



Supine Traction Versus Prone Bending Radiographs for Assessing the Curve Flexibility in Spinal Deformity

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Abstract

Study Design: Retrospective cohort study.

Objectives: No consensus exists among surgeons on which radiologic method to prefer for the assessment of curve flexibility in spinal deformity. The objective of this study was to evaluate the difference in curve correction on supine traction radiographs versus prone side bending radiographs.

Methods: A retrospective analysis of idiopathic scoliosis (IS), degenerative idiopathic scoliosis (DIS) and de novo degenerative lumbar scoliosis (DNDLS) patients was performed on supine traction as well as prone bending films (when available). Age, weight, traction force, diagnosis and Cobb angles of the primary and secondary curves were extracted. Differences in curve correction (percentages) on traction versus prone bending radiographs were analyzed for the primary and secondary curve. Subgroup analyses were performed for the 3 different diagnoses.

Results: In total, 170 patients were eligible for inclusion. 43 were diagnosed with IS, 58 with DIS and 69 with DNDLS. For the primary curve, greater curve correction was obtained with bending in the DNDLS group ($P < 0.001$). In the DIS group, there was a trend toward more correction on bending ($P = 0.054$). In de IS group no difference was found. For the secondary curve, bending showed more curve correction in the IS and DIS group ($P = 0.002$ and $P < 0.001$). No difference was found in the DNDLS group.

Conclusion: Compared to traction radiographs, bending radiographs better serve the purpose of curve flexibility assessment of IS, DIS and DNDLS spinal deformity, despite the fact that patients are exposed to more radiation.

Keywords

bending, traction, scoliosis, flexibility assessment

Introduction

The most common form of spinal deformity is idiopathic scoliosis (IS), which has an unknown etiology.¹ In the adult, spinal deformity can occur due to degenerative changes of the spine. The Aebi classification has divided adult spinal deformity into: (1) primary degenerative scoliosis, which typically occurs in the lumbar spine, hence “de novo degenerative lumbar scoliosis” (DNDLS) and (2) degenerative idiopathic scoliosis (DIS) that has progressed in adult life, which is usually combined with secondary degeneration and/or imbalance.²

In the assessment of spinal deformity for conservative care (for instance bracing in adolescent idiopathic scoliosis (AIS) patients) or as preoperative work-up, curve flexibility or

stiffness are essential; for surgical strategy it will help to determine fusion levels and estimate operative correction potential.³ Many different radiographic techniques exist for obtaining information on the flexibility of spinal deformity such as side

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bending, fulcrum bending, push-prone, suspension, push traction and traction.⁴ However, obtaining traction radiographs is more labor intensive than a bending radiograph as it requires careful preparation, 2 employees instead of 1, clear instructions, and guidance of patients. Side bending radiographs are considered the current gold standard investigation as it only requires patients to voluntarily bend to their maximum in prone position.^{3,5} Still, some studies doubt the predictability of this technique.^{6,7} In a review by Khodaei et al.,⁸ side bending was the most used method, but traction appeared to be a better method in predicting the post-operative curve correction. Khodaei et al. did note that there was a limited number of studies reporting the traction method and the quality of evidence was very low. Overall and in everyday practice, there is ongoing debate and there is no agreement among surgeons about the preferred method to assess spinal deformity flexibility.

Currently, very few studies exist assessing the curve flexibility of patients with spinal deformity. Furthermore, to our knowledge, no studies exist comparing the flexibility in IS versus DNDLS or DIS. Therefore, the main objective of our research is to assess which radiographic method displays the best method to demonstrate curve correction and potential flexibility in IS, DIS, and DNDLS patients.

Methods

Study Design and Patient Population

This study describes a single-center retrospective database of traction and posterior-anterior (PA) full spine radiographs of IS, DIS and DNDLS patients. Inclusion criteria for selection in our study database were: (1) diagnosis IS, DIS, or DNDLS, (2) at least 1 traction radiograph, (3) at least 1 standing PA full spine (StFS) radiograph and (4) bending radiographs when available. Bending radiographs of the selected patients were also included upon availability (not routinely performed in all cases, but at the discretion of the surgeon). Exclusion criteria were: (1) prior juvenile, infantile, associated congenital, developmental or neuromuscular spine abnormalities and (2) time between traction and StFS radiographs > 3 months. In case of IS, the age of 25 was chosen for the division between adolescents and adults. The hospital review board approved the study protocol (SMK879), according to the Dutch law no additional ethical review was required.

