Spine Deformity

www.spine-deformity.org

Spine Deformity 4 (2016) 200–205

Curve Progression in Adolescent Idiopathic Scoliosis With a Minimum of 2 Years' Follow-up After Completed Brace Weaning With Reference to the SRS Standardized Criteria

Benlong Shi, PhD[a,c], Jing Guo, PhD[a,c], Saihu Mao, PhD[a,c], Zhiwei Wang, PhD[b,c], Fiona W.P. Yu, MSc[b,c], Kwong Man Lee, PhD[b,c], Bobby K.W. Ng, FRCS Ed (Orth)[c], Zezhang Zhu, MD[a,c], Yong Qiu, MD[a,c], Jack C.Y. Cheng, MD, FRCS Ed (Orth)[b,c], Tsz Ping Lam, FRCS Ed[b,c,*]

[a]*Spine Surgery, the Affiliated Drum Tower Hospital of Nanjing University Medical School, Nanjing, China*
[b]*Department of Orthopaedics and Traumatology, Chinese University of Hong Kong, Hong Kong, China*
[c]*Joint Scoliosis Research Center of the Chinese University of Hong Kong & Nanjing University, Nanjing, China*

Received 21 July 2015; revised 16 November 2015; accepted 13 December 2015

Abstract

Study Design: A retrospective study.
Objectives: To investigate curve evolution after brace weaning in adolescent idiopathic scoliosis (AIS) with reference to the Scoliosis Research Society (SRS) criteria.
Summary of Background Data: Previous studies mainly focused on curve evolution during bracing in AIS. However, curve progression after brace weaning was not well addressed.
Methods: Braced AIS girls followed up for at least 2 years after brace weaning were reviewed. All patients had radiographs at initial visit, brace weaning, 6 months, 1 year, and 2 years after brace weaning, and last follow-up. Curve progression after brace weaning was separately defined as increase in Cobb angle >5 degrees and curve magnitude >45 degrees. The predictors for curve progression were identified using the independent t test.
Results: 200 AIS girls were reviewed. The average duration of follow-up after brace weaning was 51.4 ± 25.6 months. Compared with brace weaning, at 6 months, 1 year, 2 years and last follow-up after brace weaning, 50 (25.0%), 60 (30.0%), 93 (46.5%), and 87 (43.5%) patients, respectively, had curve progression >5 degrees; 0 (0%), 0 (0%), 2 (1%), and 2 (1%) patients, respectively, had surgery recommended; among those with Cobb angle ≤ 40 degrees at brace weaning, 7 (4.0%), 11 (6.3%), 16 (9.2%), and 18 (10.3%) patients, respectively, had Cobb angle >45 degrees; the mean progression magnitudes were 2.6 ± 5.8, 3.5 ± 5.8, 5.1 ± 6.5, and 5.4 ± 7.4 degrees, respectively; and the mean progression rates were 0.34 ± 0.83, 0.16 ± 0.56, 0.13 ± 0.39, and 0.006 ± 0.28 degrees/month, respectively. Cobb angle at brace weaning was associated with increase in Cobb angle >5 degrees ($p = .033$) and curve magnitude >45 degrees ($p < .001$) after brace weaning.
Conclusions: Curve progression after brace weaning is observed in 43.5% AIS patients. The highest risk occurs within 6 months after brace weaning whereas Cobb angle remains stable after 2 years' follow-up. High Cobb angle at brace weaning indicates high risk of curve progression after brace weaning.
Level of Evidence: Level III.

Keywords: Adolescent idiopathic scoliosis; Curve progression; Brace weaning; SRS

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity with a worldwide prevalence of 2% to 4% [1,2]. The onset age of AIS usually ranges from 10 to 16 years and a significantly high risk of curve progression exists during puberty [3,4]. As the only

Author disclosures: BS (none), JG (none), SM (none), ZW (none), FWPY (none), KML (none), BKWN (none), ZZ (none), YQ (none), JCYC (none), TPL (none).

*Corresponding author. Department of Orthopaedics and Traumatology, The Chinese University of Hong Kong, Shatin, Hong Kong, China. Tel.: +852-95020569; fax: +852-26377889.
E-mail address: tplam@ort.cuhk.edu.hk (T.P. Lam).

