Spine Deformity (2023) 11:1101–1107
https://doi.org/10.1007/s43390-023-00703-z

CASE SERIES

The effect of brace on apical vertebral derotation in adolescent idiopathic scoliosis

Alim Can Baymurat[1] · Ismail Daldal[2] · Mehmet Ali Tokgoz[1] · Bilge Kagan Yilmaz[3] · Alpaslan Senkoylu[1]

Received: 10 December 2022 / Accepted: 6 May 2023 / Published online: 23 May 2023

Abstract

Purpose The current study aims to evaluate the effect of Boston brace treatment on apical vertebral derotation in adolescent idiopathic scoliosis (AIS) patients receiving conservative treatment.

Methods The study included 51 AIS patients, consisting of 8 males and 43 females, with Cobb angles between 25° and 45° and Risser's findings ranging from 0 to 4. The mean age of the participants was 12.20 ± 1.34 years. All patients were treated with the Boston brace for a minimum of 2 years and evaluated before the brace, during early brace use, and at the last follow-up. Radiographs were assessed to measure apical vertebral rotation (AVR) and vertebral translation (AVT). The SRS-22 questionnaire was used to evaluate patient outcomes.

Results The radiographs of patients were evaluated over a mean follow-up period of 32.42 ± 8.65 months. Before the brace, the mean AVR was 2.1 ± 0.6, while it was 1.1 ± 0.5 with the brace. At the last follow-up, the mean AVR was 1.3 ± 0.5 ($p < 0.001$). Before the brace, the mean AVT was 36.4 ± 9.6 mm, which decreased to 16.7 ± 7.3 mm with the brace ($p < 0.001$). At the last follow-up, the mean AVT was 19.8 ± 8.1 mm ($p < 0.001$). The use of the brace had a significant corrective effect on thoracolumbar and lumbar curvatures compared to before the brace ($p < 0.001$).

Conclusion The findings of the current study suggest that the use of a Boston brace in the conservative treatment of AIS is effective in correcting the coronal and sagittal plane deformities, including thoracic, thoracolumbar, and lumbar curvatures, and in reducing apical vertebral rotation and translation.

Keywords Scoliosis · Brace · Apical vertebral rotation · Apical vertebral translation

Introduction

Adolescent idiopathic scoliosis (AIS) is a prevalent spinal disorder with a general prevalence ranging from 0.47% to 5.2% [1]. If left untreated, the natural progression of AIS can lead to serious health issues, such as severe cardiopulmonary dysfunction and negative psychosocial effects [2–6].

Bracing is an integral component of conservative treatment for AIS, and it represents a promising intervention for arresting the progression of spinal curvature and averting the need for surgical intervention [7]. A variety of brace designs are available for managing spinal deformities. The primary objective of brace application is to counteract the progression of spinal deformity by means of external forces and reinstating normal vertebral column alignment and contours in both the coronal and sagittal planes [8].

Cervico-thoraco-lumbo-sacral orthoses (CTLSO) are typically employed for curves with an apex above T7, while thoraco-lumbo-sacral orthoses (TLSO) are generally preferred for curves with an apex at T7 or below [8]. However, achieving patient compliance with CTLSO can be challenging, which is why TLSO are often favored [9]. The Boston brace is one of the most commonly used TLSO types in many institutions. Despite a considerable body of literature on TLSO use in the brace treatment of AIS, there remains a dearth of information on other clinical applications of TLSO [10–12].

✉ Alpaslan Senkoylu
drsenkoylu@gmail.com

1 Department of Orthopaedics and Traumatology, Gazi University Medical Faculty, Ankara, Turkey

2 Department of Orthopaedics and Traumatology, Medicana International Istanbul–Beylikdüzü Hospital, Istanbul, Turkey

3 Department of Orthopaedics and Traumatology, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey

Numerous studies have demonstrated the effectiveness of brace treatment in arresting the progression of spinal curvature in AIS [13–16]. However, to date, no study has investigated the impact of brace treatment on apical vertebrae in the axial plane. In the current study, it was aimed to evaluate the effect of a Boston-type TLSO brace on apical vertebrae rotation and translation in AIS patients receiving conservative treatment.

