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Predictability of Supine Radiographs for Determining In-brace Correction for Adolescent Idiopathic Scoliosis

Abstract

Purpose: Currently there is no consensus regarding a standard method to assess curve flexibility and immediate brace effectiveness in treating adolescent idiopathic scoliosis (AIS). Brace fabrication methods may be variable but ideally it should achieve maximal curve correction. Curve flexibility governs the degree of curve correction in-brace and hence dynamic radiographs are commonly performed prior to brace fitting. As such, this study aims to assess whether flexibility as revealed by the supine radiograph, predicts in-brace curve correction.

Methods: This was a radiographic analysis of AIS patients treated with underarm bracing. Correlation of pre-brace, supine and immediate in-brace Cobb angles was performed. Relationship with possible contributing factors including age, gender, body height, weight, age at menarche and Risser staging was studied. Major and minor curves were compared independently for correlation but the regression model was constructed based on the major curve only.

Results: From 105 patients with mean age of 12.2±1.2 years at brace fitting, supine Cobb angle measurement has significant correlation with immediate in-brace Cobb angle (r=0.740). Univariate analyses showed no significant relationship with age, weight, height, date of menarche, Risser stage or pre-brace Cobb angle. Our regression model (in-brace Cobb angle = 0.809 x supine Cobb angle) had good fit of the data.

Conclusions: Supine radiograph predictably determines the flexibility of the scoliotic curve to brace treatment. It can be used as a guideline to determine the amount of correction achievable with brace-wear. The effectiveness of the brace is dependent on the inherent flexibility of the curve rather than its size or type.

Key Words: Adolescent idiopathic scoliosis; underarm brace; supine; flexibility

Level of Evidence: III

Introduction

The assessment of spinal flexibility is crucial in management of adolescent idiopathic scoliosis (AIS) as it provides information regarding therapeutic strategies, optimal surgical correction and personalized preoperative planning.[1-9] Various methods for evaluating flexibility have been reported including active lateral bending radiographs in supine or standing posture, under traction or by fulcrum-bending radiographs.[1-5,7,10-18] Spinal flexibility can also be used to predict the initial effect of orthotic treatment because more flexible spines are estimated to experience better correction by orthotic treatment. Yet, unlike the more established surgical criteria, there is no strict definition for acceptable correction in bracing. Optimizing in-brace curve correction is important as it may have bearing on the Cobb angle at completion of brace treatment[19] and also at long-term.[20] A 50% in-brace correction is commonly accepted as a target for in-brace correction.[21,22] However, this is largely a generalization without taking into account the flexibility of individual patients. Based on a finite element model to simulate in-brace correction, an average correction of 48% was observed for the flexible spine and 27% for the stiff spine[20], suggesting that this 50% rule may not be applicable to all scoliosis patients.

Flexibility of the spine governs the degree of brace correction since more flexible spines will undergo more curve correction. Several methods of assessing flexibility have been proposed such as standing with traction but correlations with correction is variable.[23] The correction on supine lateral bending radiographs may reflect initial in-brace correction well.[24] However, this has only been shown for Providence bracing and lateral bending radiographs cannot provide the expected in-brace alignment information. Hence, the supine radiograph may be useful as an objective evaluation for immediate brace outcomes. The relationship between supine flexibility with in-brace correction is relatively unknown despite a previous pilot study of only 9 patients with limited correction.[25]

Hence, it is timely to study the supine radiograph's utility during brace fabrication and fitting. In the supine posture, the inherent flexibility of the spine may be more apparent without gravity forces. This provides a guide to how bracing forces should be applied to areas of curve that are stiffer or more flexible to achieve the best correction. As such, the aim of study is to determine the predictability of the supine radiograph in determining immediate in-brace correction for AIS patients.

Methods

This was a radiographic analysis of subjects prescribed with underarm brace treatment between June to December 2008 and followed until skeletal maturity at 18 years of age. Ethics was approved by our institutional review board. All subjects who were aged 10 or above, presented with Risser 0-3, and with a major curve of 25-40° not previously under treatment were included in the study. Exclusion criteria included all scoliosis with structural proximal curves that precludes underarm bracing. All braces were performed by three designated orthotists who have no previous knowledge of this study.

Demographic data included age, gender, body height, weight, and age of menarche. Supine whole spine radiographs were used to assess curve flexibility. Other radiographs obtained included the pre-brace standing whole spine anteroposterior radiograph, immediate in-brace standing whole spine anteroposterior radiograph, and after brace weaning radiograph. Major and minor curve Cobb angles, curve type and Risser staging were all measured on the same pre-brace standing radiograph. The major and minor curve Cobb angles were compared independently for correlation. Due to this analysis method, curve types were simply divided into upper thoracic, mid-thoracic and thoracolumbar. Those with single curves and double curves were also compared separately.

