

## Current Concept Review

# Scoliosis Bracing: Details Make the Difference

Gregory Benes, BS<sup>1</sup>; Benjamin D. Roye, MD<sup>2</sup>; Luke Stikeleather, CO<sup>3</sup>; M. Timothy Hresko, MD<sup>4</sup>; Daniel J. Sucato, MD<sup>5</sup>; Michelle C. Welborn, MD<sup>6</sup>; Catherine McClellan, PhD<sup>7</sup>; Paul D. Sponseller, MD, MBA<sup>1</sup>

<sup>1</sup>Department of Orthopaedic Surgery, The Johns Hopkins University, Baltimore, MD; <sup>2</sup>Department of Orthopedic Surgery, Columbia University Irving Medical Center, New York, NY; <sup>3</sup>National Scoliosis Center, Fairfax, VA; <sup>4</sup>Department of Orthopaedic Surgery, Boston Children's Hospital, Boston, MA; <sup>5</sup>Department of Orthopaedic Surgery, Texas Scottish Rite Hospital for Children, University of Texas at Southwestern Medical Center, Dallas, TX; <sup>6</sup>Department of Spine Surgery, Shriners Hospital for Children Portland, Portland, OR; <sup>7</sup>Shriners Hospitals for Children, Portland, OR

Correspondence: Paul D. Sponseller, MD, Department of Orthopaedic Surgery, The Johns Hopkins University, 601 N Caroline St., Baltimore, MD 21287. E-mail: psponse@jhmi.edu

Received: August 9, 2023; Accepted: September 30, 2023; Published: November 15, 2023

DOI: 10.55275/JPOSNA-2023-776

### Abstract

Effective bracing for idiopathic scoliosis is influenced by factors such as age, skeletal maturity, and curve attributes, with success reliant on patient adherence and engagement. The purpose of this paper is to highlight strategies for successful treatment. Using standardized, effective communication detailing patient data, including radiographic measurements, supports clear communication between orthopaedic surgeon, orthotist, and patient. Consistent orthotist visits are important to ensure correct brace fit by evaluating aspects like tightness, comfort, and deformity correction. Monitoring growth metrics like height and weight can signal necessary adjustments. An initial in-brace x-ray facilitates early refinements with subsequent imaging based on growth stages. Adherence monitors augment treatment by tracking brace-wear patterns. Weaning protocols, aiming to reduce brace wear gradually while curbing curve progression, are influenced by factors such as curve size, brace comfort, and skeletal maturity markers. Overcoming barriers like physical discomfort and self-consciousness is pivotal for effective treatment. Emphasizing resilience, choice, and emotional support ensures enhanced patient commitment and satisfaction, leading to the best possible outcomes.

### Key Concepts

- Increased time in brace leads to success in a dose-response fashion.
- Effective, convenient methods of communication between the orthotist and orthopaedic surgeon are key to optimizing patient outcomes.
- Adherence monitors can bolster patient engagement and autonomy and improve outcomes.
- Patient support sources and psychologically informed techniques can diminish perceived barriers to brace wear.

## Introduction

Various treatment modalities for idiopathic scoliosis have been proposed with bracing emerging as a cornerstone in nonoperative management. The efficacy of this intervention is profoundly influenced by a myriad of factors, including the age and skeletal maturity of the patient, intrinsic curve attributes (size and location) as well as wearing schedule and duration. While the biomechanical action of bracing holds paramount importance, the dynamics of patient care involve a multi-disciplinary approach, forming a triumvirate comprising the orthopaedic surgeon, the orthotist, and the patient. Successful coordination and communication can affect the success, as details make the difference in optimizing outcomes.