Materials and methods

The current retrospective study involved the analysis of 208 patients with the diagnosis of adolescent idiopathic scoliosis (AIS) who received conservative treatment at the Department of Orthopedics and Traumatology of the current institution between 2010 and 2020. Of these patients, 51 met the inclusion criteria, which required regular follow-up for at least 2 years, regular use of braces for at least 20 h a day, and appropriate completion of brace treatment. Exclusion criteria were defined as the use of a brace for less than 20 h a day, surgical treatment, and a lack of continuous follow-up. The study population comprised 43 females and 8 males.

No additional monitoring device was used to track patients adherence to the brace. Compliance data were collected through self-reports provided by the patients or legal guardians. The current institution's protocol involves engaging parents in all stages of examination, follow-up, and treatment for AIS patients. In cases where patients are unaccompanied by parents, adult family members residing with the patient are also involved in the follow-up and treatment process.

The mean age of the patients was 12.20 ± 1.34 years, with a range of 10 to 17 years, and the mean follow-up duration was 32.42 ± 8.65 months, ranging from 24 to 52 months. Based on the Lenke classification, 16 patients were classified as type 1, 3 as type 2, 4 as type 3, 2 as type 4, 15 as type 5, and 11 as type 6, as demonstrated in Table 1.

All patients with scoliosis between 25 and 40 degrees Cobb's angle measurement, Risser's sign of 0–2 stages, and premenarche in girls or postmenarche AIS for less than a year were fitted with a custom-made Boston-type TLSO brace. In patients who did not require surgical treatment, termination of the corset application was determined by clinical and radiological evaluations, including the presence of menarche in girls or a deepening of the voice in boys, Risser stage ≥ 4, and Sanders stage 8 patients. The SRS-22 questionnaire was applied to evaluate the patients' quality of life and perception of deformity.

Table 1 Demographic characteristics and basic information of patients

Age (mean ± sd)	12.20 ± 1.34 (range: 10–17)
Gender (M/F)	8/43
Lenke Classification (1/2/3/4/5/6)	16/3/4/2/15/11
Duration of follow-up	32.42 ± 8.65 (24–52)
Risser phase (0/1/2/3/4)	12/11/13/7/8

sd Standard deviation

Radiological examination

Radiographs obtained before bracing, at 6 weeks after the initiation of bracing, and at the last follow-up visit were analyzed in the current study. The measurements were performed twice (2 weeks apart) by two different orthopedic surgeons experienced in spine surgery. The radiological evaluation included the measurement of coronal and sagittal Cobb angles of the vertebral column. In addition, apical vertebral rotation (AVR) was assessed based on the Nash and Moe Classification.

Apical vertebral translation (AVT) was also measured in patients without coronal imbalance by determining the distance between the central sacral vertical line (an upward vertical line originating from the center of the S1 vertebra) and the midpoint of the apical vertebral body. In cases of thoracic curves with coronal imbalance, AVT was measured using a vertical line from the center of the C7 vertebra (C7 plumbline). Similarly, for thoracolumbar/lumbar curves with coronal imbalance, the central sacral vertical line was used to measure AVT, with the distance between the central sacral vertical line and the center of the apical vertebral body in the thoracolumbar/lumbar curve being measured (Figs. 1 and 2). In order to ascertain the central location of the vertebral body, a technique referred to as the "X" method was utilized. This method involves the drawing of diagonal lines, which connect the upper and lower corners of the apical vertebral body on both sides. The point of intersection of the two diagonal lines was identified as the midpoint of the vertebral body (Fig. 3) [17].

Ethics approval

The research adhered to the ethical principles outlined in the Declaration of Helsinki and was approved by the ethics committee of the institute where the study was conducted (Date: 04.10.2022 No: 16).

Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). For descriptive analysis, continuous variables were presented as mean and standard deviation (SD), while categorical variables were reported as frequencies and percentages. Chi-squared tests were used to

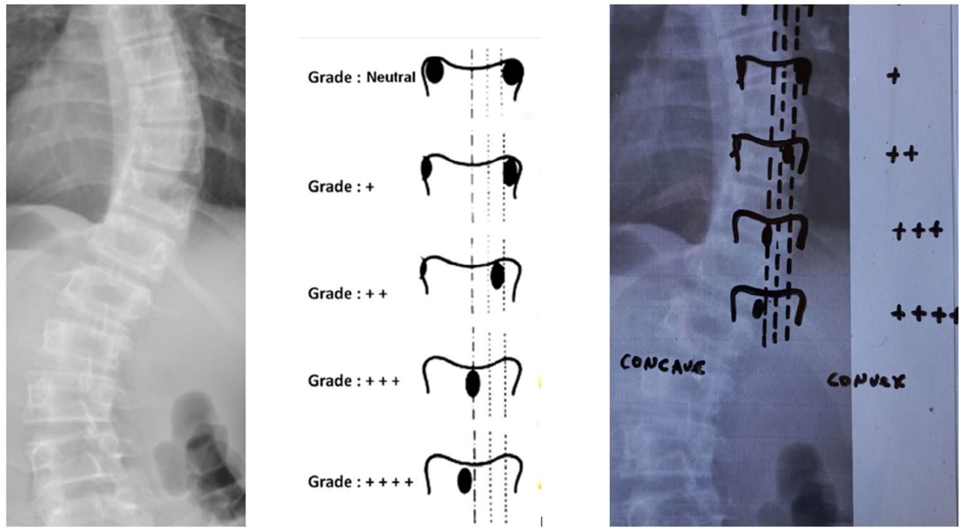

Fig. 1 Evaluation of apical vertebral rotation according to Nash and Moe classification

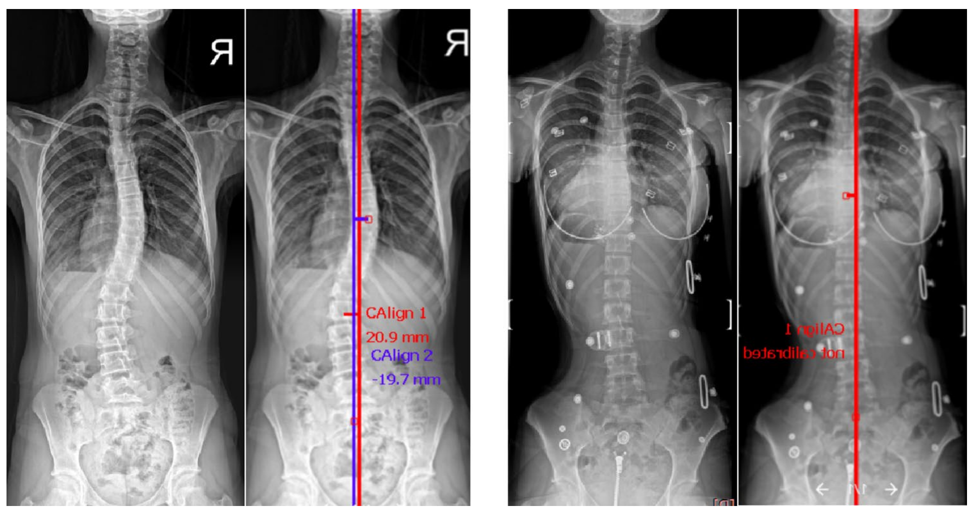

Fig. 2 Evaluation of apical vertebral translation

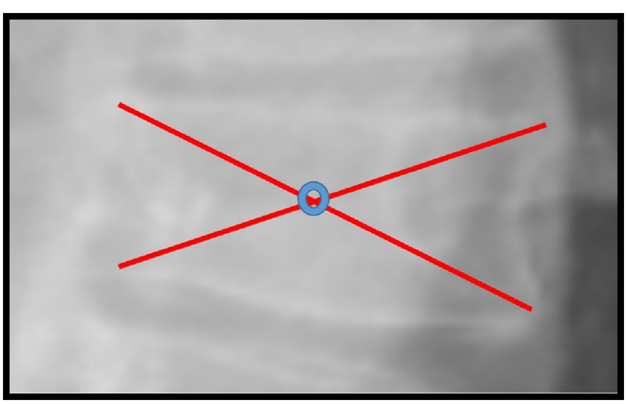

Fig. 3 "X" method for vertebral body identification

compare categorical variables across different groups. The normal distribution of continuous variables was assessed using analytical techniques (Kolmogorov–Smirnov/Shapiro–Wilk tests) and visual methods (histograms and probability plots). As the data did not follow a normal distribution, non-parametric analysis was performed. The Wilcoxon Signed Ranks test and the Kruskal Wallis test were used to compare preoperative, postoperative, and last follow-up data sets. A *p*-value of less than 0.05 was considered statistically significant.