Data Collection

All traction radiographs between 01-09-2014 and 31-08-2019 were retrieved from IntelliSpace[®] PACS Enterprise V4.4.532.10, Philips), the database of the Sint Maartenskliniek in Nijmegen, the Netherlands. This time frame was chosen as this supine traction imaging technique started in a standardized way from September 2014. Age, weight, traction force, diagnosis, and Cobb angles of the primary (major) and secondary (minor) curves were extracted from the electronic medical records. As defined by The Scoliosis Research Society (SRS),

the primary curve has the biggest Cobb angle and the secondary curve the smallest. The Cobb angles of the traction, bending or StFS radiographs were already measured by experienced radiology workers for standard care purposes. The diagnosis was retrieved from the medical history. If this was not mentioned explicitly, the radiographs and medical history were assessed by 2 experienced spinal surgeons (MP and MS) to clarify the diagnosis. To differentiate between DIS and DNDLS the classification of Aebi was used.²

Traction and Bending

Traction radiographs and bending radiographs were performed to assess spinal deformity curve flexibility. For a traction radiograph a longitudinal force was applied to the cervical spine on a low-friction surface, while the ankles were fixated with the patient in supine position (Figure 1). The traction force was applied to maximum patient tolerance, and was indicated on the dynamometer (in kilograms). Traction radiographs were not obtained with any form of anesthesia. For the bending radiographs, the patient was asked to bend maximally (left and right) in prone position (Figure 2).

When traction force is applied, or when a patient bends maximally (left and right), the Cobb angle may change. The curve correction, in percentages, is defined as follows:

Curve correction

$$= \frac{\text{Cobb angle on StFS} - \text{Cobb angle on TR or BE}}{\text{Cobb angle on StFS}} \times 100\%$$

Differences in this curve correction obtained with traction and bending were analyzed for the primary and secondary curve. Subgroup analyses were performed for the 3 different diagnoses.

Statistical Analysis

Data was tested for normal distribution (Shapiro Wilk test). Descriptive analyses were used to describe demographics and Cobb angles. Differences in Cobb angles and curve correction between the 3 subgroups were analyzed with the 1-way ANOVA test. Differences in curve correction on traction and bending radiographs within the subgroups (paired data) were analyzed with the Wilcoxon signed rank test. All statistical tests were performed with Stata (version 13.1, StataCorp LP, USA). Statistical significance was set at $P < 0.05$.

Results

Study Population

A total of 222 radiographs were retrieved from the database. 30 radiographs had no images attached to the file. Based on the study criteria, a total of 170 patients were eligible for inclusion (Figure 3).

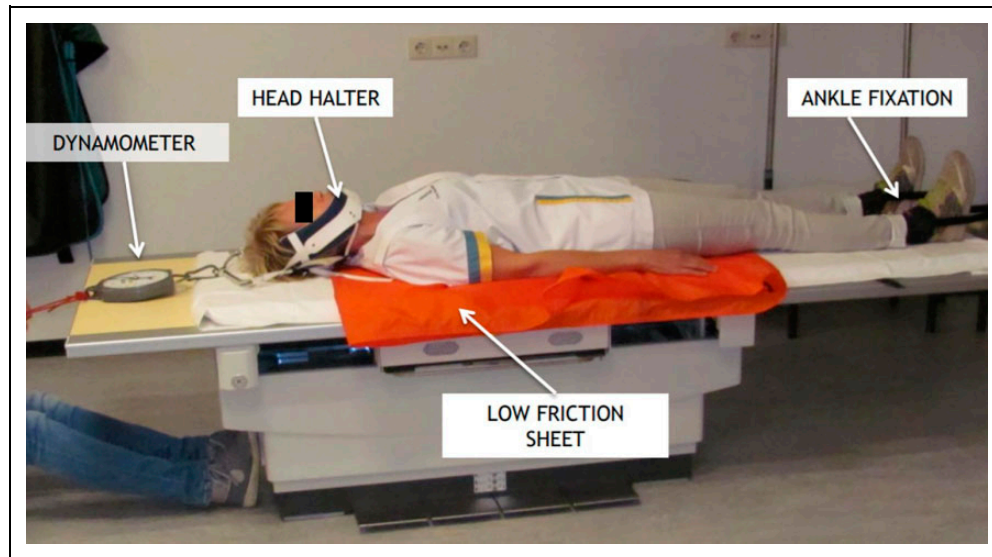


Figure 1. Traction technique in supine position, with ankles fixated and a dynamometer attached to the head halter. One employee applies traction force.