2212-134X/$ - see front matter © 2016 Scoliosis Research Society.
http://dx.doi.org/10.1016/j.jspd.2015.12.002

reliable and practical medical treatment strategy, brace has been widely prescribed for immature AIS patients with mild to moderate scoliosis [5-9]. Serving as an external corrective force to the trunk, brace needs to be worn near full-time for several years until skeletal maturity [10].

Many reported studies mainly focused on the curve evolution during brace treatment, with the exception of a few [11-17] partly about the curve evolution after brace weaning. These longitudinal studies have reported that further progression rates of curve after brace weaning ranged from 0 to 1.5 degrees per year [12]. However, the reported studies have many limitations, in particular that the follow-up after brace weaning is not synchronized, the different magnitudes and rates of curve progression after brace weaning at different time points are not accurately addressed, and the high risk indictors of curve progression after brace weaning is not clear. The aims of the current study were 1) to investigate in details the curve evolution after brace weaning and skeletal maturity with reference to the Scoliosis Research Society (SRS) standardized protocol [18] in a cohort of AIS girls followed up longitudinally and 2) to identify any predictors for curve progression after brace weaning.

Materials and Methods

Subjects

This is a retrospective cohort study on AIS girls undergoing standard brace treatment in our scoliosis center from 2001 to 2009. The indications for brace prescription in our center were as follows: 1) initial chronologic age between 10 and 14 years with less than 1 year postmenarche stage; 2) Risser stage between 0 and 2; 3) initial major curve magnitude between 20 and 40 degrees; and 4) no prior treatment history. All the items were selected according to the SRS standardization of criteria, except for the initial major curve magnitude modified according to the local ethical consideration. The custom-made underarm Thoraco-Lumbo-Sacral-Orthosis (TLSO) was prescribed for the patients. Brace regime was 23 hours per day for wearing and 1 hour for rest including bathing and exercises. The radiographs were taken with brace 1 or 2 weeks after brace wearing to assess the initial in-brace correction rate, which was aimed to be 50%. For those with correction rate $<50\%$, the tension of straps and position of apical pads were adjusted accordingly to maximize the initial correction rate. Regular follow-up with detailed clinical and radiologic evaluations at 3- to 6-month intervals until weaning were then required in our scoliosis clinic. The radiographs taken during the whole brace treatment period were standard standing whole spine full length with brace. The x-ray protections for breast and gonads were routinely performed using lead jacket and gonadal shields, respectively. Brace compliance was evaluated by patient's recall of the average number of hours of wearing the brace per day. Brace weaning would be recommended for AIS girls with 1) Risser stage $\geqslant 4$ and more than 2 years post menarche and 2) no growth between 2 visits. The brace wearing time were shortened to night wearing for 6 more months and generally the bracing would be totally stopped then.

At the final follow-up, only those braced AIS girls fulfilling the following criteria were included in the analysis: 1) followed up longitudinally for at least 2 years after completed brace weaning and 2) complete sets of radiographs with documented Cobb angles of major curves including the initial visit; first visit after bracing; brace weaning; 6 months, 1 year, and 2 years after brace weaning; and the last follow-up.

Curve evolution assessment

Compared with brace weaning, the curve evolution after brace weaning at each time point was evaluated based on the SRS standardized criteria [18]: 1) percentage of patients who had curve progression more than 5 degrees; 2) percentage of patients who had surgery recommended or done; 3) percentage of patients who had Cobb angle more than 45 degrees (those who already exceeded 40 degrees at brace weaning were excluded); and 4) mean values of curve progression magnitudes and rates.

Predictors for curve progression

In the current study, curve progression was separately defined as increase in Cobb angle >5 degrees and curve magnitude >45 degrees at the 2-year follow-up, respectively. The potential predictors for curve progression after brace weaning included chronologic age at initial visit, initial Cobb angles, menarche age, initial correction rate, curve patterns, age at brace weaning, and Cobb angles at brace weaning.

Statistical methods

Data were statistically analyzed using the SPSS software 17.0 (SPSS Inc, Chicago, IL). Patient's demographics were analyzed using the descriptive statistics. Data were presented with mean $\pm$ standard deviation (SD). Comparison analysis were performed with the independent-sample *t* test, chi-square test, and one-way ANOVA. Statistically significant difference was defined as $p < .05$.

