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ORIGINAL ARTICLE

# Outcomes and predictors of brace treatment for girls with adolescent idiopathic scoliosis

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**Objective:** To evaluate the effectiveness and to identify the predictive factors of standardized brace treatment for girls with adolescent idiopathic scoliosis (AIS).

**Methods:** From July 2003 to July 2009, 142 girls with AIS completed standardized brace treatment. These patients had a mean age of (13.1 ± 1.5) years (range, 10.1–15.9 years), a mean main curve of 29.6° ± 5.4° (range, 20°–40°), and a mean Risser grade of 2.0 ± 1.5 (range, 0–4) before brace treatment. Based on whether their scoliosis progressed or not, patients were divided into two groups: progressed (Group Pr, n = 27, 19%) and non-progressed (Group NP, n = 115, 81%), and were then divided into a further two groups: surgery (Group Su, n = 18, 13%) and non-surgery (Group NS, n = 124, 87%). $\chi^2$ and logistic regression analyses were performed to investigate factors predicting outcomes of brace treatment.

**Results:** The duration of brace treatment in all patients averaged 2.5 ± 1.0 years (range, 0.6–5.9). $\chi^2$ analysis revealed that patients with progressive curves tended to be younger, with lower Risser grade, initial larger curve magnitude and a main thoracic curve pattern. Using stepwise logistic regression, pre-menarche status ($P = 0.00028$) and a main thoracic curve pattern ($P = 0.012$) were found to be independent risk factors of curve progression despite brace treatment, while an initial Cobb angle >30° ($P = 0.022$) was an additional independent risk factor of curve requiring surgery due to progression.

**Conclusion:** Brace treatment can prevent curve progression in most girls with AIS. The outcomes of brace treatment in these girls are influenced by growth status, curve pattern and curve magnitude. Less mature patients, and those with larger curves and thoracic curves are at risk of scoliosis progression despite brace treatment.

**Key words:** Braces; Female; Prognosis; Scoliosis; Treatment outcome

## Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity occurring predominantly in peri-pubertal girls[1–3]. Current treatment for AIS consists of corrective surgery and non-operative intervention, such as exercise, physical therapy, electric stimulation and brace treatment. As shown by many clinical studies, brace treatment is believed to be the most effective non-operative method for preventing curve progression in immature AIS patients with a mild or moderate curve[4–6]. The outcomes of brace treatment and the factors influencing it in white AIS patients have been widely discussed in several studies[4,7–10]. Whether the same efficacy and factors influencing brace treatment apply to all AIS girls, regardless of ethnic diversity, remains unclear. There are few similar studies in Chinese AIS patients[11]. The purpose of the current study is to evaluate the effectiveness of, and predictive factors for, standardized brace treatment in Chinese AIS girls.

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## Materials and methods

### *Patients*

A consecutive series of AIS girls patients who had received brace treatment in the authors' hospital from July 2003 to July 2009 was retrospectively reviewed. The diagnosis of AIS was based on a detailed medical history, physical and neurological examination, and standing postero-anterior radiograph of the total spine. Patients with congenital scoliosis, neuromuscular scoliosis, scoliosis of connective tissue disorders, or scoliosis of other known etiologies were excluded. Inclusion criteria for the

current study were as follows: (i) girls aged from 10 to 16 years old with skeletal immaturity; (ii) initial standing Cobb angle of 20° to 40°; (iii) undergoing brace treatment (a Milwaukee or Boston brace) with satisfactory compliance (greater than 75%)[12]; (iv) followed up at intervals of 3 to 6 months, until weaned off the brace or surgical intervention became necessary due to curve progression; and (v) complete records of pubertal growth and anthropometric measurements during brace treatment available. Informed consent was obtained from the parents of all AIS girls before entry. Patients with a prior history of brace or traction treatment, or who refused to continue with brace treatment were excluded.

A total of 142 AIS girls were included in this study. The mean age before brace initiation was 13.1 ± 1.5 years (range, 10.1–15.9 years), mean Cobb angle 29.6° ± 5.4° (range, 20°–40°), and mean Risser grade 2.0 ± 1.5 (range, 0–4). Ninety-six girls underwent treatment with a Milwaukee brace, 42 girls with a Boston brace, and 4 with a Milwaukee brace initially followed by a Boston brace because of alterations in curve pattern.