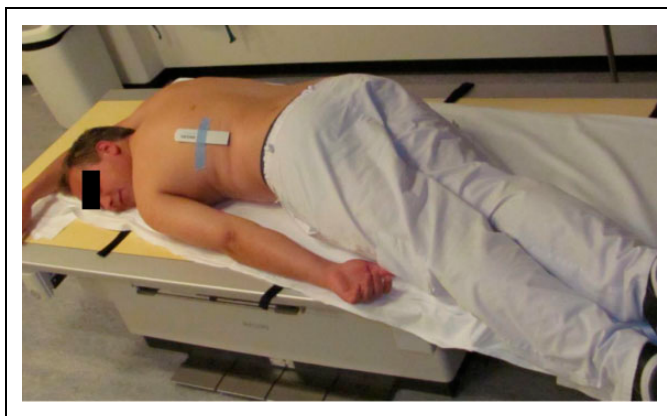


Figure 2. Bending technique in prone position. The patient is asked to bend in maximally both sides.

Patient Characteristics

Table 1 provides information on the patient characteristics. Of the 170 patients, 43 were diagnosed with IS (25.3%), 58 with DIS (34.1%) and 69 with DNDLS (40.6%). The age and weight differed between IS and DIS, and between DIS and DNDLS, $p < 0.001$. Corrected for their weight, IS patients tolerated the most traction force (53.1%), while DIS and DNDLS patients tolerated an equal percentage (respectively 46.1% and 46.7%).

Primary Curve (Table 2)

The differences between Cobb angles on StFS between the 3 subgroups were statistically significant ($P < 0.001$).

The percentage curve correction on a traction radiograph between IS, DIS and DNDLS was not statistically significant ($P = 0.30$), whereas the percentage curve correction on a bending radiograph was different between the different groups ($P =$

0.014). The greatest curve correction with bending was obtained in the DNDLS group; 44.5% vs. 38.6% (IS) and 34.9% (DIS).

In the DNDLS group, bending showed statistically significant more curve correction compared to traction (44.5% vs. 30.7%; $P < 0.001$). In the DIS group, the difference showed a trend toward more curve correction with bending (34.9% vs. 27.9%; $P = 0.054$). In the IS group, no difference in curve correction was found between bending and traction (38.6% vs. 33.6%; $P = 0.18$).

Secondary Curve: (Table 3)

Also the Cobb angles of the secondary curve on StFS differed between the groups ($P < 0.001$).

In contrast to the results for the primary curve, there was a statistically significant difference between curve correction on the traction radiograph between IS, DIS and DNDLS (respectively 34.8% vs. 23.2% vs. 36.1%; $P = 0.002$). No difference in curve correction on a bending radiograph was seen between the subgroups. (55.0% vs. 41.9% vs. 52.4% for IS, DIS and DNDLS, respectively; $P = 0.16$).

In the IS and DIS group, bending showed more curve correction compared to traction (55.0% vs. 34.8%; $P = 0.002$ for IS and 41.9% vs. 23.2%; $P < 0.001$ for DIS).

Discussion

This study demonstrated that prone bending radiographs showed a greater curve correction compared to traction radiographs in DNDLS patients for the primary curve and in IS and DIS patients for the secondary curve. Bending radiographs are considered the current golden standard for assessing the flexibility of the spine in patients with spinal deformity,^{3,5} and it is the most used and most investigated method.⁸ In an addition to