Imaging method and measurements

Standing radiographs were obtained with the patient standing upright in a relaxed position with the arms raised and slightly fisted hands resting on clavicles. For the supine radiographs, patients were lying comfortably on a radiolucent table. The film focus distance was 180cm and the exposure factors were 77 kilovoltage peak and 20 miliamperage seconds. Two 35x35cm cassettes were used to include from C7 to the hip joints. For in-brace radiographs, the images must be taken at least two hours after the patient donned the brace.[26]

All parameters were collected on radiographs using the DICOM based Radworks 5.1 (Applicare Medical Imaging BV, Zeist, The Netherlands) computer software program. All radiographs were measured by two independent observers who were spine surgeons and were blinded to patient details. When the difference in the measurements between the two assessors was less than 5 degrees, the mean of the two measurements were reported. When the discrepancy was more than 5 degrees, a consensus between the individuals was determined.

Arrangement of brace fabrication and fitting

Supine radiographs are obtained on the day of brace casting and is within 6 weeks of the pre-brace radiograph. Patients undergo negative casting in the supine position with traction and counter-traction along the long axis of the curve. The amount of traction is dependent on the patient's tolerance. The moulded cast is used to manufacture the underarm brace. After the brace fitting is complete, the patient wears the brace for two weeks before an in-brace radiograph is obtained.

Statistical analysis

All analyses were performed by SPSS version 19.0. Mean ± standard deviation (SD) were used for descriptive analysis. Univariate analyses were performed by Pearson correlation to determine any significantly contributing factors for supine and in-brace Cobb angles. Pearson correlation is a measure of the strength of a linear association between two variables. The strength of association is considered weak with correlation coefficient of <0.39, moderate with 0.40-0.59, strong for 0.60-0.79 and very strong of 0.80-1.00.[27] Only the major Cobb angle (single curve Cobb or major Cobb angle for double curves) analyses were used to create a regression model. P-values of <0.05 was considered significant.

Results

A total of 105 patients (97 females, 8 males) with mean age of 12.2 ± 1.2 years were recruited. Mean weight was 41.6 ± 7.1 kg and mean height was 152.9 ± 8.2 m. The date of starting brace wear was a mean 4.1 ± 6.0 months before menarche and the mean Risser stage was 1.0 ± 1.0. There were 33 patients with single curves (12 mid-thoracic and 21 thoracolumbar) and 72 patients with double curves. Of the double curve patients, the major curve was located predominantly in the thoracolumbar region (n = 42), followed by the mid-thoracic (n = 30). The minor curve was located predominantly in the mid-thoracic region (n = 44), followed by thoracolumbar (n = 24) and upper thoracic (n = 3). The mean pre-brace Cobb angles were 31.7 ± 4.2 degrees and 24.0 ± 5.9 degrees for the major and minor curves respectively. The supine Cobb angles were 22.5 ± 7.5 degrees and 20.3 ± 5.8 degrees for the major and minor curves respectively. The immediate in-brace Cobb angles were 18.9 ± 8.2 degrees and 19.3 ± 6.4 degrees for the major and minor curves respectively. Comparisons for the Cobb angles for different curve types are listed in **table 1**. The mean difference in supine and immediate in-brace Cobb angle was 3.6 ± 5.7 degrees. The mean correction with supine radiographs from pre-brace Cobb angle was 70.6 ± 21.0%. The supine radiograph Cobb angle was 85.1 ± 29.4% of in-brace correction Cobb angle.

Univariate analyses for contributing factors to supine Cobb angle change showed no significant relationship with age (p = 0.502), weight (p = 0.747), height (p = 0.933), date of menarche (p = 0.884) and Risser stage (p = 0.444). Hence, only the Cobb angles were used for analyses. Strong correlation was observed between supine and immediate in-brace Cobb angles (r = 0.740; p < 0.001). The univariate regression model created was:

In-brace Cobb angle = 0.809 x supine Cobb angle.

The model predicted 54.8% of the variance with good fit of data (F = 124.983, p < 0.001). Only moderate correlation was observed between pre-brace and supine Cobb angles (r = 0.491; p < 0.001) and pre-brace with in-brace Cobb angles (r = 0.526; p < 0.001). Similar strong correlation was noted for the minor curve relating to supine and immediate in-brace Cobb angles (r = 0.676; p < 0.001).