Results

A total of 200 consecutive AIS girls fulfilling the inclusion criteria were retrospectively extracted from 2500 samples, of which the average chronologic age at the initial visit was 12.1 ± 1.2 years and the average menarche age was 12.6 ± 1.2 years. The average Cobb angles at initial visit and the first follow-up after brace prescription were 27.7 ± 5.9 and 21.7 ± 7.6 degrees. The numbers of patients

with initial correction rates of <25%, 25% to 50% and >50% were 105, 73, and 22, respectively, of which the average increases in Cobb angle at the last follow-up were 9.5 ± 10.2, 6.7 ± 10.5, and 3.9 ± 13.8 degrees. For the curve patterns, there were 105 main thoracic curves, 73 thoracolumbar/lumbar curves, and 22 double curves, respectively. The average duration of follow-up after brace weaning was 51.4 ± 25.6 months. The detailed demographic data are summarized in Table 1, whereas the Cobb angles at each time point during the longitudinal follow-up are shown in Figure 1.

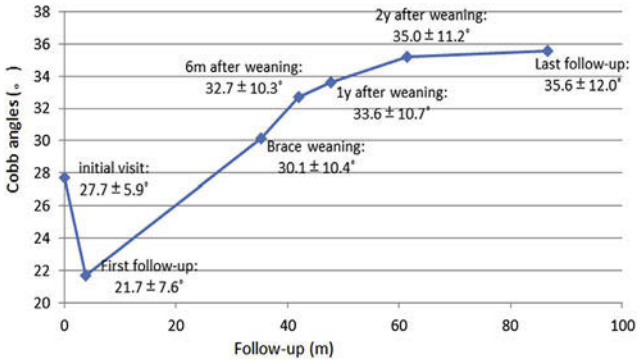

Fig. 1. Curve evolution from initial visit to last follow-up.

Curve evolution assessment

The assessments of curve evolution at each time point are summarized in Table 2.

Percentage of patients who had curve progression >5 degrees

Compared with the initial visit, there were 61 patients (30.5%) with curve progression more than 5 degrees at brace weaning. The numbers of patients with curve progression more than 5 degrees increased to 85 (42.5%), 88 (44%), 112 (56%), and 113 (56.5%) at 6 months, 1 year and 2 years after brace weaning, and the last follow-up, respectively (Fig. 2). At the last follow-up, there were, compared with the initial visit, 43 (21.5%) patients with improved Cobb angles, 44 (22%) patients with curve progression ⩽5 degrees, 46 (23%) patients with curve progression between 6 and 10 degrees, and 67 (33.5%) patients with curve progression >10 degrees, respectively. When the Cobb angles at brace weaning was regarded as the baseline reference, the numbers of patients who had curve progression more than 5 degrees at 6 months, 1 year, and 2 years after brace weaning were 50 (25.0%), 60 (30.0%), and 93 (46.5%), respectively. At the last follow-up, a total of 87 patients (43.5%) had curve progression more than 5 degrees when compared with that taken at brace weaning. For the 87 patients with curve progression >5 degrees at last follow-up, the average curve magnitudes at initial visit and brace weaning were 28.6 ± 6.1 and 29.6 ± 10.2 degrees, respectively.

Table 1
Demographics at initial visit of the cohort.

Parameters	Mean±SD	Range
Chronologic age (years)	12.1±1.2	10, 14
Menarche age (years)	12.6±1.2	9.5, 15.9
Risser sign	0.4±0.7	0, 2
Cobb angle of major curve (degrees)	27.7±5.9	20, 40
Initial correction rate (%)	22.0±21.4	−26.7, 91.7
Duration of brace treatment (months)	35.2±14.0	10, 94
Follow-up after brace weaning (months)	51.4±25.6	24, 190

SD, standard deviation.

Percentage of patients who had surgery recommended or done

From the initial visit to 1 year after brace weaning, there was no patient (0%) undergoing surgery. At 2 years after brace weaning and last follow-up, a total of 2 patients (1%) had surgery recommended or done.

Percentage of patients who had Cobb angle >45 degrees

At brace weaning, 26 patients (13.0%) had Cobb angle >40 degrees. Excluding these 26 patients, the numbers of patients with Cobb angle more than 45 degrees at 6 months, 1 year, and 2 years after brace weaning were 7 (4.0%), 11 (6.3%), and 16 (9.2%), respectively. At the last follow-up, a total of 18 patients (10.3%) had Cobb angles >45 degrees.