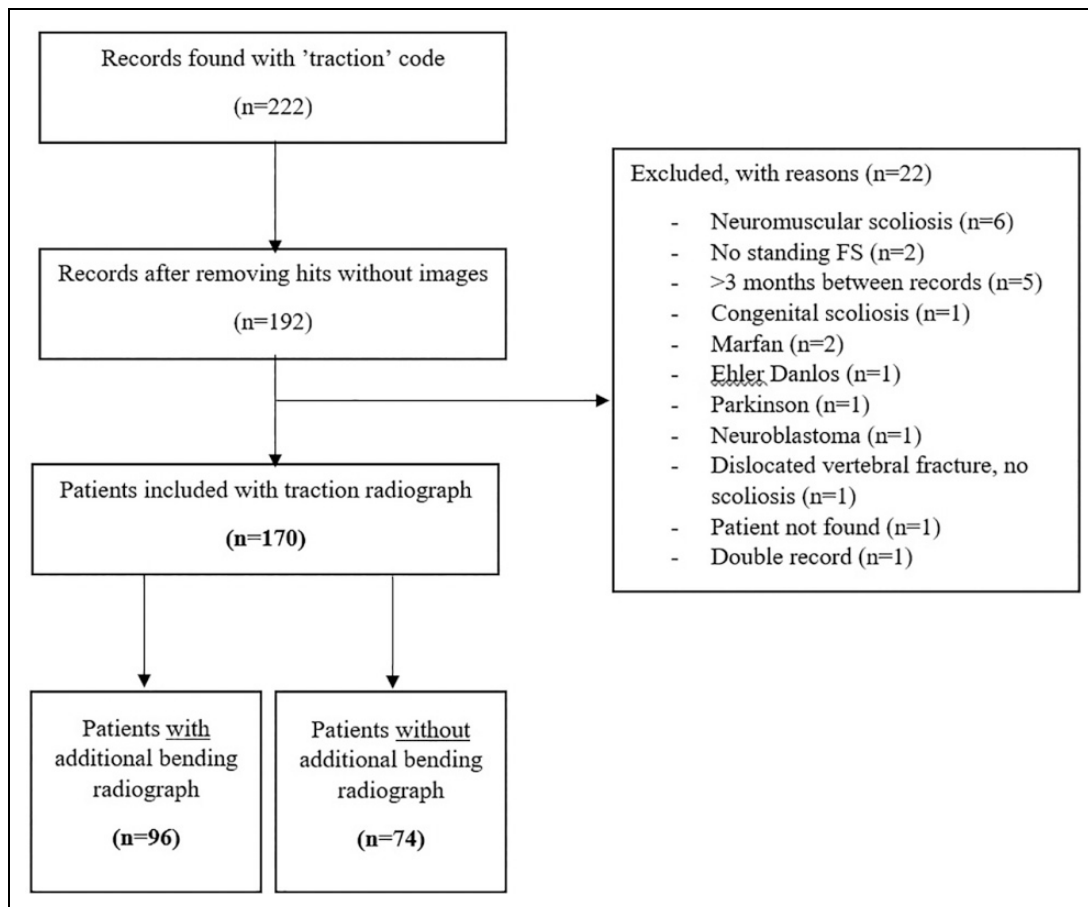


Figure 3. Flowchart of the inclusion and exclusion of radiographs.

Table 1. Characteristics of Included Patients.

	IS (n = 43)	DIS (n = 58)	DNDLS (n = 69)	Total (n = 170)
Age (yrs) *§	17.8 ± 3.8	46.4 ± 12.2	59.8 ± 8.4	44.6 ± 19.0
Weight (kg)**	55 [16] (n = 38)	65 [19.5] (n = 44)	71 [16] (n = 53)	65 [18] (n = 135)
Traction force (N)**	32.5 [14] (n = 40)	30 [10] (n = 45)	35 [10] (n = 55)	33 [12] (n = 140)
Traction force / weight (%)**	53.1 [15.4] (n = 38)	46.1 [11.5] (n = 42)	46.7 [14.6] (n = 51)	48.8 [15.4] (n = 131)

*: Normal distribution. The mean and the standard deviation (SD) are shown. P-value was calculated with the ANOVA test.

** : Non-normal distribution. The median and the interquartile range [IQR] are shown. P-value was calculated with the Kruskal-Wallis test.

§: n = all patients in that group.

the existing research on spinal deformity assessment techniques, we performed an analysis on traction versus bending radiographs in a cohort of IS, DIS and DNDLS patients. To our knowledge, this is the first study that compares traction and bending radiographs in IS as well as adult spinal deformity.