Discussion

The effectiveness of conservative treatment in adolescent idiopathic scoliosis (AIS) has been the subject to considerable debate for many years.[28] Numerous studies of brace treatment for AIS have been published.[29-31] In spite of some studies that questioned its effectiveness,[32] or even that showed a negative impact of bracing on the quality of life,[33] brace treatment is now the gold standard for conservative treatment of AIS.[34] Most uncertainties with bracing studies are by virtue of the varying inclusion criteria, outcome measurements and effectiveness criteria. However, the goal of brace treatment is consistent and that is to prevent curve magnitude progression and to reduce if not avoid the need for surgical spinal fusion.[35]

Emans *et al* suggested that the curve magnitude in the first in-brace radiograph should be less than 50% of the pre-brace curve magnitude.[22] However, this 50% “rule” cannot be generalized to all AIS patients. In our study, the correction from pre-brace to supine was quite variable. This reflects the variability in curve flexibility between different patients. Curve correction rates are highly dependent on curve flexibility and as such decisions regarding brace fabrication and fitting should be individualized.

Ultimately, a good flexibility assessment should predict the correction of the structural component of the curve while also predict the response of the curve to bracing. With the exception of the supine and fulcrum-bending radiographs, all other radiological examinations such as traction and side-bending radiographs are subjective and prone to inherent variations depending on patient effort and technician expertise. Curve flexibility may be underestimated in patients with back pain due to an inability to provide maximal forces. A consistent amount of force should be exerted on a curve to provide reliable and reproducible results. Although the fulcrum-bending radiograph is not effort dependent[1,9], it requires a non-physiological force on the spine to maintain reduction. Supine radiographs in contrast are expected to closely predict curve correction with bracing due to the identical positioning during the brace fabrication process. Patients commonly undergo a negative casting in the supine position while under traction in the long axis of the curve. Thereafter, the cast is used as a mould for brace manufacture. Hence, it is reasonable to think that the supine radiograph closely predicts the curve correction with bracing.

The correlations generated from this study showed that supine radiographs have predictive value for in-brace correction of AIS. This supports the significant influence curve flexibility has on the expected curve correction with underarm bracing. Findings from this study provide a guide for brace fabrication and fitting in AIS patients. Similar to supine lateral bending radiographs[24], our results showed only a 3.6 degree mean difference in supine and immediate in-brace Cobb angles. This is supported by the strong correlation (r=0.740) generated from our analysis. It is clear that the correction achieved by our flexibility assessment predicts what is achievable with bracing.

Our univariate analyses suggest that flexibility is the only parameter that significantly influences the in-brace curve correction. Despite the strong correlation, further improvement in Cobb angle was achieved with underarm bracing. From our regression model, the in-brace Cobb angle is ~81% of the supine Cobb angle. The basis of this finding is uncertain and it is reasonable to contribute this to the brace fabrication and fitting process. The effectiveness of brace moulding and strap tightness may provide this further correction. These factors have yet to be addressed but are difficult to quantify as this is subjected to the experience of the orthotist. Although we have proven a strong correlation between the supine radiograph and the in-brace correction, there is no objective guideline for the orthotist to utilize the supine radiograph for brace fabrication or fitting. Presently, brace correction is usually determined by the patient's tolerance to traction while forming a negative mould. As such, the relationship between what is observed on the flexibility assessment, brace tightness and brace success is unknown. The authors hypothesize that the degree of tightness will correlate with flexibility and in-brace correction. However, we are unable to measure the degree of tightness at the current stage. This should be addressed in future study.

There are several limitations to this study. Due to its retrospective nature, we do not know the duration of brace-wear before in-brace radiographs. Although all patients must have minimum 2 hours of brace-wear before the radiographs, any differences seen on the first in-brace radiograph between 2 hours and continuous 24-hour wear is not well-defined. In addition, whether the degree of strap tightening may affect the Cobb angle in-brace is also unknown and is difficult to measure. Additional studies should design a method to measure strap tightness to determine its influence on brace effectiveness. Further study should also determine the utility of supine flexibility in predicting curve progression and brace success. However, only a prospective study design with compliance data can provide the necessary parameters for study.

This is the first robust study to test the utility of the supine radiograph in predicting in-brace curve correction. From the multiple parameters under study, flexibility is the key factor in influencing curve correction by underarm bracing. Strong correlation between supine flexibility and in-brace curve correction was observed. Our generated easy-to-use model serves as a guide to the expected correction with bracing. The effectiveness of the brace is dependent on the inherent flexibility of the curve rather than the patient and curve size. Further study should address the impact of brace fitting on curve correction and the predictability of supine flexibility on curve progression.

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Figure Legends

Figure 1: Illustration of the predictability of a supine radiograph in a patient with a flexible curve. A 12-year-old patient with (a) a 34.9 degrees T10-L3 curve reduced to 16 degrees on (b) supine radiograph and was 13 degrees in the (c) immediate in-brace radiograph.

Figure 2: Illustration of the predictability of a supine radiograph in a patient with a stiff curve. A 12-year-old patient with (a) a 38 degrees T6-12 curve reduced to only 34.7 degrees on (b) supine radiograph and was 33.4 degrees in the (c) immediate in-brace radiograph.