## Guidelines and Considerations for Bracing in Idiopathic Scoliosis

Indications for bracing in idiopathic scoliosis (IS) vary across different age groups, and decisions for part-time versus full-time use are contingent on numerous factors.<sup>1</sup> The general principles that determine brace treatment for IS include patient age at diagnosis, skeletal maturity, and curve characteristics (magnitude, location, and rate of progression).<sup>1</sup> The patient and family's willingness and ability to participate in the treatment process strongly influences successful management.<sup>2,3</sup>

The landscape for bracing significantly changed following the BrAIST trial, which demonstrated the effectiveness of bracing in decreasing progression of the curve to a surgical level for patients with curves ranging from 20-40 degrees and skeletal immaturity.<sup>4</sup> Full-time wear (16-23 hours/day) is the standard of care for most curves and increased time in brace leads to greater success as demonstrated by the clear dose-response curve in the BrAIST study.<sup>4</sup> A part-time bracing regimen (typically around 12-13 hours/day) may be considered for smaller stable curves (<25 degrees) in younger patients (4-10 years old).<sup>5</sup> Hypercorrective braces, like Providence or Charleston braces, can be considered for patients with single lumbar/thoracolumbar curves or those who have passed their peak growth velocity.<sup>5-7</sup>

Adequate in-brace correction of at least 70% curve correction is recommended if part-time bracing should be considered.<sup>7</sup> Each patient will have an optimal brace wear time based on their individual scoliosis treatment plan, which should be discussed and reviewed with the patient and their family regularly.

Several contraindications to bracing exist, warranting careful consideration in determining the optimal management strategy for scoliosis. Firstly, thoracic curves with a proximal apex might be less amenable to bracing. The authors suggest a curve higher than T7-8 may be less responsive to an orthosis. Secondly, curve magnitude can impact the success of bracing. Generally, bracing is less favored with curve magnitudes greater than 50 degrees; however, there may still be a role for bracing of these curves in the juvenile population. Thirdly, overweight patients with AIS exhibit increased curve progression and decreased success with orthotic treatment compared to their nonoverweight counterparts.<sup>8</sup> While there is limited literature exploring brace effectiveness and adherence amidst behavioral issues, such as autism spectrum and sensory processing disorders, it is imperative to approach treatment on an individualized basis. Each patient's response may vary, even if they share a similar diagnosis.

## When to Use Different Braces in Idiopathic Scoliosis

In general, lumbar curves, which are more flexible and often present with smaller curve magnitudes, can be managed with a nighttime brace in which overcorrection of the brace can be achieved. However, nighttime brace should be reconsidered if the bracing regimen makes the compensatory thoracic curve worse. Excellent success in avoiding progression and the need for surgery has been demonstrated for curves less than 35 degrees.<sup>9</sup> Curves that are smaller than 25 degrees at brace initiation in skeletally immature patients have been successfully treated and include 25% of patients who demonstrate some permanent improvement in their curves at skeletal

maturity. Thoracic curves and double curves are best treated with a full-time orthosis.

Several studies have found varying effectiveness by brace type.<sup>10-14</sup> Katz et al. found that the Boston brace is more effective than the Charleston brace, both in preventing curve progression and in avoiding the need for surgery.<sup>13</sup> In another retrospective study, Sponseller et al. found that patients treated with Rigo Cheneau orthoses (RCOs) had significantly lower rates of spinal surgery and lower mean and percent major curve progression compared to patients treated with Boston-style TLSOs.<sup>12</sup> Patients with large high thoracic curves are not suitable for RCOs. While studies have demonstrated varying effectiveness of brace types, a well-designed and built brace paired with the commitment of the treating team are the keys to the success of orthotic management of scoliosis.

## Brace Fabrication

Historically, TLSOs were crafted using negative body casts and manual shaping of the braces. Although computer-aided design/computer-aided manufacturing (CAD/CAM) technology has been prevalent in the prosthetic and orthotic sectors since the 1970s, recent enhancements in this technology, coupled with reduced costs, have facilitated its adoption by most orthotists in the domain of scoliosis braces. CAM/CAD TLSOs have been shown to have equivalent, if not superior, correction of the Cobb angle compared to standard TLSOs.<sup>11</sup> Furthermore, patients have been shown to prefer the CAD/CAM method over the standard plaster molded TLSO.<sup>11</sup> Engaging patients in the process of brace making can instill a sense of empowerment and active participation in their treatment.

In addition to establishing clear communication with an orthotist, efforts should be made to encourage excellence by asking the orthotist about their training and continuing education experiences specific to scoliosis. To fully appreciate the orthotist's role, it can be beneficial to visit the orthotic facility to understand the process of making, fitting, and checking a brace which is important for the orthopaedic surgeon to understand (Videos 1, 2, 2.1).