Our study provides detailed information on the curve correction between traction and bending in 3 different subgroups of scoliosis, including the traction force needed to obtain supine traction films. The analysis showed that for the primary curve, bending showed a greater correction than traction in the

DNDLS and DIS group (trend for the DIS group, $P = 0.054$). As for the secondary curve, the analysis showed that the most curve correction was obtained by bending radiographs in IS and DIS patients. In the DNDLS group, bending obtained a considerably greater curve correction but this was not statistically significant ($P = 0.185$). Probably, due to the small number of patients ($n_{\text{traction}} = 18$ and $n_{\text{bending}} = 10$) in this group.

In the literature, only few studies exist evaluating traction versus bending radiographs. All of these studies analyzed the IS population.^{4,9-12} Our analysis showed similar results as

Table 2. Primary Curve Analysis.

	IS (n = 43)	DIS (n = 58)	DNDLS (n = 69)	Total (n = 170)	p value
Cobb on StFS (°)*§	58.5 [10.3]	55.7 [17]	36 [19.4]	50.5 [25]	<0.001
Cobb on TR (°)§	37.9 [14]	37.7 [17.3]	25.5 [13.2]	32.7 [17.6]	-
Cobb on BE (°)	37 [20.7] (n = 30)	35.0 [24.3] (n = 34)	21.4 [19] (n = 32)	30.8 [26.1] (n = 96)	-
CC on TR vs. StFS (%)**§	33.6 [18.0]	27.9 [17.8]	30.7 [21.1]	30.8 [18.6]	0.30
CC on BE vs. StFS (%)**§	38.6 [22.8] (n = 30)	34.9 [24.8] (n = 33)	44.5 [27.4] (n = 32)	37.7 [25.5] (n = 95)	0.014
p-value CC TR vs. CC BE**	0.18	0.054	<0.001	-	

*: Non-normal distribution. The median and the interquartile range [IQR] are shown. P-value was calculated with the Kruskal-Wallis test.

§: n = all patients in that group.

** : Non-normal distribution. The median and the interquartile range [IQR] are shown. P-values were calculated with the Wilcoxon signed-rank test.

StFS = Standing Full Spine radiograph; TR = traction radiograph; BE = bending radiograph; CC = curve correction.

Table 3. Secondary Curve Analysis.

	IS (n = 43)	DIS (n = 58)	DNDLS (n = 69)	Total (n = 170)	P value
Cobb on StFS(°)*§	46.6 [8.9] (n = 24)	45.7 [17.9] (n = 39)	23 [10.9] (n = 19)	41.3 [21.9] (n = 82)	<0.001
Cobb on TR (°)	29.3 [10.6] (n = 24)	35.8 [18.7] (n = 39)	12.3 [10.1] (n = 19)	25.7 [16.5] (n = 82)	
Cobb on BE (°)	20.1 [16.3] (n = 16)	25.5 [20.1] (n = 26)	10.2 [8.1] (n = 10)	20.8 [18.6] (n = 52)	
CC on TR vs. StFS (%)**§	34.8 [18.9] (n = 24)	23.2 [12.1] (n = 37)	36.1 [24.0] (n = 18)	28.0 [22.2] (n = 79)	0.002
CC on BE vs. StFS (%)**§	55.0 [31.1] (n = 16)	41.9 [28.4] (n = 25)	52.4 [39.4] (n = 10)	49.3 [32.7] (n = 51)	0.16
p-value CC TR vs. CC BE**	0.002	<0.001	0.185		

*: Non-normal distribution. The median and the interquartile range [IQR] are shown. P value was calculated with the Kruskal-Wallis test.

§: n = all patients in that group.

** : Non-normal distribution. The median and the interquartile range [IQR] are shown. P values were calculated with the Wilcoxon signed-rank test.