Of the 26 patients with Cobb angle >40 degrees at brace weaning, the average Cobb angles at the initial visit and first follow-up were 30.0 ± 6.5 and 25.1 ± 10.1 degrees, respectively. Significant difference was found between the 26 patients and the remaining 174 patients in terms of Cobb angle at initial visit (30.0 ± 6.5 vs. 27.7 ± 5.9 degrees, p = .031) instead of Cobb angle at the first follow-up (25.1 ± 10.1 vs. 21.7 ± 7.6 degrees, p = .066). The average Cobb angles of the 26 patients at 6 months, 1 year, 2 years after brace weaning, and last follow-up were 47.0 ± 6.1, 49.4 ± 7.8, 50.3 ± 8.1, and 52.8 ± 9.1 degrees, respectively.

Mean values of progression magnitudes and rates

Compared with the initial pre-brace visit, the average progression magnitude at brace weaning was 2.4 ± 9.6 degrees with an average rate of 0.03 ± 0.33 degrees/month. The Cobb angle at brace weaning was then defined as the baseline reference for the postweaning follow-up analysis. At 6 months after brace weaning, the average increase in Cobb angle was 2.6 ± 5.8 degrees. The highest progression rate was identified at 6 months after brace weaning, measuring 0.34 ± 0.83 degrees/month. At 1 year and 2 years after brace weaning, the mean progression magnitudes were 3.5 ± 5.8 and 5.1 ± 6.5 degrees, respectively, whereas the average progression rates were 0.16 ± 0.56 and

Table 2
Curve evolution at each time point.

Time points[a]	Curve progression >5 degrees	Surgery	Cobb angle >45 degrees[b]	Progression magnitude (degrees)	Progression rate (degrees/month)
6 months after weaning	50 (25.0%)	0 (0%)	7 (4.0%)	2.6±5.8	0.34±0.83
1 year after weaning	60 (30.0%)	0 (0%)	11 (6.3%)	3.5±5.8	0.16±0.56
2 years after weaning	93 (46.5%)	2 (1%)	16 (9.2%)	5.1±6.5	0.13±0.39
Last follow-up	87 (43.5%)	2 (1%)	18 (10.3%)	5.4±7.4	0.006±0.28

[a] Data were compared with brace weaning.
[b] Patients who already exceeded 40 degrees at brace weaning were excluded.

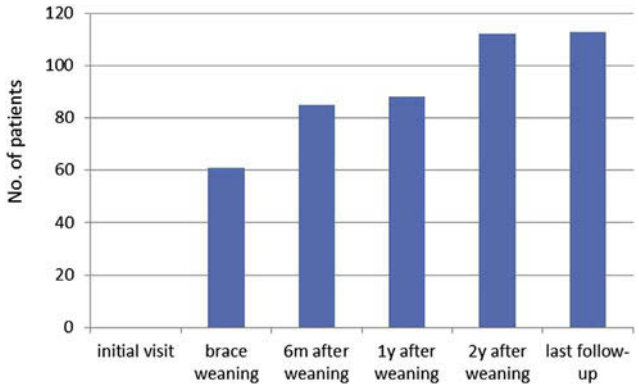

Fig. 2. Numbers of patients with curve progression >5 degrees compared with initial visit.

0.13 ± 0.39 degrees/month, respectively. At the last follow-up, the Cobb angle progressed 5.4 ± 7.4 degrees and the progression rate decreased to 0.006 ± 0.28 degrees/month.

Predictors for increase in Cobb angle >5 degrees

There were 107 patients with increase in Cobb angle ⩽5 degrees and 93 patients with increase in Cobb angle >5 degrees at the 2-year follow-up, respectively. Differences between 2 groups are shown in Table 3. The comparison analysis showed that Cobb angles at brace weaning (28.4 ± 10.0 vs. 31.6 ± 10.5 degrees, p = .033) were significantly different between the two groups. However, no significant difference was found in terms of chronologic age at the initial visit, initial Cobb angles, menarche age, initial correction rate, curve patterns, and age at brace weaning (p > .05). In addition, the comparison analysis among different groups with different curve progression magnitudes (<0, 0–5, 6–10, >10 degrees) at last follow-up revealed that high progression magnitude was significantly associated with high Cobb angle at brace weaning (p < .001).