## Video 1. Brace-making process.

## How to Check Brace Fit and Working with Your Orthotist

When the patient is seen in clinic, the clinician should examine for skin contact and note any areas of redness on the skin indicating areas of higher contact pressures. Have the patient don the brace to determine whether the brace might be becoming too small. Brace discomfort mentioned by the patient is a significant part of deciding when the brace is too small. It's also essential to regularly monitor the patient's growth in terms of height and weight.

Working closely with your orthotist, who regularly checks the brace fit as scheduled, is an integral part of scoliosis treatment. It's important to establish clear, intentional communication between all parties. Sharing contact information and making efficiency a priority with email can be an effective and convenient way to exchange same-day clinic radiographs and share information between the orthopaedic surgeon and orthotist (Table 1). This can be performed during the patient visit or immediately following. Informing the

**Table 1. Template for E-mail Communication Between Orthopaedic Surgeon and Patient's Orthotist After Clinic Visit**

<b>Bracing Prescription Communication Template: Orthopaedist and Orthotist</b>
Name:
Age:
Menarche (if applicable):
iButton data (if applicable):
Radiographic measurements (Cobb angle):
Skeletal maturity (Risser, Sanders):
Concerns (i.e., brace fit):
Orthopedics Follow-Up:
Include screenshot of radiograph with Cobb angle measurements from clinic visit.

patient and family that you are sharing the x-rays from the clinic visit demonstrates the collaboration.

During follow-up appointments, the orthotist should take time to engage in the patient's life, such as school activities and upcoming trips. Regular discussions to understand the patient's perspective at each visit are important to identify and mitigate any barriers to brace adherence. Thorough examination to ensure proper brace fit at each follow-up every 3 to 6 months is important. Monitor height and weight at each visit to determine when brace adjustments are warranted.

A few areas an orthotist looks for:

- **Brace tightness.** Allow the patient to apply the brace without instruction and see if the brace straps are tightened to the correct amount of tension. Application of the brace while supine allows for a tighter fit for anterior opening brace. Posterior opening braces should be applied with slight hip and knee flexion.
- **Skin contact areas.** Examine the skin contact areas in order to confirm the brace forces are being applied in the correct vector. Excessive redness or irritation could indicate the brace needs to be adjusted or the patient may have outgrown the current brace.
- **Overall pressure and discomfort.** Ask the patient if there are any areas of pressure or discomfort, such as around the iliac crests. Specific areas of the brace are cut out, such as concavities of the curve, to allow for pressure relief so the spine can shift in that direction.
- **Shoulder balance.** In certain cases, the goal is to have one shoulder higher than the other due to bending of the torso to correct the curve.
- **Padding.** Padding can be added to increase contact pressure to correct rotational deformity. Rotation correction can also be monitored by obtaining scoliometer measurements at each appointment.

**Video 2.** *Checking brace fit in an orthotist's office.*

**Video 2.1.** *An example of checking brace fit where a patient has outgrown his brace.*

## Orthotic Appointments: Frequency, Radiographic Monitoring, and Indications for a New Brace

The significance of the first in-brace x-ray cannot be understated, as it offers an opportunity for early adjustments. While a Cobb reduction of 30-50% is generally adequate for preventing curve progression, a hyperfixation on Cobb angle correction can be counterproductive, compromising patient comfort and compliance, and potentially causing iatrogenic curves and chest wall deformity.<sup>15</sup> If less than 30% correction is observed, it may be necessary to adjust or replace the brace.<sup>15-17</sup> Use of a brace monitor is encouraged and should be assessed, as prescribed brace wear predicts future brace wear and success.<sup>18</sup>

The second visit typically occurs 4-6 months into the brace treatment, and the patient's radiographs should be performed out of the brace. While the timing of brace removal varies, many suggest brace removal in the morning, at least 2 hours prior to the x-ray to be sufficient.<sup>19</sup> Radiographs should be done every 4-6 months for patients in a rapid growth phase (Sanders stage 3 or 4) and every 6-12 months for those outside of the rapid growth phase. A new brace may be needed around every 12 months, especially if the brace becomes too tight or uncomfortable, potentially compromising treatment.