### *Brace treatment*

All patients received brace treatment according to previously described brace treatment protocols[4,12]. According to the curve pattern of each patient, the choice of a Milwaukee or Boston brace was determined by an experienced senior doctor (Dr Yong Qiu). When brace treatment was initiated, detailed individual instructions were given to each patient. Initial brace wearing of 22 hours per day was prescribed. During follow-up, the daily brace wearing time was adjusted according to changes in the Cobb angle of the main curve. In addition, if the curve pattern altered during brace treatment, alteration of the brace type was adopted accordingly[12]. The outcome of brace treatment was assessed by comparing the magnitude of the main curve at latest follow-up and that immediately before initiation of brace treatment. According to the standardizations previously described by the Scoliosis Research Society (SRS) committee[13], if the Cobb angle increased by more than 6°, or if the curve deteriorated enough to be eligible for surgical correction (Cobb angle >45°) at latest follow-up, the curve was considered to have progressed, otherwise it was classified as non-progressed. Based on whether the scoliosis progressed or not, patients were divided into two groups: progressed (Group Pr) and non-progressed (Group NP). Based on the latest curve eligible for correction surgery or not, patients were divided into a further two groups: surgery (Group Su) and non-surgery (Group NS).

### *Statistical analyses*

The data was analyzed using SPSS version 13.0 (Chicago, IL, USA). The proportions of patients with non-progressed outcome and those ineligible for surgical correction were computed to evaluate the effectiveness of brace treatment. The differences in these parameters between progressed and non-progressed patients before brace initiation, and between patients eligible and ineligible for surgery, were assessed through analysis by one-way ANOVA. To determine the predictive factors for outcome of brace treatment, associations between brace outcome and the parameters before initiation of brace treatment were explored, using the methods of $\chi^2$ test, Fisher's exact test and logistic stepwise regression. Statistical significance was set at $P < 0.05$.

## Results

### *Effectiveness of brace treatment*

After a mean brace treatment period of 2.5 ± 1.0 years (range, 0.6–5.9), a progressed curve was found in 27 girls, and non-progressed in 115 girls. Among the progressed patients, 18 cases required corrective surgery. The remaining 9 girls together with the 115 non-progressed girls completed brace treatment and avoided surgical intervention. Thus, there were 27 and 115 girls in Groups Pr and NP, respectively, and 18 and 124 girls in Group Su and NS, respectively. The proportion of non-progressed scoliosis after brace treatment was 81% (115/142), and that of non-surgical intervention was 87% (124/142).

The physical characteristics of the patients in Groups Pr, NP, Su and NS are shown in Table 1. After analysis of physical data before bracing with ANOVA, it was found that patients in Group Pr had a significantly lower Risser grade, yet an insignificantly younger age and an insignificantly larger curve, as compared to those in Group NP. Patients in Group Su had a significantly lower Risser grade, a significantly younger age and a significantly larger curve than those in Group NS. Age at menarche, years after menarche and duration of brace treatment were similar between Groups Pr and NP, and between Groups Su and NS.

### *Predictive factors for brace treatment outcome*

The distribution of physical data before bracing in each group is displayed in Table 2. Obviously, a greater frequency of curve progression was observed in younger than in older girls (59% versus 41%), in pre-menarchic than in post-menarchic (59% versus 41%), in those with larger curve magnitude than those with smaller curve magnitude (67% versus 33%), and in those with

**Table 1** Physical characteristics of AIS girls by group

| | Group Pr | Group NP | Group Su | Group NS |
|---|---|---|---|---|
| Age before bracing (years) | 12.7 ± 1.7 | 13.2 ± 1.4 | 12.2 ± 1.5 | 13.2 ± 1.4* |
| Years after menarche before bracing (years) | 1.0 ± 0.7 | 0.9 ± 0.7 | 0.9 ± 1.0 | 0.9 ± 0.7 |
| Age at menarche (years) | 13.1 ± 1.0 | 12.6 ± 1.2 | 13.1 ± 0.9 | 12.6 ± 1.2 |
| Risser grade before bracing | 1.4 ± 1.6 | 2.1 ± 1.5† | 0.8 ± 1.2 | 2.2 ± 1.5* |
| Curve magnitude before bracing (°) | 30.4 ± 6.1 | 29.4 ± 5.5 | 32.6 ± 4.3 | 29.2 ± 5.4* |
| Duration of brace treatment (years) | 2.4 ± 1.5 | 2.5 ± 0.9 | 2.2 ± 1.4 | 2.5 ± 0.9 |