Table 3
Comparison between increase in Cobb angle ⩽5-degree (n = 107) and >5-degree (n = 93) groups.

	⩽5-degree group	>5-degree group	p
Age at initial visit (years)	12.0±1.2	12.1±1.2	.496
Initial Cobb angles (degrees)	27.7±6.1	27.7±5.6	.952
Menarche age (years)	12.6±1.3	12.7±1.1	.517
Initial correction rate (%)	22.3±21.3	21.7±21.6	.851
Main thoracic curves (n)	60	45	.321
Thoracolumbar/lumbar curves (n)	36	37	.381
Double curves (n)	11	11	.822
Age at brace weaning (years)	14.8±1.2	14.8±1.1	.986
Cobb angle at brace weaning (degrees)	28.4±10.0	31.6±10.5	.033

Table 4
Comparison between Cobb angles ⩽45-degree (n = 158) and >45-degree (n = 16) groups.

	⩽45-degree group	>45-degree group	p
Age at initial visit (years)	12.1±1.2	12.5±1.3	.678
Initial Cobb angles (degrees)	26.7±5.3	34.0±6.1	<.001
Menarche age (years)	12.6±1.1	12.5±1.3	.859
Initial correction rate (%)	23.0±20.6	20.6±22.0	.663
Main thoracic curves (n)	82	8	1.000
Thoracolumbar/lumbar curves (n)	61	5	.788
Double curves (n)	15	3	.219
Age at brace weaning (years)	14.7±1.0	15.2±1.3	.109
Cobb angles at brace weaning (degrees)	26.6±7.8	35.7±5.5	<.001

Predictors for curve magnitude >45 degrees

When excluding the 26 patients who already exceeded 40 degrees at brace weaning, 174 patients were further divided into 2 groups according to the curve magnitudes at the 2-year follow-up. A total of 158 patients had curve magnitude ⩽45 degrees, whereas 16 patients had curve magnitude >45 degrees. Cobb angles at initial visit (26.7 ± 5.3 vs. 34.0 ± 6.1 degrees, p < .001) and at brace weaning (26.6 ± 7.8 vs. 35.7 ± 5.5 degrees, p < .001) were significantly different between 2 groups, respectively. There was no significant difference with respect to chronologic age at the initial visit, menarche age, initial correction rate, curve patterns, and age at brace weaning between the 2 groups (p > .05) (Table 4).

Discussion

Though brace has been widely accepted now as an effective conservative treatment strategy for AIS patients, curve progression after brace weaning in AIS still raises considerable

challenges and concerns to the overall prognosis [12,17,19,20]. Ylikoski et al. [11] reported that for AIS girls with age more than 17 years and Risser 5, significant curve progression velocity could still be observed. Maruyama [12] further performed a systematic review looking for the end results 5 years after weaning of bracing treatment and found that the average rate of correction loss after brace discontinuation ranged from 0 to 0.5 degrees per year. Based on the previous studies, Maruyama [12] summarized that curve progression after brace weaning was comparable to the natural history after skeletal maturity. Bulthuis et al. [13] investigated the clinical effect of the TriaC-brace, in which they reported a slight trend of improvement in Cobb angles during follow-up after termination of brace treatment. However, most studies revealed a slow but significant trend of curve progression after brace weaning. Escalada et al. [14] demonstrated a significant progressive velocity in Cobb angle for AIS girls with more than 4 years post menarche. Aulisa et al. [15,16] evaluated the curve evolution using the SRS criteria in AIS girls, which revealed an average of 1.9–2.2 degrees increase in Cobb angles from brace weaning to at least 2 years' follow-up. In addition, Guo et al. [17] reported an average curve progression rate of 1.5 degrees per year in AIS girls after brace weaning. Until now, the data about curve evolution after brace weaning were only obtained from those studies mainly discussing about the curve evolution during brace treatment. The curve evolution after brace weaning, a significant concern, was, however, inadequately studied.

