J Med Biosci Vol. 7 No. 2 July - December 2025; 207 - 212 DOI: 10.58837/CHULA.JMBS.7.2.11

Case report

Preliminary design of an underarm brace for improving Cobb angle reduction in adolescent idiopathic scoliosis: A case report

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Abstract

Adolescent idiopathic scoliosis (AIS) is a condition commonly found in teenagers. The treatment depends on the severity of the curvature and the patient's skeletal maturity. Brace treatment is a successful conservative method for preventing curve progression. Various brace designs are available, with the underarm brace based on Boston principles being a common choice at Sirindhorn School of Prosthetics and Orthotics (SSPO) Clinic, Thailand. According to the Boston principles, a window is provided contralateral to the thoracic curve; however, no specifications regarding window opening in the lumbar area are mentioned. This study aimed to investigate the impact of a modified underarm brace with openings on in-brace Cobb angle reduction, coronal decompensation, and apical vertebral translation, compared to a conventional underarm brace without openings. Two participants were fitted with two types of underarm braces: one without openings (D1) and one with openings on the contralateral thoracic and lumbar areas (D2). Thoracic Cobb angle (TCA), lumbar Cobb angle (LCA), coronal decompensation (CD), thoracic apical vertebral translation (TAVT), and lumbar apical vertebral translation (LAVT) were measured for both designs and compared to baseline measurements. Additionally, patient satisfaction and feedback were collected. Results indicated that Cobb angle reduction for both thoracic and lumbar regions was superior with D2 compared to D1 for both cases. However, no significant changes were observed in CD, TAVT, or LAVT. Patient satisfaction was higher with D2, except ease of donning and breathing.

Keywords: Adolescent idiopathic scoliosis, in-brace Cobb angle reduction, opening area, thoracolumbosacral orthosis, underarm brace.

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Received: February 24, 2024
Revised: May 22, 2025
Accepted: June 16, 2025

Scoliosis is a prevalent spinal disorder among adolescents, characterized by a lateral curvature of the spine with a Cobb angle exceeding 10 degrees. Scoliosis classification considers etiology, age onset, curve type, and severity. Idiopathic scoliosis (IS), the most common variant based on etiology, lacks an identified cause and is categorized by age of onset: infantile idiopathic scoliosis (IIS; 0 - 3 years), juvenile idiopathic scoliosis (JIS; 4 - 10 years), adolescent idiopathic scoliosis (AIS; 11 - 18 years), and adult idiopathic scoliosis (onset above 18 years). [1] In Thailand, the prevalence of AIS among teenagers, as reported by Kunakornsawat S*, et al.,* is 13.0%. [2] Treatment approaches for IS, including operative and conservative methods, depending on the severity of the curvature severity and skeletal maturity. [1 - 3] The main objective of conservation treatment is to prevent curve progression during puberty. [3, 4] Brace treatment is proved to be a successful conservative method, with 76.0% of AIS curves stabilized. [5]

The underarm brace, or thoracolumbosacral orthosis (TLSO), based on Boston principles, is a commonly employed brace design at Sirindhorn School of Prosthetics and Orthotics (SSPO) Clinic, Thailand. Nowadays, various underarm brace designs exist, with different principles of correcting and controlling the curvature, such as the Boston brace and the Cheneau brace. [6, 7] The Boston brace combines active and passive mechanisms by providing an opening contralateral to the thoracic corrective force to optimize in-brace curve correction and achieve trunk balance. The brace's interior passive mechanism allows soft tissue to translate towards the opening. While its active mechanisms include vertebral growth, asymmetrically guided respiratory thoracic movements, thoracic repositioning, and anti-gravitational effects. [8] Although the Boston bracing system typically provides an opening contralateral to the thoracic curve, to allow trunk shifting and accommodate the migration of soft tissue from the corrective area, no specific references mention openings contralateral to the lumbar corrective force. [9] Based on the principle of in-brace correction, the effective brace should achieve at least 50.0% immediate in-brace curve reduction, which is essential for predicting the long-term treatment outcomes. [10, 11]

To the best of our knowledge, the effect of openings contralateral to both thoracic and lumbar curvatures has not yet been investigated. Therefore, this study aimed to examine the impacts of a modified underarm brace with openings on in-brace Cobb angle reduction, coronal decompensation, and apical vertebral translation, compared to a conventional underarm brace without openings.