The reliability of both inter- and intra-observer measurements was assessed using the intraclass correlation coefficient (ICC) within a 95% confidence interval. A value above 0.75 is deemed excellent, while a value between 0.75 and 0.60 is considered good. A value ranging from 0.59 to 0.40 is categorized as fair, and a value below 0.40 indicates poor agreement. For this study, the inter-observer reliability of measurements was determined to be 0.882 (95% confidence

Table 2 Data of radiological evaluation

	n	Before the brace	After the brace	Last control
Proximal thoracic curvature	5	28.2 ± 3.1°	26.8 ± 1.8°	30.6 ± 5.9°
The main thoracic curvature	36	31.3 ± 3.6°	20.0 ± 6.1°	27.2 ± 5.9°
Thoracolumbar/lumbar curvature	32	30.1 ± 4.3°	20.0 ± 6.5°	24.2 ± 7.3°
Apical vertebral rotation	51	2.1 ± 0.6	1.1 ± 0.5	1.3 ± 0.5
Apical vertebral translation	51	36.4 ± 9.6 mm	16.7 ± 7.3 mm	19.8 ± 8.1 mm

n Number

Table 3 Results of statistical analysis of radiological evaluations

	p (BB-AB)	p (BB-LC)	p (AB-LC)
Proximal thoracic curvature	0.135	0.208	0.110
The main thoracic curvature	< 0.001	< 0.001	< 0.001
Thoracolumbar/lumbar curvature	< 0.001	< 0.001	< 0.001
Apical vertebral rotation	< 0.001	< 0.001	0.004
Apical vertebral translation	< 0.001	< 0.001	0.001

BB Before the brace, *AB* after the brace, *LC* last control

Table 4 Results of the SRS-22 questionnaire

Pain	4.6 ± 0.5 (range: 3.2–5.0)
Self-image/appearance	4.0 ± 0.5 (range: 3.0–4.8)
Function	4.7 ± 0.4 (range: 3.2–5.0)
Mental health	3.9 ± 0.5 (range: 2.0–4.8)
Satisfaction with the treatment	4.4 ± 0.6 (range: 3.0–5.0)
Total	4.3 ± 0.3 (range: 3.4–4.9)

SRS-22 Scoliosis Research Society-22

interval [CI] 0.752–0.914), while the intra-observer reliability was 0.920 (95% CI 0.818–0.970).

Results

The results indicated that the mean value for the main thoracic curves was 31.3 ± 3.6° before bracing, 20.0 ± 6.1° at the early follow-up (at 6 weeks), and 27.2 ± 5.9° at the final follow-up (mean 32.42 ± 8.65 months) after bracing. Similarly, the mean value for the thoracolumbar/lumbar curves was 30.1 ± 4.3° before bracing, which decreased to 20.0 ± 6.5° at the early follow-up and 24.2 ± 7.3° at the last follow-up after bracing. The statistical analysis revealed a significant improvement in both the main thoracic and thoracolumbar/lumbar curves in the early and last follow-ups after bracing ($p < 0.001$) (Tables 2 and 3). The proximal thoracic curves' Cobb angles were evaluated before the brace, after the brace, and at the final follow-up, yielding values of 28.2 ± 3.1°, 26.8 ± 1.8°, and 30.6 ± 5.9°, respectively. There was no significant difference in the Cobb angles of proximal thoracic curves before brace application, after brace application, and at the final follow-up ($p = 0.135$, $p = 0.208$, $p = 0.110$, respectively) (Tables 2 and 3).

The AVR was evaluated radiologically using the Nash Moe classification. The results demonstrated an initial AVR of 2.1 ± 0.6, which decreased to 1.1 ± 0.5 and 1.3 ± 0.5 after the brace and at the last follow-up, respectively. Statistical analysis using Tables 2 and 3 indicated that there was a significant decrease in AVR between the post-brace and final follow-up measurements, as compared to the pre-brace AVR values ($p < 0.001$, $p < 0.001$, and $p = 0.004$, respectively).