To our knowledge, this is the first study, with reference to the SRS standardized criteria, being systematically devoted to the curve evolution after brace weaning in AIS patients using serial matched radiographs at multiple regular time points. The current study demonstrated that, compared with Cobb angles at brace weaning, 87 (43.5%) patients had curve progression of more than 5 degrees at the last follow-up. In a prospective study [20] conducted by the SRS, the success rate of brace treatment was around 74% according to survivorship analysis, which was significantly higher than the success rate of observation only. Besides, the prospective randomized controlled study performed by Guo et al. [17] showed that around 30% to 40% of AIS patients with initial in-brace successful treatment would exhibit curve progression after skeletal maturity. Therefore, our results further supported these two prospective studies. In addition, the curve progression rate within 6 months after brace weaning was found to be 0.34 degrees/month, identified as the highest rate during the longitudinal follow-up. We assumed that the high progression rate within 6 months after brace weaning should be mainly attributed to the rebound effects on brace weaning. However, this assumption needed further documentation. Nevertheless, the results indicated that carefully monitoring the curve evolution within this high-risk phase was still needed.

The SRS committee on bracing and interventional management recommended a minimum of 2 years' follow-up after brace weaning and skeletal maturity in order to evaluate the long-term effects of brace treatment [18]. The international Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) recommended a minimum of 1 year's follow-up after the end of bracing treatment as the standardization of methods of medical research [21]. Our results revealed that the progression rate decreased from 0.34 degrees/month at 6 months after brace weaning to 0.16 degrees/month at 1 year after brace weaning and to 0.13 degrees/month at 2 years after brace weaning. At last follow-up, the progression rate averaged 0.006 degrees/month, implying relatively stable curvatures. Therefore, 6 months after brace weaning could be regarded as the rapid rebound phase whereas beyond 2 years after brace weaning could be defined as the stable phase. Though the progression rate from 1 year after brace weaning to 2 years after brace weaning seemed stable, significant curve progression might occur in some patients. The results highly supported the recommendation of SRS committee that a minimum 2-year follow-up after skeletal maturity were reliable to finally determine the effectiveness of brace treatment.

In the current study, we further performed the comparison analysis to identify the high-risk indicators for curve progression after brace weaning. The results showed that a high Cobb angle at brace weaning indicated high risks of increase in Cobb angles >5 degrees and Cobb angle >45 degrees during the longitudinal postbrace follow-up. Upadhyay et al. [22] reported that the Cobb angle after application of a brace yielded the valuable information about flexibility of the curvature and thus indicated the final bracing outcome. Ylikoski [11] and Soucacos et al. [23] found that the Cobb angle was an important predictor for curve progression in untreated AIS patients. Therefore, previous studies showed that Cobb angle, as a biomechanical factor, was significantly associated with curve progression in AIS patients both with and without brace treatment. Our results further proved that the Cobb angle at brace weaning was significantly associated with the risk of curve progression after brace weaning, which emphasized the importance of bracing curves at smaller magnitudes.

A potential weakness of the current study was its retrospective nature. The compliance of brace treatment was not objectively and quantitatively monitored, which might influence the calculation of the initial correction rate. Second, only AIS girls were included in the analysis although difference between girls and boys might somehow exist. Therefore, further prospective studies including AIS boys are warranted. Nevertheless, to our knowledge, this is the first study focusing on the in-depth investigation of curve evolution after brace weaning with reference to the SRS criteria in AIS patients.

Conclusion

In summary, curve progression after completed brace weaning is observed in 43.5% AIS patients. The rate of curve progression is significantly different during the longitudinal follow-up. Six months after brace weaning is the

highest-risk phase of curve progression with the progression rate of 0.34 degrees/month, which could be related to the rebound effects on brace weaning. Curve magnitude becomes stable beyond 2 years after brace weaning. High Cobb angle at brace weaning indicates high risk of curve progression after brace weaning.

Key points

- The average duration of follow-up after brace weaning was 51.4 ± 25.6 months in the current study. Curve progression after brace weaning was observed in 43.5% adolescent idiopathic scoliosis (AIS) patients during longitudinal follow-up.
- The highest risk of curve progression occurs within 6 months after brace weaning whereas the Cobb angles remain stable after 2 years' follow-up. High Cobb angle at brace weaning indicates high risk of curve progression after brace weaning.

References

[1] Luk KD, Lee CF, Cheung KM, et al. Clinical effectiveness of school screening for adolescent idiopathic scoliosis: a large population-based retrospective cohort study. *Spine* 2010;35:1607−14.

[2] Weinstein SL, Dolan LA, Cheng JC, et al. Adolescent idiopathic scoliosis. *Lancet* 2008;371:1527−37.