Materials and methods

Case presentation

Two fourteen-year-old AIS participants exhibiting double major curve with right thoracic (apex at T8) and left lumbar (apex at L2) curve were recruited in this study. Both curves were semi-rigid and had moderate Cobb angles, indicated for brace treatment. Participants had more than six months of brace usage experience. This study has been approved by the Siriraj Institutional Review Board (SIRB), under project no. 660/2561 (EC1).

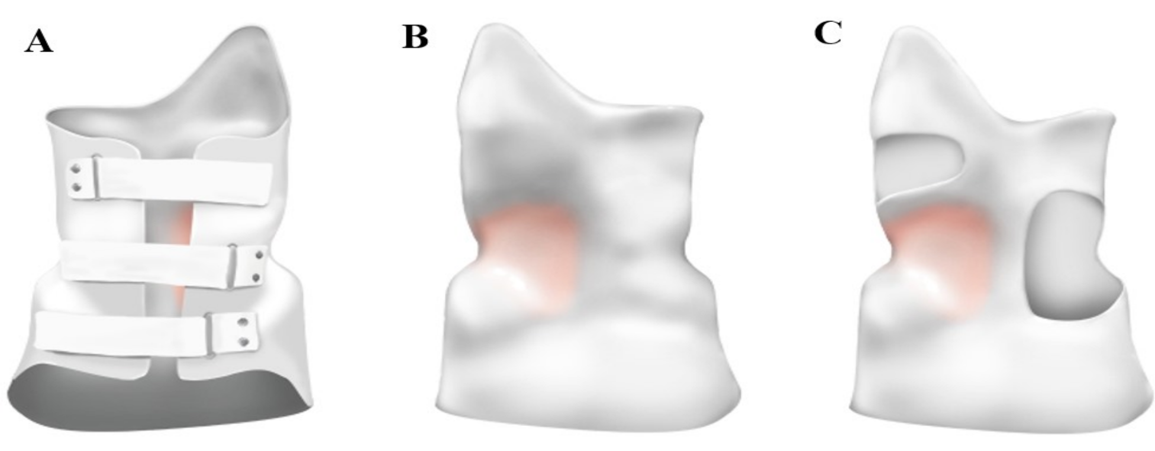

Figure 1. **(A)** Anterior view of a conventional underarm brace; **(B)** Posterior view of a conventional underarm brace without openings, D1; and **(C)** Posterior view of a modified underarm brace with openings, D2.