The mean AVT $p <$ s were found to be 36.4 ± 9.6 mm prior to bracing, 16.7 ± 7.3 mm during the early post-bracing phase, and 19.8 ± 8.1 mm at the final follow-up. The statistical analysis demonstrated at Tables 2 and 3 revealed a significant decrease in AVT at both the early post-bracing and final follow-up assessments, as compared to the pre-bracing measurements ($p < 0.001$, $p < 0.001$, $p = 0.001$, respectively).

According to the results of the Scoliosis Research Society-22 questionnaire (SRS-22), satisfactory values were observed in the domains of pain, function, and treatment satisfaction. However, the scores for mental health and self-image/appearance were found to be slightly lower, as indicated by the data presented in Table 4.

Discussion

Despite ongoing debates on the effectiveness of brace treatment for adolescent idiopathic scoliosis (AIS), it is still considered an indispensable component of conservative treatment. Positive treatment outcomes can be achieved through careful patient selection and thorough patient and parental education on the proper use of braces [18, 19]. In order to standardize the use of braces for AIS treatment, the Scoliosis Research Society (SRS) has developed guidelines based on the patient's age, Cobb angle, and skeletal growth potential [20]. The criteria outlined by the SRS include: (1) patients aged 10 years and older, (2) Risser's sign between 0 and 2, (3) Cobb angle between 25° and 40°, (4) no previous treatment, and (5) in girls, pre-menarchal or less than 1 year post-menarchal.

The SRS has developed guidelines for evaluating the effectiveness of brace treatment for AIS. These guidelines include assessing the proportion of patients with curve progression of ≤ 5 degrees and ≥ 6 degrees after skeletal maturity, evaluating the curvature after skeletal maturity with a cutoff value of > 45 degrees, and conducting a follow-up period of 2 years to assess the progression of the deformity after skeletal maturity and brace termination [20]. These guidelines are critical in determining the success of brace treatment for AIS and in deciding when to terminate brace treatment.

According to various studies that have used different types of braces, success rates ranging from 50 to 95% have been reported within the SRS criteria for AIS treatment [21–25]. Specifically, studies focusing on the Boston-type brace have reported correction rates between 30 and 55%. In the current study, we used the Boston-type brace for all patients. Previous research has reported a 54% correction rate for curvatures with an apex at T10 or below using the Boston-type brace, while another study found a correction rate of 29% to 37% for curvatures with an apex at T8 or below [26–28].

The initial mean Cobb angles for the main thoracic and thoracolumbar/lumbar curvatures were 31° and 30°, respectively. Brace treatment resulted in a mean correction of approximately 35%, with an average reduction of 20° in the Cobb angle. At the final follow-up, the mean Cobb angles of the main thoracic and thoracolumbar/lumbar curves were 27.2° and 24.2°, respectively, indicating an average improvement of approximately 13% compared to the pre-brace angles.

In the current study, it was found that among the cohort of patients with structural proximal thoracic curvature (defined as a curvature apex above T7), five individuals (9.8%) had a mean Cobb angle of 28° before brace treatment. Following brace therapy, the mean Cobb angle decreased to 27°, but at the last follow-up, it had increased to 31°. While there was no statistically significant improvement between the pre-brace and final follow-up angles, we interpreted the results positively because, on average, there was less than 5° progression among the five affected patients.

Kuroki et al. described the mechanism of action of braces in correcting spinal deformities, which involves distraction to the concave side, compression to the convex side, pressure from the sides using the principle of three points, and a bending effect [11]. The correct placement of pads in the apex area is crucial, as incorrect placement may lead to hypokyphosis or an increase in apical vertebral rotation [8]. While previous studies have evaluated the correction rates of deformities in the coronal and sagittal planes with brace treatment in adolescent idiopathic scoliosis (AIS) [21–28], no study has yet investigated the effect of brace application on the apical vertebrae in AIS. Apical vertebral rotation is a critical component of structural scoliosis [29, 30], and manipulation of the apical vertebrae during brace treatment may result in better curve control.