[3] Shi B, Mao S, Xu L, et al. Integrated multi-dimensional maturity assessments predicting the high risk occurrence of peak angle velocity during puberty in progressive female idiopathic scoliosis. *J Spinal Disord Tech* 2014.

[4] Sanders JO, Browne RH, McConnell SJ, et al. Maturity assessment and curve progression in girls with idiopathic scoliosis. *J Bone Joint Surg* 2007;89:64−73.

[5] Danielsson AJ, Hasserius R, Ohlin A, et al. A prospective study of brace treatment versus observation alone in adolescent idiopathic scoliosis: a follow-up mean of 16 years after maturity. *Spine* 2007;32:2198−207.

[6] Emans JB, Kaelin A, Bancel P, et al. The Boston bracing system for idiopathic scoliosis. Follow-up results in 295 patients. *Spine* 1986;11:792−801.

[7] Lonstein JE, Winter RB. The Milwaukee brace for the treatment of adolescent idiopathic scoliosis. A review of one thousand and twenty patients. *J Bone Joint Surg* 1994;76:1207−21.

[8] Weinstein SL, Dolan LA, Wright JG, et al. Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med* 2013;369:1512−21.

[9] Negrini S, Minozzi S, Bettany-Saltikov J, et al. Braces for idiopathic scoliosis in adolescents. *Spine* 2010;35:1285−93.

[10] Qiu Y, Sun X, Cheng JC, et al. Bone mineral accrual in osteopenic and non-osteopenic girls with idiopathic scoliosis during bracing treatment. *Spine* 2008;33:1682−9.

[11] Ylikoski M. Growth and progression of adolescent idiopathic scoliosis in girls. *J Pediatr Orthop B* 2005;14:320−4.

[12] Maruyama T. Bracing adolescent idiopathic scoliosis: a systematic review of the literature of effective conservative treatment looking for end results 5 years after weaning. *Disabil Rehabil* 2008;30:786−91.

[13] Bulthuis GJ, Veldhuizen AG, Nijenbanning G. Clinical effect of continuous corrective force delivery in the non-operative treatment of idiopathic scoliosis: a prospective cohort study of the TriaC-brace. *Eur Spine J* 2008;17:231−9.

[14] Escalada F, Marco E, Duarte E, et al. Assessment of angle velocity in girls with adolescent idiopathic scoliosis. *Scoliosis* 2009;4:20.

[15] Aulisa AG, Guzzanti V, Marzetti E, et al. Brace treatment in juvenile idiopathic scoliosis: a prospective study in accordance with the SRS criteria for bracing studies—SOSORT award 2013 winner. *Scoliosis* 2014;9:3.

[16] Aulisa AG, Guzzanti V, Perisano C, et al. Treatment of lumbar curves in scoliotic adolescent females with progressive action short brace: a case series based on the Scoliosis Research Society Committee Criteria. *Spine* 2012;37:E786−91.

[17] Guo J, Lam TP, Wong MS, et al. A prospective randomized controlled study on the treatment outcome of SpineCor brace versus rigid brace for adolescent idiopathic scoliosis with follow-up according to the SRS standardized criteria. *Eur Spine J* 2014;23:2650−7.

[18] Richards BS, Bernstein RM, D'Amato CR, et al. Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS Committee on Bracing and Nonoperative Management. *Spine* 2005;30:2068−75; discussion 76−7.

[19] Sanders JO, Newton PO, Browne RH, et al. Bracing for idiopathic scoliosis: how many patients require treatment to prevent one surgery? *J Bone Joint Surg* 2014;96:649−53.

[20] Nachemson AL, Peterson LE. Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. A prospective, controlled study based on data from the Brace Study of the Scoliosis Research Society. *J Bone Joint Surg* 1995;77:815−22.

[21] Negrini S, Hresko TM, O'Brien JP, et al. Recommendations for research studies on treatment of idiopathic scoliosis: Consensus 2014 between SOSORT and SRS Non-operative Management Committee. *Scoliosis* 2015;10:8.

[22] Upadhyay SS, Nelson IW, Ho EK, et al. New prognostic factors to predict the final outcome of brace treatment in adolescent idiopathic scoliosis. *Spine* 1995;20:537−45.

[23] Soucacos PN, Zacharis K, Gelalis J, et al. Assessment of curve progression in idiopathic scoliosis. *Eur Spine J* 1998;7:270−7.