Note: *†Indicates significant difference between Groups Pr and NP, and between Groups Su and NS, respectively ($P < 0.05$).
NP, non-progressed; NS, ineligible for surgery; Pr, progressed; Su, eligible for surgery.

main thoracic pattern than with other patterns (63% versus 37%). Among the above findings, menstrual status and curve pattern were found to be significantly associated with curve progression through univariate analysis.

At the same time, a higher frequency of curve progression eligible for corrective surgery was found in younger than in older girls (67% versus 33%), in pre-menarchic than in post-menarchic (78% versus 22%), in those with lower Risser grade than with higher grade (72% versus 28%), in those with larger curve magnitude than with smaller curve magnitude (89% versus 11%), and in those with main thoracic pattern than with other patterns (60% versus 40%). Using univariate analysis, menstrual status, Rissser grade and curve magnitude were shown to be significantly associated with risk of curve progression eligible for correction surgery.

The results of multivariate logistic stepwise regression showed that menstrual status (pre-menarche) and curve pattern (thoracic) were risk factors for predicting curve progression despite brace treatment (Table 3). As for curve progression requiring surgical intervention, multivariate logistic stepwise regression established that menstrual status (pre-menarche), curve magnitude (>30°) and curve pattern (thoracic) are predictive risk factors (Table 4). Among these, menstrual status (pre-menarche) ranks the highest of all (OR = 12.009, 95% CI: 3.373–47.255).

**Table 2** Comparisons of distribution of physical data before bracing between groups

| | Group Pr versus Group NP | | | Group Su versus Group NS | | |
|---|---|---|---|---|---|---|
| Parameters before bracing | Group Pr | Group NP | *P* value | Group Su | Group NS | Test |
| Age | | | | | | |
| 10.0–12.9 years | 16 (59%) | 49 (43%) | 0.118 | 12 (67%) | 53 (43%) | 0.057 |
| 13.0–15.9 years | 11 (41%) | 66 (57%) | | 6 (33%) | 71 (57%) | |
| Menstrual status | | | | | | |
| Pre-menarche | 16 (59%) | 27 (23%) | <0.001 | 14 (78%) | 29 (23%) | <0.001* |
| Post-menarche | 11 (41%) | 88 (77%) | | 4 (22%) | 95 (77%) | |
| Risser grade | | | | | | |
| 0–1 | 14 (52%) | 41 (36%) | 0.120 | 13 (72%) | 42 (34%) | 0.002 |
| 2–4 | 13 (48%) | 74 (64%) | | 5 (28%) | 82 (66%) | |
| Curve magnitude | | | | | | |
| >30° | 18 (67%) | 63 (55%) | 0.262 | 16 (89%) | 65 (52%) | 0.002* |
| ≤30° | 9 (33%) | 52 (45%) | | 2 (11%) | 59 (48%) | |
| Curve pattern | | | | | | |
| Th | 17 (63%) | 45 (39%) | 0.044† | 11 (60%) | 51 (41%) | 0.278† |
| Th + TL/Lu | 6 (22%) | 41 (36%) | | 4 (25%) | 43 (35%) | |
| TL/Lu | 4 (15%) | 29 (25%) | | 3 (15%) | 30 (24%) | |

Note: *Indicates Fisher's exact test, otherwise $\chi^2$ test.
†Indicates comparison between Th curve pattern and the other curve patterns (including Th + TL/Lu and TL/Lu).
Lu, lumbar; Th, thoracic; TL, thoracolumbar.

