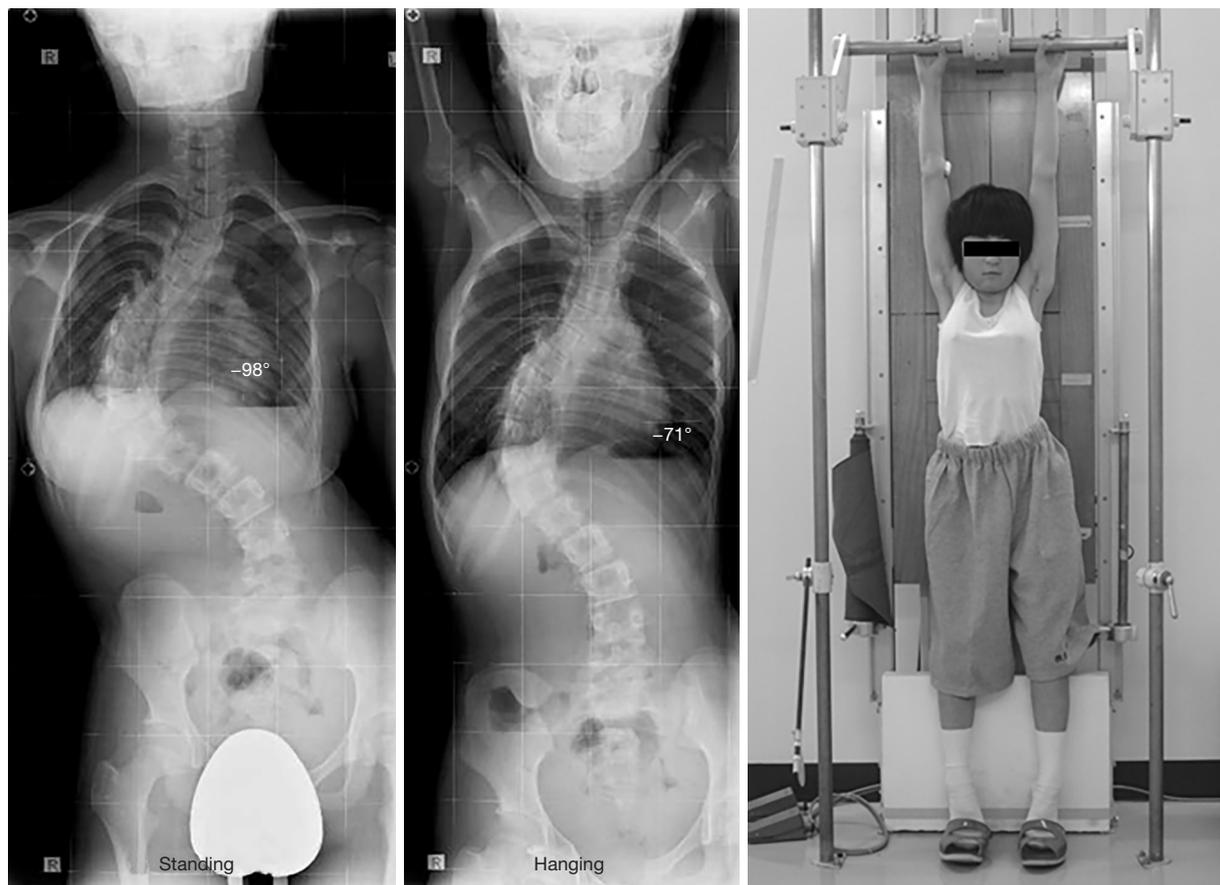
The average preoperative Cobb angle of main thoracic curves was  $61.1^\circ \pm 9.3^\circ$ . It was corrected with surgery to  $21.3^\circ \pm 9.5^\circ$ , and the stress X-rays by way of side-bending, traction, and hanging positions to  $34.6^\circ \pm 10.4^\circ$ ,  $32.7^\circ \pm 8.5^\circ$ , and  $47.7^\circ \pm 10.6^\circ$ , respectively (*Figure 2*).

The mean correction rate after surgery was 65.9% that was statistically higher than those in side-bending (44.2%), traction (46.6%), and hanging (22.1%) positions (*Figure 3*). There were statistical correlations between the correction rates after surgery and in side-bending position ( $R=0.73$ ) and those after surgery and in traction position ( $R=0.57$ ). However, there was no statistical correlation between the correction rates after surgery and in hanging position ( $R=-0.01$ ) (*Figure 4*).