In the current study, the apical vertebral rotation (AVR) was assessed according to the Nash Moe classification. It was observed a correction in AVR from a mean value of 2.1 before brace treatment to a mean value of 1.1 after brace treatment (47.6% improvement). At the last follow-up, the AVR correction was 1.3 (38%). The apical vertebral translation (AVT) decreased from a mean value of 36.4 mm before brace treatment to a mean value of 16.7 mm (54% improvement) after brace treatment. At the last follow-up, a mean AVT decrease of 20 mm was observed, representing a 45% improvement.

The SRS-22 questionnaire was used in the current study to evaluate the patients' quality of life and perception of their deformity. The results showed satisfactory values in the domains of pain, function, and satisfaction with treatment, while a slightly lower score was obtained in the domains of mental health and self-image/appearance. In a study by Schwieger et al., it was recommended that patients with AIS be informed about the potential negative impact of brace treatment on their body image and quality of life. Poor self-image may be a barrier to starting and continuing brace treatment. Adolescence is a developmental stage where self-esteem and self-confidence are established, and living with a chronic illness such as AIS can make that process difficult. Although AIS itself is not a life-threatening disease, it has been associated with the development of serious mental disorders in patients, as reported in previous studies [31–33].

The study had several limitations that should be considered. First, it was a retrospective study and, therefore, was limited by the quality of the data available. Second, some patients were still undergoing treatment with braces, which limits the ability to draw final conclusions about the long-term effectiveness of the treatment (However, since the study was aimed to evaluate the rotation of the apical vertebrae in the brace, we present these data). Third, the number of patients included in the study was limited, which may effect the generalizability of the findings. Fourth, compliance with the brace was not evaluated using any follow-up device, which could have provided valuable information on the effectiveness of the treatment. An additional constraint of the study is the exclusive administration of the SRS-22 questionnaire during the final follow-up visit.

In conclusion, the current study provides evidence that the implementation of the Boston-type brace as a conservative treatment for AIS is effective in managing the coronal curve of the main thoracic, thoracolumbar, and lumbar regions. Moreover, it successfully corrects the rotation and translation of the apical vertebrae. The mentioned valuable finding highlights the importance of brace utilization for hindering the curve progression in AIS. Although the upper thoracic curvatures did not exhibit corrective effects, there were no negative trends observed in the clinical and radiological parameters during and after the brace treatment, as indicated by our follow-up assessments. Thus, we recommend that healthcare providers and parents motivate and support patients with scoliosis to adapt to the brace treatment for better outcomes.

Author contributions ACB contributed significantly to hypothesis formulation and study design and he drafted the work and revised it critically for important intellectual content. He approved the version of the manuscript to be published. ID made significant contributions to the review of recent papers and the drafting of the manuscript. He approved the version of the manuscript to be published. MAT made significant contributions to the study design, data analysis and data interpretation. He approved the version of the manuscript to be published. BKYcontributed significantly to the conception, design and data collection of the study. He approved the version of the manuscript to be published. AS contributed significantly to the formulation of the study hypothesis and the design of the study. He also revised and approved the version of the manuscript to be published. All authors listed have made significant contributions in almost all areas of the study.

Funding No financial support was received from any institutions and organizations for the study.

Data availability The data that support the findings of this study are openly available and can be provided if needed. The authors confirm that the data supporting the findings of this study are available within the article.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose. There is no conflict of interest between the authors.

Ethical approval Ethics committee approval was obtained from Gazi University Ethics Commission for the study (Date: 04.10.2022; No:16).

Informed consent The data collected for the study do not include the identity information of the patients. In addition, patients were not invited to our institution for the study. The examination findings and radiographs of the patients during routine outpatient visits were obtained from hospital archives and analyzed retrospectively.