**Table 3** Results of multiple logistic regression of curve progression

| Parameters before bracing | Regression coefficient (B) | Odds Ratio (95%CI)* | *P* value |
|---|---|---|---|
| Menstrual status | 1.727 | 5.624 (2.217–14.267) | 0.00028 |
| Curve pattern† | 1.203 | 3.330 (1.300–8.525) | 0.012 |

Note: *95% CI indicate 95% confidential interval of odds ratio.
†Indicates comparison between Th curve pattern and the other curve patterns (including Th + TL/Lu and TL/Lu).

## Discussion

### *Assessment of the effectiveness of brace treatment*

As a conservative method for controlling curve progression of AIS, brace treatment has been utilized for over 60 years. However, there controversy remains about its effectiveness[4,5,14,15]. In the 1990s, brace treatment was proved by several clinical studies with large samples to effectively halt scoliosis progression in mild and moderate idiopathic scoliosis[4,5]. Lonstein and Winter analyzed the outcome of brace treatment in 1020 AIS patients, among which were 920 females, and reported that only 22% of them required surgical intervention because of curve progression after brace treatment[4]. In a multicenter prospective study by the SRS, the effectiveness of three types of conservative treatment including observation only, brace, and electrical stimulation, was compared. It was found that brace treatment was effective in preventing curve progression, while the other two methods were not[5]. A previous study by the present team reported treatment with a Milwaukee or Boston brace in a consecutive series of 77 AIS patients, amongst whom a majority of cases (70%) displayed curve increases of <5°[11]. Twenty-one of them required surgical correction despite brace, amongst whom 13 cases had been eligible for surgery before brace initiation but had chosen brace treatment on account of their younger skeletal age. Surgeries for them were successfully postponed by 12 to 20 months[11].

With regards to the effectiveness of brace treatment, it has been suggested by Katz and Durrani that success could be defined as an increase in the primary curve of no more than 5°, and failure as progression of >5°[7]. The SRS committee on brace and non-operative management has advised that evaluation of the effectiveness of brace treatment should involve the following three aspects: (i) the percentages of patients who have less than 5° curve progression and more than 6° progression at maturity; (ii) the percentages of patients with curves exceeding 45° at maturity and who have had surgery recommended/undertaken; and (iii) 2-year follow-up beyond maturity to determine the percentage of patients who subsequently undergo surgery. In the present study, 19% of AIS patients had a curve increase of more than 6°, and 13% showed curve progression with curves exceeding 45° at maturity, for which surgical intervention is recommended. The success rate of brace treatment in this study is comparable to that reported by Lonstein and Winter[4], Nachemson and Peterson[5] and Zhu *et al.*[11] Yet, a limitation of this study lies in the inability to ascertain the percentage of patients who subsequently underwent surgery at 2-year follow-up beyond maturity, because of the fact that not all of the patients in this cohort were followed up for more than 2 years after discontinuation of brace treatment.

### *Factors predictive of effectiveness of brace treatment*

As is revealed by study of the natural history of AIS, in some cases scoliosis tends to stabilize, yet in others it deteriorates. It has been well documented by AIS studies that the behavior of curve progression is associated with gender, growth status and the curve features of patients[16–19]. As for AIS patients managed with brace treatment, the outcome may be somewhat influenced by gender, growth potential, growth velocity, curve magnitude and curve pattern[4–11]. Because AIS boys are seen much less commonly, this study focused on analyzing the

**Table 4** Results of multiple logistic regression of a progressed curve eligible for surgery

| Parameters before bracing | Regression coefficient (B) | Odds Ratio (95% CI)* | *P* value |
|---|---|---|---|
| Menstrual status | 2.486 | 12.009 (3.373–47.255) | 0.00012 |
| Curve magnitude | 1.869 | 6.484 (1.302–32.289) | 0.022 |
| Curve pattern† | 1.256 | 2.671 (1.064–11.591) | 0.039 |

Note: *95% CI indicate 95% confidential interval of odds ratio.
†Indicates comparison between Th curve pattern and the other curve patterns (including Th + TL/Lu and TL/Lu).

factors influencing brace treatment outcome only in AIS girls. It was found that patients with a younger age (10.0–12.9 years), lower Risser grade (grade 0–1), pre-menarche status, larger curve magnitude (>30°) and main thoracic curve were at higher risk of curve progression and requirement for surgery, despite brace treatment.