## Practical Aspects of Adherence Monitors

When it comes to tracking patient compliance with brace wearing, certain tools can be particularly effective.<sup>20,21</sup> The iButton (iButtonLink, Whitewater, WI) is a small, wearable device that tracks the body temperature to accurately ascertain when the brace is being worn.<sup>21</sup> With the ability to store data for up to 90 days, the iButton provides a comprehensive picture of the patient's adherence to the brace regimen (Video 3).

**Video 3.** *Clinic workflow of loading iButton data (iButtonLink, Whitewater, WI), which can be performed while the patient is in the exam room before or during evaluation by the physician.*



The use of the iButton requires a designated computer to be used for downloading data and is printed for the family's understanding; data can be entered into the Electronic Medical Record (EMR). Such data allows a discussion regarding brace adherence, identifying areas of concern and presenting opportunities for improvement.

Another notable technology in brace wear monitoring is the Brace Rite Scoliosis app, developed at Texas Scottish Rite Hospital (TSRH).<sup>22</sup> This app is compatible with all brace prescriptions and provides a seamless patient experience due to frequent updates and improvements. There is only a slight difference in average wear time recorded between iButton and the Bluetooth-connected Brace Rite app.<sup>22</sup> With its back-end data processing mechanism, the app can be initialized either by parents alone or by both the child and parents.

### **Guide to Brace Weaning and Monitoring After Completion of Bracing**

Key to weaning is considering various skeletal maturity indices, like radiographic skeletal maturity markers (Risser, Sanders, TOCI), timing of peak height velocity, chronological age, Greulich and Pyle Bone Age, and the Collagen X biomarker.<sup>23-25</sup> Historically, RS 4 was a commonly utilized determinant of skeletal maturity but subsequently, Thompson et al. reported 25% of RS4 patients progressed >5 degrees.<sup>26</sup> Many then transitioned to Sanders method, but Grothaus et al. reported that 21% of Sanders stage 7 patients progressed >10 degrees after cessation of bracing.<sup>27</sup> Thus, it is now generally advised to continue bracing until the distal ulna physis is closed (Sanders stage 7B), particularly for larger curves to minimize the risk of progression due to continued growth.<sup>28</sup> The best predictor of cessation of growth (less than 1 cm per year) is Sanders stage 8 and Collagen X biomarker level less than 3 ng/dL, while the worst predictor is Risser 4 (overall) and chronological age (for boys).<sup>25,29</sup> There are many protocols for brace weaning, and there is no consensus on when to stop bracing. It usually depends on various factors, including radiographic skeletal maturity indices, curve magnitude, brace tolerance, and the patient's sex. It's worth noting

that over 50% of physicians recommend a prescribed weaning period over 1 to 6 months.<sup>30</sup>

Monitoring the patient after the completion of bracing treatment is crucial to ensure the success and effectiveness of the intervention. It's important to acknowledge to the family that the progression of the deformity after cessation of bracing can be due to a combination of unexpected growth remaining, as well as stress relaxation of the curve due to coronal imbalance, varying degrees of ligamentous laxity, as well as the impact of gravity on larger curve magnitudes. Thoracic curves less than 40 degrees at brace cessation should be monitored for at least 1.5 to 2 years after skeletal maturity, and curves greater than 40 degrees should be monitored for several years. Lumbar curves less than 30 degrees require at least 1.5 to 2 years of monitoring after skeletal maturity and cessation of bracing, and those greater than 30 degrees should be monitored for several years. If no progression occurs, intermittent monitoring is appropriate.

### **Patient Support Sources and Psychologically Informed Techniques**

Patients often encounter various barriers when it comes to consistent brace wear.<sup>3</sup> These can include physical discomfort, concern about the appearance of the brace, and feelings of helplessness and hopelessness when first introduced to the brace. Initial responses to the brace prescription can vary greatly among patients and their parents. For youth, responses range from acceptance to anger or disgust, even acute stress. Parents, on the other hand, may react with acceptance, shock, guilt, or anxiety. These feelings of helplessness can impede treatment, extend the duration of treatment, and reduce patient satisfaction.<sup>31</sup>

Addressing these feelings can be achieved using the CARE principles: Choices, Agenda, Resilience, and Emotional Support.<sup>31</sup> Clear communication of expectations can help manage anxieties while emphasizing the patient's strengths and reframing negative aspects can enhance resilience. Offering emotional support through acknowledging and normalizing common fears and reactions can also be highly beneficial.