The correction indices of side-bending, traction, and hanging positions were 1.51, 1.45, and 3.67, respectively. The correction index in hanging position was statistically higher than those in side-bending and traction positions (*Figure 5*).

## Discussion

The assessment of the spine flexibility has been conventionally implemented by use of the side-bending radiograph obtained with the patient in the supine or standing position (1). In addition, the push-prone radiograph in which the examiner applies manual pressure on the apices of the curve (2,3), the fulcrum-bending

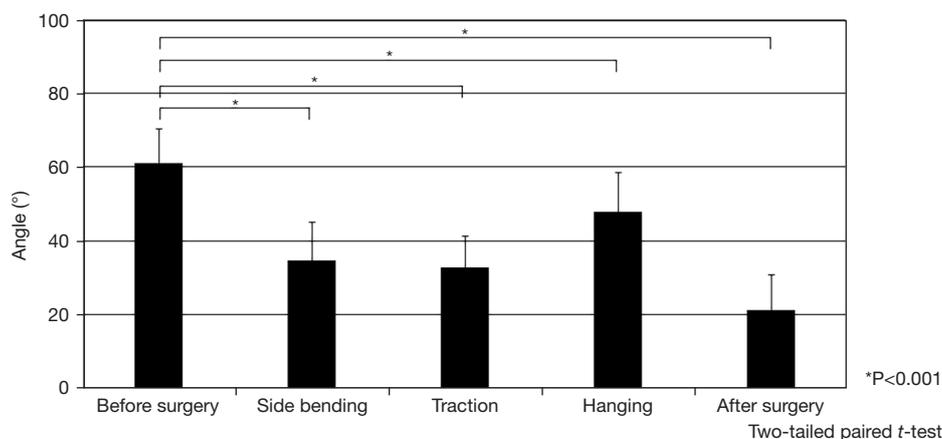


**Figure 1** Position of the taking hanging radiograph. The hanging radiograph was taken in a position that the patient is hanging onto the bar, stretching the back, and touching the toes lightly to the floor not to sway the body. Patients were instructed making a great effort to stretch their back as much as possible. This image is published with the patient and her guardians' consent. Quoted from the reference (17).

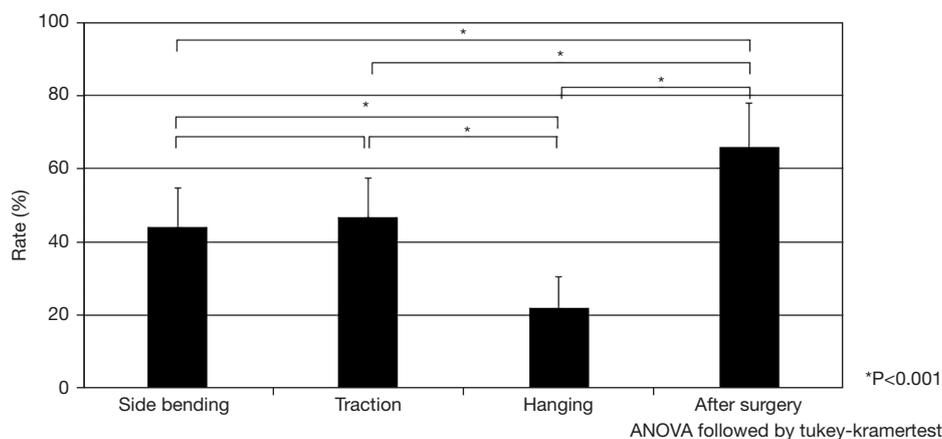
radiograph which is made with patient lying on his or her side over a large radiolucent plastic cylinder (4-6), the supine traction radiograph which is obtained by applying traction force using a standard cervical traction halter with a second individual applying countertraction on both lower extremities (7,8), the cervical suspension radiograph after application of a traction force corresponding to 30% of the patient's body weight through a standard cervical traction head halter (9), and the axillary suspension radiograph which was taken in lifting position by a axillary harness to create a spinal traction force resulting from the patient's own weight (10) have been reported as the stress X-rays to estimate the spinal flexibility in patients with idiopathic scoliosis. Further, general anesthesia is employed by some surgeons to take the supine traction radiograph for evaluation of maximum curve flexibility just before surgery (11-13). After advent of the EOS system, Hirsch *et al.* (14,15)

utilized it to record the cervical suspension and the side-bending images in upright position and demonstrated that they showed similar results in classic supine position with seven and five times less radiation exposure, respectively. Recently, Ceyhan *et al.* (16) introduced a new piece of equipment; an electric traction table (ETT) that can apply simultaneously longitudinal traction and lateral pushing forces to the patient and predict the balance of the corrected body for choosing selective fusion levels. In a systematic review, Khodaei *et al.* (18) reported that the supine side-bending technique was the most practically used to assess the spinal flexibility but the fulcrum-bending technique was the most accurate in predicting post-operative correction among different radiographic methods.