Chronological age, Risser grade and menstrual status are often used clinically to assess the status of growth and development in AIS girls. As stated by Vijvermans *et al.*, patients with curve progression after treatment with a Boston brace had a younger age and lower Risser grade than those with curve stabilization or improvement[8]. Lonstein and Winter reported that patients with Risser grade 0 to 1 had a higher risk than those with Risser grade 2 to 4, and that 32% and 10% of patients had to resort to surgical correction due to curve progression despite brace treatment, respectively[4]. They believe that chronological age and menstrual status can influence brace outcome in the same manner as Risser grade[4]. Obviously, risk of curve progression is much higher in AIS girls with less growth maturity or larger growth potential. In the present study, patients displaying curve progression were found to be more frequently of younger age, lower Risser grade, and per-menarche status. Menstrual status was found to be an independent factor influencing the outcome of brace treatment. Such a finding is consistent with the above studies. One possible reason for chronological age and Risser grade not being independent influencing factors might be that these two factors do not reflect the growth status of AIS girls to the same degree as does menstrual status[20].

Larger curve magnitude before brace initiation was found to be a risk factor for curve progression in the study reported by Lonstein and Winter[4]. Zhu *et al.* stated that a smaller percentage of curve progression was observed in patients with Cobb angle 20–35° in contrast to those with Cobb angle >35°[11]. In a study by Nachemson and Peterson, curve progression took place in 17 of 111 patients (15 per cent) with an initial Cobb angle from 25°–35°[5]. In another study by Katz and Durrani, 39% of patients with an initial Cobb angle from 36°–45° experienced curve progression[7]. An evident trend appears to be that a larger curve magnitude before brace initiation results in a worse outcome. This might be attributable to the fact that curve flexibility decreases while instability increases in cases with a large curve magnitude, resulting in curve progression. In agreement with the above studies, the percentage of curve progression or requirement for surgery increased with the increment in initial curve magnitude, and a larger curve magnitude before brace initiation was identified to be an independent risk factor for scoliosis progressing to over 45°, which requires surgery.

Controversy still remains with respect to the influence on brace outcome of curve pattern. In the natural history study of AIS, Soucacos *et al.* found that progression of scoliosis was associated with curve pattern[21]. A double thoracic and lumbar curve was most liable to progress, followed by a thoracic curve and a thoracolumbar/lumbar curve, and a right thoracic curve was at the highest risk of progression, while a left thoracic curve was at the lowest risk. Ylikoski reported greatest progression velocity in cases with right thoracic scoliosis[22]. In a study regarding brace treatment in AIS boys by Karol, 79% of patients with main thoracic scoliosis displayed progression, which was a little higher than in patients with main thoracolumbar/lumbar scoliosis[9]. However, no significant association between brace treatment outcome and curve pattern was detected. In the present study, a main thoracic curve was found to be an independent risk factor for curve progression and requirement for surgery. It is thought that curve flexibility is reduced in main thoracic scoliosis because the restriction of the thorax cage compromises the outcome of brace treatment.

In this study, curve progression of >6° was found in 27 of 142 AIS girls, and a final curve of more than 45°, and therefore requiring surgery, occurred in 18 girls. Nine girls had a latest curve of <45° and thus avoided eventual surgical correction despite curve progression of over 6°. Among these, a Rissser grade of 2–4 was found in eight cases, menarche had occurred in seven, and there was a curve magnitude of <30° in seven. It is supposed that the avoidance of correction surgery for these patients may be due to the higher degree of maturity and smaller curve magnitude.

In sum, nearly 81% of patients had a non-progressed scoliosis and only 13% of them required surgical intervention. This suggests that brace treatment is effective for most AIS girls with a curve <40°. Patients with a lower degree of maturity, a larger curve and a thoracic curve are at risk of scoliosis progression. Pre-menarche status and a main thoracic curve act as independent risk factors for curve progression. Besides these, a larger curve is an additional independent risk factor for scoliosis progressing to >45°, which requires surgery. Comprehensive assessment of these risk factors is very helpful in predicting the outcome of brace treatment in AIS girls.

## Disclosure

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