References

1. Konieczny MR, Senyurt H, Krauspe R (2013) Epidemiology of adolescent idiopathic scoliosis. J Child Orthop 7(1):3–9. https://doi.org/10.1007/s11832-012-0457-4
2. Fong DY, Lee CF, Cheung KM, Cheng JC, Ng BK et al (2010) A meta-analysis of the clinical effectiveness of school scoliosis screening. Spine (Phila Pa 1976) 35:1061–1071. https://doi.org/10.1097/BRS.0b013e3181bcc835
3. Clayson D, Luz-Alterman S, Cataletto MM, Levine DB (1978) Long-term psychological sequelae of surgically versus nonsurgically treated scoliosis. Spine (Phila Pa 1976) 12:983–986. https://doi.org/10.1097/00007632-198712000-00007
4. Weinstein SL, Dolan LA, Spratt KF, Peterson KK, Spoonamore MJ et al (2003) Health and function of patients with untreated idiopathic scoliosis: a 50-year natural history study. JAMA 289:559–567. https://doi.org/10.1001/jama.289.5.559
5. Weinstein SL, Ponseti IV (1983) Curve progression in idiopathic scoliosis. J Bone Joint Surg Am 65:447–455
6. Weinstein SL, Zavala DC, Ponseti IV (1981) Idiopathic scoliosis: long-term follow-up and prognosis in untreated patients. J Bone Joint Surg Am 63:702–712
7. Weinstein SL, Dolan LA, Wright JG, Dobbs MB (2013) Effects of bracing in adolescents with idiopathic scoliosis. N Engl J Med 369:1512–1521. https://doi.org/10.1056/NEJMoa1307337
8. Kuroki H (2018) Brace treatment for adolescent idiopathic scoliosis. J Clin Med 7:6. https://doi.org/10.3390/jcm7060136
9. Maruyama T, Takesita K, Kitagawa T, Nakao Y (2011) Milwaukee brace. Physiother Theory Pract 27:43–46. https://doi.org/10.3109/09593985.2010.503992
10. Wiley JW, Thomson JD, Mitchell TM, Smith BG, Banta JV (2000) Effectiveness of the boston brace in treatment of large curves in adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 25:2326–3232. https://doi.org/10.1097/00007632-200009150-00010
11. Karol LA, Virostek D, Felton K, Wheeler L (2016) Effect of compliance counseling on brace use and success in patients with adolescent idiopathic scoliosis. J Bone Joint Surg Am 98:9–14. https://doi.org/10.2106/JBJS.O.00359
12. Alvarez I, Poppino K, Karol L, McIntosh AL (2021) Lack of in-brace x-rays in compliant AIS patients wearing full-time TLSO braces associates with failure. J Orthop Surg Res 16:540. https://doi.org/10.1186/s13018-021-02650-9
13. Dolan LA, Weinstein SL (2007) Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence-based review. Spine (Phila Pa 1976) 32:91–100. https://doi.org/10.1097/BRS.0b013e318134ead9
14. Focarile FA, Bonaldi A, Giarolo MA, Ferrari U, Zilioli E et al (1991) Effectiveness of nonsurgical treatment for idiopathic scoliosis. Overview of available evidence. Spine (Phila Pa 1976) 16:395–401. https://doi.org/10.1097/00007632-199104000-00001
15. Lenssinck ML, Frijlink AC, Berger MY, Bierman-Zeinstra SM, Verkerk K et al (2005) Effect of bracing and other conservative interventions in the treatment of idiopathic scoliosis in adolescents: a systematic review of clinical trials. Phys Ther 85:1329–1339
16. Rowe DE, Bernstein SM, Riddick MF, Adler F, Emans JB et al (1997) A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. J Bone Joint Surg Am 79:664–674. https://doi.org/10.2106/00004623-199705000-00005
17. Blanke KM, Kuklo TR, Lenke LG, O'Brein MF, Polly DW Jr, Richards BS, Sanders JO (2008) Ch 4. Adolescent Idiopathic Scoliosis. In: O'Brein MF, Kuklo TR, Blanke KM, Lenke LG (eds) Spine Deformity Study Group. Radiographic Measurment Manual. Medtronic Sofamor Danek USA, Inc, Memphis, pp 47–71
18. Schwieger T, Campo S, Weinstein SL, Dolan LA, Ashida S et al (2016) Body image and quality-of-life in untreated versus brace-treated females with adolescent idiopathic scoliosis. Spine 41:311–319. https://doi.org/10.1097/BRS.0000000000001210
19. Meng ZD, Li TP, Xie XH, Luo C, Lian XY et al (2017) Quality of life in adolescent patients with idiopathic scoliosis after brace treatment: a meta-analysis. Medicine 96:6828. https://doi.org/10.1097/MD.0000000000006828
20. Richards BS, Bernstein RM, D'Amato CR, Thompson GH (2005) Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS committee on bracing and nonoperative management. Spine (Phila Pa 1976) 30:2068–2075. https://doi.org/10.1097/01.brs.0000178819.90239.d0