StFS = Standing Full Spine radiograph; TR = traction radiograph; BE = bending radiograph; CC = curve correction.

reported by Hamzaoglu et al.⁹ They studied 34 IS patients and found that supine bending had an overall greater curve correction than traction, although no statistical significance was reported. In contrast, O’Neill et al.⁴ showed an overall greater correction on the traction radiograph. However, the traction force was applied to the axillae instead of the cervical spine, only 15 patients were analyzed and most patients had thoracic curves (10/15). Although they showed that a greater curve correction was achieved on traction, our data showed a greater correction on bending. A possible explanation for our different conclusion is the increased stability/stiffness of the thoracic spine due to the rib cage and the number of thoracic curves in their population. A computer-simulated mathematical model on the flexibility of the thoracic spine¹³ which suggested that the rib cage enhances the stability of the normal thoracic spine during lateral bending. In addition, Watanabe et al.,¹² who studied 229 IS patients, suggested that more curve correction is seen on traction radiographs when the

curve apex is located more cranially than T9, which can also be attributed to the rib cage.

The procedure to obtain a traction radiograph is more labor intensive compared to a bending radiograph. As it requires 2 radiology workers; 1 to obtain the radiograph, and 1 to provide the traction force. Also, a traction radiograph is very uncomfortable for patients, compared to side bending radiographs, as the cervical traction is applied to maximum patient tolerance. On the other hand, making side bending radiographs requires 2 radiographs instead of 1. This exposes the patients to twice the amount of radiation. Taking these 3 factors into account when choosing a method for flexibility assessment, in combination with the results of our analysis (greater correction on bending, or no difference between traction or bending), bending radiographs seem the preferable method for everyday clinical care of the spinal deformity patients. Based on the results of the present study, we abandoned the traction radiographs for curve flexibility assessment in IS, DIS and DNDLS patients in our practice.

Limitations

Several limitations should be mentioned. First, this is a retrospective cohort study and therefore we could not influence the decision-making process for obtaining which radiographs. The type of radiographs obtained in each case was at the surgeon's discretion. The available radiograph sets, including bending radiographs, were less frequently available in the DNDLS group (32/69; 46%) compared to the IS (30/43; 70%) and DIS (34/58; 59%) group. Second, although the Cobb angle is considered the gold standard in evaluating the coronal plane, a measurement error of 3 to 5 is known.¹⁴ This subsequently increases the chance of obtaining a nonsignificant result.¹⁵ Third, no distinction in curve severity or Lenke classification was made for IS curves. Our subgroups would become too small and the analysis would lose its power. Fourth, our research only included the flexibility assessment in the coronal plane for the bending and traction radiographs. Fifth, the surgical implications (planning, surgical approach and determining osteotomy or fusion levels) and the sagittal parameters were not included in the scope of our research.

Conclusion

In conclusion, prone bending radiographs compared to supine traction radiographs better serve the purpose of curve flexibility assessment of (IS, DIS and DNDLS) spinal deformity, despite the fact that patients are exposed to more radiation.

Authors' Note

Niek te Hennepe and Martin H. Pouw are currently employed at Radboudumc, Nijmegen, The Netherlands.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Niek te Hennepe and Petra Heesterbeek. The first draft of the manuscript was written by Niek te Hennepe and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. Niek te Hennepe collected data, performed statistical analyses, together with P. Heesterbeek, wrote the first draft of the manuscript, produced tables, and revised manuscript based on comments of co-authors. Maarten Spruit formulating hypothesis, supervised meetings, interpreted results for clinical use, read and reviewed article and provided comments. Martin Pouw interpreted results for clinical use, read and reviewed article and provided comments. Marco Hinderks provided project idea, provided the radiographs for database, read and reviewed article and provided comments. Petra Heesterbeek provided project idea, supervision project, supervised data collection, performed statistical analyses, together with N. te Hennepe, read and reviewed article and provided comments.

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Declaration of Conflicting Interests

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Informed Consent

For this retrospective cohort study radiographs from the radiographic database formed the basis for this study, no patients. The X-rays were taken quite some time ago, it would be difficult to trace all patients and ask for informed consent. No identifiable information was included in the study database; the radiographs obtained a study number and the code was kept separately. The persons on the photographs demonstrating the techniques are no patients but radiographers and consented to volunteer for the pictures.

No identifying information is visible on the chosen radiographs in the manuscript.

IRB Approval

The present study has been approved by the hospital's review committee. Because of the nature of the study (retrospective study on radiographs) our study is not subject to the Medical Research Involving Human Subjects Act (WMO) so no review by an ethical review board was required.

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