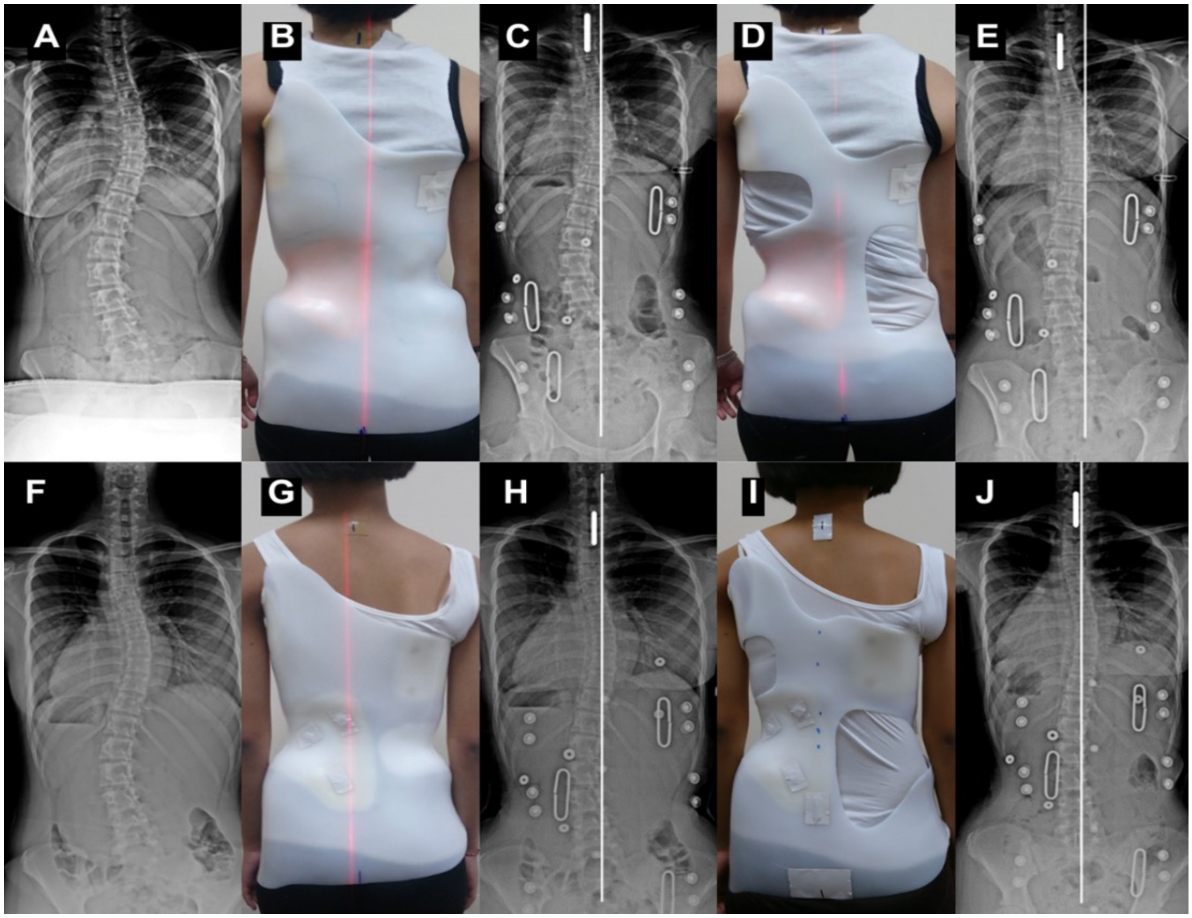

Figure 2. **(A - E)** Case 1: **(A)** OBR; **(B)** D1 brace; **(C)** IBR with D1; **(D)** D2 brace; **(E)** IBR with D2. **(F-J)** Case 2: **(F)** OBR; **(G)** D1 brace; **(H)** IBR with D1; **(I)** D2 brace; and **(J)** IBR with D2.

Brace design and production

Two orthotists performed the entire brace production process, including patient assessment, casting, modification, brace fabrication, and fitting, ensuring that the devices were safe, well-fitted, and functional. Two underarm brace designs, a conventional design without openings (D1) and a modified version with openings (D2), were fabricated using 4-mm co-polymer plastic as depicted in **Figure 1.**

Initially, D1 was fabricated, fitted, and evaluated with in-brace radiograph (IBR) in the morning. Subsequently, openings were cut into D1 to create D2. The openings, located contralateral to the corrective force application area, followed Boston principles. If the brace fit was compromised due to the openings, straps were tightened to the maximum tolerable tension. IBR for D2 brace were taken in the afternoon of the same day after an hour of brace usage, as shown in **Figure 2.**

Outcome measurement

Three posteroanterior radiographs were captured for each participant in standing position: out-of-brace radiograph (OBR) before brace intervention (baseline), IBR with a conventional design (D1), and IBR with a modified design (D2). Thoracic Cobb angle (TCA) and lumbar Cobb angle (LCA) were measured in degrees, and reduction percentages were calculated compared to baseline. Coronal decompensation (CD), thoracic apical vertebral translation (TAVT), and lumbar apical vertebral translation (LAVT) were measured in centimeters. Coronal decompensation (CD) was measured as the distance between the center sacral line and the seventh cervical vertebra, representing the middle of the head. Apical vertebral translation (AVT) was measured as the distance between the center sacral line and the apical vertebra's midpoint. Measurement directions were labeled as right (R) or left (L) relative to the central sacral line or mid body line. Data were collected manually by three orthotists using the Siriraj Picture Archiving and Communication System (SiPACs) measuring program. Each orthotist independently measured each measurement twice over a two-week interval. Following the fitting of each brace design, a patient satisfaction was assessed using a survey evaluating lightness of the device, ease of donning, and ease of breathing. A five-point Likert scale with emoticon-based visual cues was used for scoring, along with an open-ended question to allow for additional comments or feedback.

Table 1. Outcomes of the out-of-brace, in-brace in D1, and in-brace in D2 in the two cases.