Optimal outcomes can be achieved through effective screening and coordinated care.<sup>32</sup> Understanding patient-reported outcomes, such as the importance of peer relationships, can shed light on social dynamics that might influence brace use.<sup>33</sup> Potential barriers to brace use need to be investigated early, with a focus on behavioral, physiological, or other impediments expressed by the patient or parents. For example, sleep hygiene can often be neglected in evaluation of bracing barriers; however, it is an essential factor to consider.<sup>33</sup>

Coordinating care with the orthotist and providing adherence counseling has shown improvements in brace use and overall treatment success.<sup>32</sup> Situations warranting referral to behavioral health services include persistent novel apathy and disengagement, high levels of irritable behavior, strained parent-child dynamics, or significant body image concerns.

## Summary

Scoliosis bracing is the primary nonsurgical approach for idiopathic scoliosis, yet it introduces patients to a unique set of physical and psychological challenges. Successful treatment depends on appropriate indications and patient and family engagement on the importance of orthotic treatment. Consistent wear is facilitated by a team of orthotists, providers, and clinical staff committed to communication and tailoring treatment for potential discomfort and the emotional and psychological realm that patients and their parents navigate. Strategies for weaning and monitoring are similarly individualized to ensure long-term success.

## Disclaimer

No funding was received. The authors report no conflicts of interest related to this manuscript.

## References

- Kaelin AJ. Adolescent idiopathic scoliosis: indications for bracing and conservative treatments. *Ann Transl Med*. 2020;8(2):28-28.
- Motyer G, Dooley B, Kiely P, et al. Parents' information needs, treatment concerns, and psychological well-being when their child is diagnosed with adolescent idiopathic scoliosis: a systematic review. *Patient Educ Couns*. 2021;104(6):1347-1355.
- Donnelly MJ, Dolan LA, Grande L, et al. Patient and parent perspectives on treatment for adolescent idiopathic scoliosis. *Iowa Orthop J*. 2004;24:76-83.
- Weinstein SL, Dolan LA, Wright JG, et al. Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med*. 2013;369(16):1512-1521.
- Ohrt-Nissen S, Lastikka M, Andersen TB, et al. Conservative treatment of main thoracic adolescent idiopathic scoliosis: full-time or nighttime bracing? *J Orthop Surg (Hong Kong)*. 2019;27(2):2309499019860017.
- Yrjönen T, Ylikoski M, Schlénzka D, et al. Effectiveness of the Providence nighttime bracing in adolescent idiopathic scoliosis: a comparative study of 36 female patients. *Eur Spine J*. 2006;15(7):1139-1143.
- Simony A, Beuschau I, Quist L, et al. Providence nighttime bracing is effective in treatment for adolescent idiopathic scoliosis even in curves larger than 35°. *Eur Spine J*. 2019;28(9):2020-2024.
- O'Neill PJ, Karol LA, Shindle MK, et al. Decreased orthotic effectiveness in overweight patients with adolescent idiopathic scoliosis. *J Bone Joint Surg Am*. 2005;87(5):1069-1074.
- Katz DE, Herring JA, Browne RH, et al. Brace wear control of curve progression in adolescent idiopathic scoliosis. *J Bone Joint Surg Am*. 2010;92(6):1343-1352.
- Capek V, Westin O, Brisby H, et al. Providence nighttime brace is as effective as fulltime Boston brace for female patients with adolescent idiopathic scoliosis: a retrospective analysis of a randomized cohort. *N Am Spine Soc J*. 2022;12:100178.
- Sankar WN, Albrektson J, Lerman L, et al. Scoliosis in-brace curve correction and patient preference of CAD/CAM versus plaster molded TLSOs. *J Child Orthop*. 2007;1(6):345.
- Minsk MK, Venuti KD, Daumit GL, et al. Effectiveness of the Rigo Chêneau versus Boston-style orthoses for adolescent idiopathic scoliosis: a retrospective study. *Scoliosis Spinal Disord*. 2017;12(1).
- Katz DE, Stephens Richards B, Browne RH, et al. A comparison between the Boston brace and the Charleston bending brace in adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)*. 1997;22(12):1302-1312.
- Lee CS, Hwang CJ, Kim DJ, et al. Effectiveness of the Charleston nighttime bending brace in the treatment of adolescent idiopathic scoliosis. *J Pediatr Orthop*. 2012;32(4):368-372.
- Yen TC, Weinstein SL. Evaluation of predictors and outcomes of bracing with emphasis on the immediate effects of in-brace correction in adolescent idiopathic scoliosis. *Iowa Orthop J*. 2019;39(2):62.
- Landauer F, Wimmer C, Behensky H. Estimating the final outcome of brace treatment for idiopathic thoracic scoliosis at 6-month follow-up. *Pediatr Rehabil*. 2003;6(3-4):201-207.
- Emans JB, Kaelin A, Bancel P, et al. The Boston bracing system for idiopathic scoliosis. Follow-up results in 295 patients. *Spine (Phila Pa 1976)*. 1986;11(8):792-801.
- Linden GS, Emans JB, Karlin LI, et al. Early adherence to prescribed brace wear for adolescent idiopathic scoliosis is associated with future brace wear. *Spine (Phila Pa 1976)*. 2023;48(1):8-14.
- Zaborowska-Sapeta K, Giżewski T, Binkiewicz-Glińska A, et al. The Duration of the correction loss after removing cheneau brace in patients with adolescent idiopathic scoliosis. *Acta Orthop Traumatol Turc*. 2019;53(1):61.
- Karol LA, Virostek D, Felton K, et al. Effect of compliance counseling on brace use and success in patients with adolescent idiopathic scoliosis. *J Bone Joint Surg Am*. 2016;98(1):9-14.
- Benish BM, Smith KJ, Schwartz MH. Validation of a miniature thermochron for monitoring thoracolumbosacral orthosis wear time. *Spine (Phila Pa 1976)*. 2012;37(4):309-315.
- Bracing for Scoliosis I Scottish Rite for Children. <https://scottishriteforchildren.org/scoliosisbracing>. Accessed June 29, 2023.
- Shi B, Guo J, Mao S, et al. 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. *Spine Deform*. 2016;4(3):200-205.