21. Coillard C, Vachon V, Circo AB, Beauséjour M, Rivard CH (2007) Effectiveness of the SpineCor brace based on the new standardized criteria proposed by the scoliosis research society for adolescent idiopathic scoliosis. J Pediatr Orthop 27:375–379. https://doi.org/10.1097/01.bpb.0000271330.64234.db
22. Janicki JA, Poe-Kochert C, Armstrong DG, Thompson GH (2007) A comparison of the thoracolumbosacral orthoses and providence orthosis in the treatment of adolescent idiopathic scoliosis: results using the new SRS inclusion and assessment criteria for bracing studies. J Pediatr Orthop 27:369–374. https://doi.org/10.1097/01.bpb.0000271331.71857.9a
23. Negrini S, Atanasio S, Fusco C, Zaina F (2009) Effectiveness of complete conservative treatment for adolescent idiopathic scoliosis (bracing and exercises) based on SOSORT management criteria: results according to the SRS criteria for bracing studies - SOSORT Award 2009 Winner. Scoliosis 4:19. https://doi.org/10.1186/1748-7161-4-19
24. Aulisa AG, Guzzanti V, Galli M, Perisano C, Falciglia F et al (2009) Treatment of thoraco-lumbar curves in adolescent females affected by idiopathic scoliosis with a progressive action short brace (PASB): assessment of results according to the SRS committee on bracing and nonoperative management standardization criteria. Scoliosis 4:21. https://doi.org/10.1186/1748-7161-4-21
25. Zaborowska-Sapeta K, Kowalski IM, Kotwicki T, Protasiewicz-Fałdowska H, Kiebzak W (2011) Effectiveness of Chêneau brace treatment for idiopathic scoliosis: prospective study in 79 patients followed to skeletal maturity. Scoliosis 6:2. https://doi.org/10.1186/1748-7161-6-2
26. Watts HG, Hall JE, Stanish W (1977) The Boston brace system for the treatment of low thoracic and lumbar scoliosis by the use of a girdle without superstructure. Clin Orthop Relat Res 126:87–92
27. Udén A, Willner S, Pettersson H (1982) Initial correction with the Boston thoracic brace. Acta Orthop Scand 53:907–911. https://doi.org/10.3109/17453678208992847
28. Jonasson-Rajala E, Josefsson E, Lundberg B, Nilsson H (1984) Boston thoracic brace in the treatment of idiopathic scoliosis. Initial correction Clin Orthop Relat Res 183:37–41
29. Senkoylu A, Ilhan MN, Altun N, Samartzis D, Luk KDK (2021) A simple method for assessing rotational flexibility in adolescent idiopathic scoliosis: modified Adam's forward bending test. Spine Deform 9:333–339. https://doi.org/10.1007/s43390-020-00221-2
30. Senkoylu A, Luk KD, Wong YW, Cheung KM (2014) Prognosis of spontaneous thoracic curve correction after the selective anterior fusion of thoracolumbar/lumbar (Lenke 5C) curves in idiopathic scoliosis. Spine J 14:1117–1124. https://doi.org/10.1016/j.spinee.2013.07.467
31. Eliason MJ, Richman LC (1984) Psychological effects of idiopathic adolescent scoliosis. J Dev Behav Pediatr 5:169–172
32. Tones M, Moss N, Polly DW Jr (2006) A review of quality of life and psychosocial issues in scoliosis. Spine (Phila Pa 1976) 31:3027–3038. https://doi.org/10.1097/01.brs.0000249555.87601.fc
33. Payne WK 3rd, Ogilvie JW, Resnick MD, Kane RL, Transfeldt EE et al (1997) Does scoliosis have a psychological impact and does gender make a difference? Spine (Phila Pa 1976) 22:1380–1384. https://doi.org/10.1097/00007632-199706150-00017