Case	Radiography	Mean thoracic Cobb angle; TCA (degrees)	Thoracic Cobb angle reduction (%)	Mean lumbar Cobb angle;LCA (degrees)	Lumbar Cobb angle reduction (%)	Mean coronal decompensation; CD (cm)	Mean thoracic apical vertebral translation; TAVT (cm)	Mean lumbar apical vertebral translation; LAVT (cm)
1	**OBR**	30.8 (R)	N/A	32.3 (L)	N/A	2.5 (L)	0.2 (L)	3.5 (L)
	IBR of D1	26.0 (R)	15.7	24.0 (L)	25.8	1.7 (L)	0.6 (L)	2.9 (L)
	IBR of D2	19.8 (R)	35.7	19.3 (L)	40.2	2.8 (L)	0.6 (L)	2.4 (L)
2	**OBR**	30.3 (R)	N/A	29.0 (L)	N/A	1.6 (L)	0.3 (L)	2.7 (L)
	IBR of D1	24.8 (R)	18.1	21.0 (L)	27.6	1.1 (L)	0.4 (R)	2.2 (L)
	IBR of D2	18.3 (R)	39.6	16.3 (L)	43.7	0.6 (L)	0.6 (R)	1.3 (L)

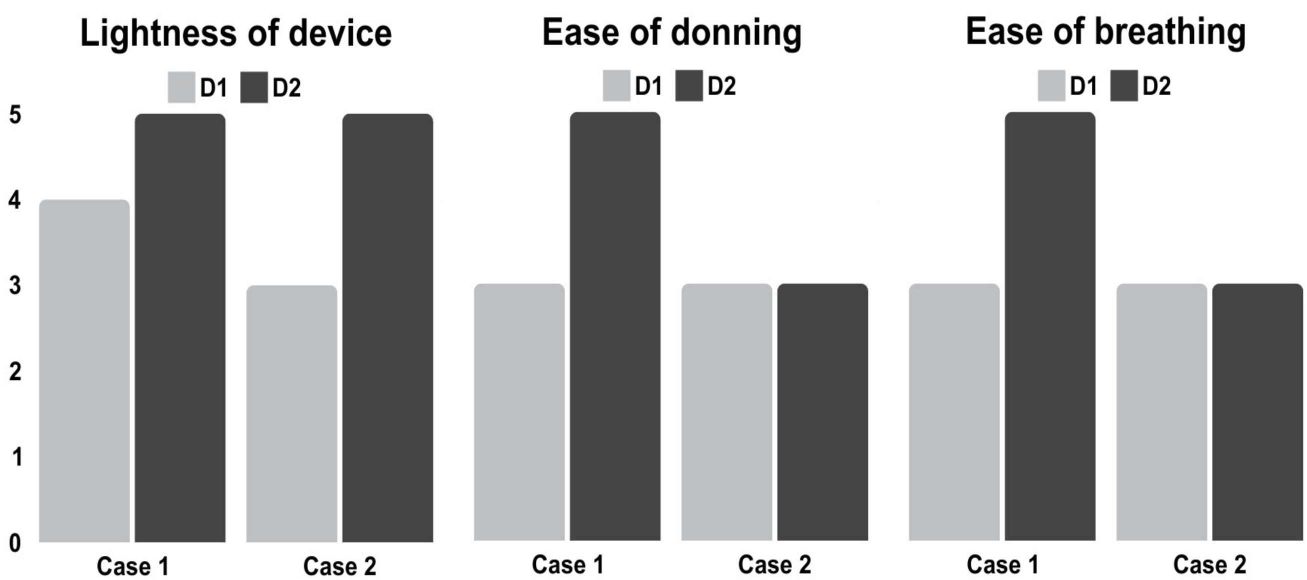

Figure 3. Participants satisfaction score chart.

Results

TCA and LCA were measured then, and reduction percentage of each Cobb angle was calculated in comparison with the OBR baselines, along with CD, TAVT and LAVT measurements. Results for both cases are summarized in **Table 1.** Participant satisfaction scores for both designs are presented in **Figure 3.**

Discussion

Cobb angle reduction

The Cobb angle reduction demonstrated improvement with the D2 design when compared to D1 in both cases. Although the immediate in-brace correction did not achieve the optimum goal of 50.0%, Katz DE, *et al.* suggested that a double curve demonstrating an in-brace correction exceeding 25.0% often indicates a high rate of successful treatment. [10, 12] Moreover, the superior improvement observed with D2 may be due to the additional space provided for the trunk to shift towards the concave side of the curve, facilitated by the brace's opening.