24. Sanders JO, Khoury JG, Kishan S, et al. Predicting scoliosis progression from skeletal maturity: a simplified classification during adolescence. *J Bone Joint Surg Am.* 2008;90(3):540-553.
25. Welborn MC, Coghlan R, Sienko S, et al. Correlation of collagen X biomarker (CXM) with peak height velocity and radiographic measures of growth in idiopathic scoliosis. *Spine Deform.* 2021;9(3):645-653.
26. Thompson RM, Hubbard EW, Jo CH, et al. Brace success is related to curve type in patients with adolescent idiopathic scoliosis. *J Bone Joint Surg Am.* 2017;99(11):923-928.
27. Grothaus O, Molina D, Jacobs C, et al. Is it growth or natural history? Increasing spinal deformity after sanders stage 7 in females with AIS. *J Pediatr Orthop.* 2020;40(3):E176-E181.
28. Cheung JPY, Cheung PWH, Luk KDK. When should we wean bracing for adolescent idiopathic scoliosis? *Clin Orthop Relat Res.* 2019;477(9):2145.
29. Welborn MC. The impact of growth, cessation of growth and bracing on curve progression in idiopathic scoliosis: Part 1 Predicting Growth in Idiopathic Scoliosis; 2023.
30. Welborn MC. Cessation of Bracing in Idiopathic Scoliosis: Significant Equipose Remains. Charlotte, North Carolina: ICEOS; 2023.
31. Lerwick JL. Minimizing pediatric healthcare-induced anxiety and trauma. *World J Clin Pediatr.* 2016;5(2):143.
32. Tavernaro M, Pellegrini A, Tessadri F, et al. Team care to cure adolescents with braces (avoiding low quality of life, pain and bad compliance): a case-control retrospective study. 2011 SOSORT Award winner. *Scoliosis.* 2012;7(1):1-11.
33. Lertudomphonwanit T, Pengrung N, Kriwattanapong C, et al. Novel questionnaire to enhance brace wear adherence in patients with adolescent idiopathic scoliosis and the relationship of the quality of life. *Orthop Rev (Pavia).* 2021;13(1).