It has been previously reported that the hanging radiograph is taking for the idiopathic scoliosis patients to assess if an appropriate correction by OMC brace is attained



**Figure 2** Mean Cobb angles. The mean preoperative Cobb angle of main thoracic curves was  $61.1^{\circ} \pm 9.3^{\circ}$ , and it was corrected with surgery to  $21.3^{\circ} \pm 9.5^{\circ}$ , and the stress X-rays by way of side-bending, traction, and hanging positions to  $34.6^{\circ} \pm 10.4^{\circ}$ ,  $32.7^{\circ} \pm 8.5^{\circ}$ , and  $47.7^{\circ} \pm 10.6^{\circ}$ , respectively.



**Figure 3** Mean correction rates. The mean correction rate after surgery was 65.9% that was statistically higher than those in side-bending position of 44.2%, traction position of 46.6%, and hanging position of 22.1%.

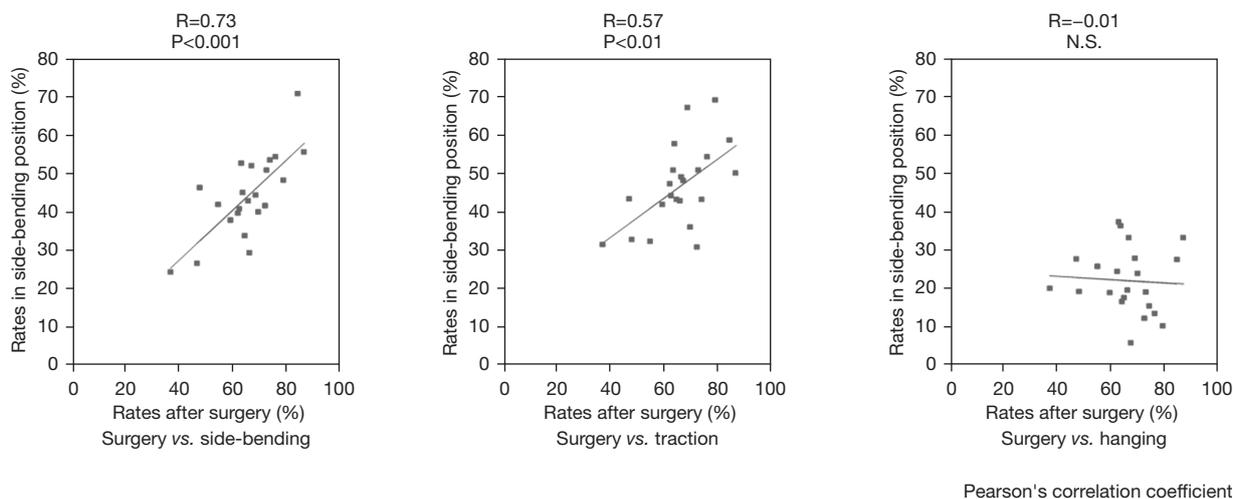
before prescription (17). The Cobb angle in hanging position were approximately correlated with the Cobb angle on OMC brace wearing independent of curve patterns, except some curves in multiple curve patterns, and were useful confirming adequate correction by OMC brace (17).

Advantages of the hanging radiograph are as follows: it is easily taken in outpatient clinic without any expensive equipment, extra-time, and extra-workforce, the target angle corrected by OMC bracing can be estimated, and the condition of traction force remains relatively steady because it depends just on the patient's own weight. By contrast, disadvantages of it are as follows: it is insusceptible to take for the patients who cannot hang onto the bar, the