This design enables the straps to be more tightened, leading to a snugger fit and increased pressure on the patient's torso for better curve correction. [11, 13, 14] The researcher observed the skin redness after brace removal, if the redness disappeared within 20-30 minutes, it is considered as normal. Several studies evidenced a correlation between strap tension and pad pressure, emphasizing that strap tension should be at the maximum level a patient can comfortably tolerate. (13, 15) The TCA showed a greater reduction in D2 due to the contralateral tissue being pushed posteriorly, allowing it to migrate posterolaterally towards the opening. As for the lumbar region, even though the correction force was applied medially and anteriorly, the opening's posterior location resulted in a more posterior distribution of soft tissue, leading to less centralization of the lumbar spine compared to that of the thoracic spine.

Coronal decompensation

CD results varied between the two cases in this study. Case 1 showed improved CD in D1 (1.7 cm to the left) but worsened in D2 (2.8 cm to the left), possibly due to the opening on the left thoracic area, which might have induced more migration of the thoracic and cervical spine towards the left and, resulting in increased left decompensation. In contrast, case 2 demonstrated a more balanced compensation in D1 (1.1 cm to the left) and an even better result of 0.6 cm to the left in D2. However, due to the limited number of participants involved in this study, the impact of brace design on coronal decompensation remains controversial and inconclusive.

Apical vertebral translation

In case 1, TAVT shifted towards the right in D1. However, once the left window was opened in D2, TAVT migrated to the left, possibly influenced by the increased area of leftward shifting. On the other hand, LAVT shifted from the left in D1 to the right in D2, moving closer to the center sacral line. In case 2, both TAVT and LAVT shifted to the right side in D1, and the shift was more pronounced in D2. This may be attributed to the larger lumbar counter force on the thoracic compared to the thoracic correction force, reflecting the greater correction of the lumbar curve, and resulting in right migration of the entire spine. While LAVT consistently showed centralization to the right side in both D1 and D2, the change in TAVT is controversial due to the opposite changes in case 1 (shift to the right in D1 and shift to the left in D2) and case 2 (both shifts to the right).

Window opening

The introduction of an opening at the right lumbar region of an underarm brace for patients with double curves demonstrated improved reduction of the lumbar curve and vertebral translation. However, careful consideration should be given to padding adjustment to ensure optimal trunk alignment. (15) As Thailand has a hot and humid climate, an underarm brace with openings would allow for better ventilation and increased comfort for full-time brace users. (3) Therefore, D2 is more suitable considering the physiological conditions in Thailand, without compromising the effectiveness of the brace. Although increasing the opening area may weaken the strength of the brace, it does not affect the ability of the brace to stabilize the curve. The efficacy and comfort of the brace are two crucial factors for successful brace treatment, influencing good compliance and improving the patient's quality of life. (16 - 18)

Patient satisfaction

Patient satisfaction scores were higher for D2, except for ease of donning and ease of breathing, which were comparable between both designs in case 2. The reason could be due to the opening areas were located on the postero-lateral aspect of the brace which create no difference in terms of the brace opening for donning. In addition, both brace designs encompass the lung area below the chest which could not alter the breathing comfortability. One participant mentioned the there was no difference in the amount of pressure applied on her trunk even though the openings were present. Overall, D2 was preferred as it provided a more comfortable wearing experience.

The analysis of this study was limited by the small sample size which made it difficult to perform the reliable statistical analysis and validity of statistical tests. While descriptive statistics can identify trends and provide initial insights, the absence of formal statistical testing cannot definitively establish the significance of the differences noted. To validate these results and conduct thorough statistical evaluations, future research with larger sample size should be further conducted.

Conclusion

The study demonstrates that incorporating openings into the brace design contralateral to the corrective force improves in-brace Cobb angle reduction without significantly affecting other parameters. Although no significant changes were observed in other aspects, further brace adjustment should be considered to achieve optimal alignment. Patient satisfaction was higher with a modified underarm brace with openings which may have contributed to improved brace compliance and underscores the importance of balancing efficacy and comfort in brace design.

Acknowledgements

The authors would like to express their heartfelt thanks to Juthamas Siriwatsopon for her invaluable research assistance and to Sutinar Parinpunnapok for providing the illustrative figures. This research project was supported by Siriraj Research Development Fund (Grant No. R016231020), Faculty of Medicine Siriraj Hospital, Mahidol University.

Conflicts of interest

The authors declare no conflict of interest.

Data sharing statement

Data sharing statement. Data generated or analyzed for the present report are included in this published article. Further details are available from the corresponding author on reasonable request after deidentification of the patient whose data are included in the report.

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