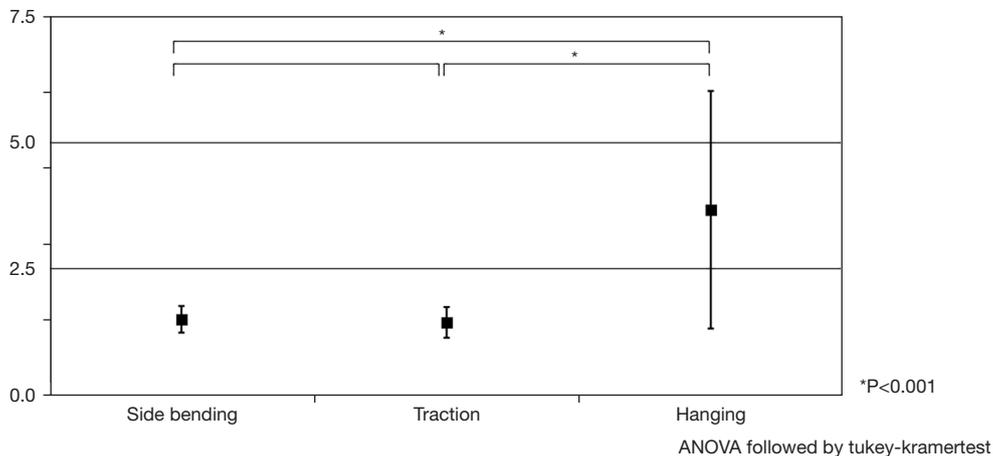
force direction applied by this technique is just longitudinal which is not same as corrective force of OMC brace and corrective surgery by ISOLA method, and this technique is not applicable to some curves in multiple curve patterns (17).

In the current study, we investigated the significance of the hanging radiograph for preoperative evaluation of posterior instrumentation and fusion by ISOLA method. As a result, the correction rates of the side-bending and the traction radiographs seem to be useful anew to predict the amount of curve correction before surgery. Whereas, the hanging radiograph did not have any significance as preoperative evaluation at all.

The spinal flexibility is influenced by various factors, such



**Figure 4** Correlations of correction rates. There were statistical correlations between the correction rates after surgery and in side-bending position ( $R=0.73$ ) and those after surgery and in traction position ( $R=0.57$ ). However, there was no statistical correlation between the correction rate after surgery and in hanging position ( $R=-0.01$ ).



**Figure 5** Correction indices. The correction indices of side-bending, traction, and hanging positions were 1.51, 1.45, and 3.67, respectively. The correction index in hanging position was statistically higher than those in side-bending and traction positions.

as age, gender, apex level, number of involved vertebrae besides curve magnitude. Further, the optimal stress X-ray is suspected to be different in each case. Watanabe *et al.* (19) generally provided that the traction radiographs have a superior corrective ability than the side-bending radiographs in main and proximal thoracic curves, whereas the side-bending radiographs have a superior corrective ability than the traction radiographs in thoracolumbar and lumbar curves from their prospective clinical and radiologic study of adolescent idiopathic scoliosis. He *et al.* (20) reported

that curve magnitude and location are two important parameters in selecting appropriate technique for the spinal flexibility assessment and the treatment effect prediction. They advocated that the traction technique should be considered for the patient with severe curves, while the side-bending technique is suggested for the patients with moderate curves, and then the fulcrum-bending technique is recommended to assess thoracic curve flexibility, whereas the side-bending technique is for the assessment of thoracolumbar/lumbar curve flexibility. Accordingly, the

adoption of the favorable stress X-rays for each patient must be desirable for the scrupulous preoperative planning to obtain ideal and well-balanced correction of scoliosis.

This study included a couple of limitations. First, this is a retrospective observational study. Second, multiple types of curve pattern were evaluated together. Third, the number of patients was relatively small. Fourth, the stress conditions applied by all three different positions were not always standardized. This was an unavoidable issue in current study. Despite these drawbacks, we would emphasize that our study will make a contribution to some advancement for the future management of AIS because accumulation of such minor data based on clinical experiences from a large number of institutions must be imperative to the future solution of issues regarding the outcome of surgery for AIS.

## Conclusions

The correction rates in side-bending and traction positions seem to be useful to estimate the amount of curve correction before surgery. In the meanwhile, that in hanging position did not have any significance as preoperative evaluation.

## Acknowledgments

*Funding:* None.

## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at <https://dx.doi.org/10.21037/jss-21-74>

*Data Sharing Statement:* Available at <https://dx.doi.org/10.21037/jss-21-74>

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <https://dx.doi.org/10.21037/jss-21-74>). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This research has been approved by the IRB of the authors' affiliated institution (IRB No. 30-07). We obtained written informed consent from the patients and their guardians

for publication of this report and any accompanying images. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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**Cite this article as:** Kuroki H, Nagai T, Chosa E, Tajima N. Hanging radiograph in idiopathic scoliosis patients: significance as a preoperative stress X-ray. *J Spine Surg* 2021;7(4):495-501. doi: 10.21037/jss-21-74