Advances in Scoliosis Brace Treatment for Adolescent Idiopathic Scoliosis

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Brace treatment of adolescent idiopathic scoliosis remains an excellent option for skeletally immature individuals with scoliosis curve magnitudes between 20° and 40°. Among options available for managing spinal disorders in children are observation, bracing, and surgery. The use of a spinal orthosis was first documented in the sixteenth century by Pare [1]. The lack of imaging techniques and the absence of an understanding of spinal growth led to unpredictable results with orthotic treatment until the second half of the twentieth century [2,3]. As the natural history of scoliosis and the effects of growth and development became better understood, the indications for bracing narrowed considerably. Bracing is significantly limited by such factors as neuromuscular disease, skin insensitivity, spasticity, osteoporosis, and congenital spinal disorders. Despite these limitations and with a more refined understanding of treatment indications, brace treatment continues to play an important role in the management of adolescent idiopathic scoliosis.

The goal of brace treatment is to prevent curve magnitude progression and to avoid the need for surgical spinal arthrodesis. Surgery is indicated for Cobb angles of greater than 45° to 50°. While other nonoperative treatments have been reported, none have shown efficacy in treating adolescent idiopathic scoliosis. Methods that have not shown success include electrical stimulation, exercise, and manipulation [4].

Brace treatment is used to prevent curve progression during growth. As such, orthotic treatment ends with skeletal maturity and is not useful in adults. The brace must allow continued growth of the spine while simultaneously preventing the spinal deformity from becoming worse. It should be assumed that scoliosis will not be cured by brace treatment. An acceptable “brace result” is for the deformity to be no worse at skeletal maturity than when brace treatment started.

During the past 20 years there have been many studies of brace treatment for adolescent idiopathic scoliosis. In addition to the Milwaukee brace, multiple variants of the thoracolumbar sacral orthosis (TLSO) brace have been described and reported on, each variant being named for the city of its origin [5–21]. Most of these studies support the effectiveness of bracing in preventing curve progression and the subsequent need for surgery [5,6,8–10,13,14,16–18,20,21]. Several studies have suggested that bracing may not be effective [11,12,15,19,21]. While these studies do not show brace efficacy, they have been helpful. Like electrical stimulation, ineffective bracing reveals the natural history of scoliosis, so these studies have helped to refine the natural history and indications for successful bracing.

Natural history

Few studies have attempted to document the natural history of progression in adolescent idiopathic scoliosis. To correctly judge the efficacy of any treatment, some knowledge of the natural history is necessary. Several studies have identified the population at risk of progression [22–27]. This includes those with curves of greater than 20° at the time of peak adolescent skeletal growth, classically reported as Risser 0 or 1 maturity and premenarchal to 1 year postmenarchal in females.
[25–27]. For this group at risk, Rogala and colleagues [24] found progression among 79% of immature patients with curves between 20° and 30°, Bunnell [26] found progression of 5° or more in 68% of those with a Risser sign of 0. Lonstein and Carlson [27] reported the same 68% progression rate of greater than 5° for curves of 20° to 29° in those with a Risser sign of 0 or 1. Nachemson and colleagues [18] performed a randomized, multicenter study comparing brace treatment to observation in 10- to 15-year-old females with thoracic curves. The investigators documented progression of at least 6° in 66% of the observation group. The best available data show, therefore, that 66% to 79% of immature females with curves of 20° to 35° will progress more than 5° if observed. Progression has been shown to be greater for curves of larger magnitude and less probable for curves smaller than 20°, Risser 3, or greater maturity, and for females more than 1 year postmenarchal [27].

It is not known what percentage of the at-risk population would progress to surgery if left untreated. The ultimate goal of brace treatment is not so much to prevent 5° of progression as it is to prevent the need for surgery. Virtually all studies, including those noted above, use curve progression of more than 5°, rather than surgical rates, as an endpoint. Unfortunately, none of these natural history studies followed untreated patients to surgery or to curve magnitudes of more than 45°, when surgery would ordinarily be recommended. It can be reasonably assumed, however, that this information can be gleaned from well-done brace studies with poorly compliant patients or ineffective braces. Such studies suggest that 60% to 79% of immature females with curves larger than 25° may progress to surgery [28]. It can also be assumed that results with lower progression and surgical rates than these indicate a beneficial treatment effect and demonstrate the efficacy of brace treatment. While a randomized, blinded study would be helpful, the ethical and logistical difficulty in performing such a study may be insurmountable.

**indications for brace treatment**

The results of bracing in early studies were inconsistent because many individuals now known to be at low risk for progression were included [29]. These included patients with skeletal maturity at brace initiation and small curve magnitudes that were not likely to progress. Some studies also included individuals with large curve magnitudes and nonidiopathic curves, which are not likely to respond to brace treatment.

As the natural history of scoliosis becomes better understood, the identification of those patients at risk of progression becomes more accurate [27,30–32]. Patients at greatest risk of progression, and therefore those most likely to benefit from bracing, include growing children (Risser 0–2 and, if female, either premenarchal or less than 1 year postmenarchal) with primary curve magnitudes of 25° to 40°. Patients with curve magnitudes of between 20° and 25° with documented progression should also be considered for brace treatment [17,29]. Initiation of brace treatment involves fitting the orthosis, obtaining a standing posterior-anterior radiograph with the patient wearing the brace, and increasing the number of hours in the brace over the course of 1 to 2 weeks. It is important that the curve magnitude on the first in-brace radiograph be less than 50% of the original, prebrace curve magnitude [8]. Time-in-brace is increased 1 to 4 hours each day until full-time brace wear is achieved. Full-time wear is prescribed initially for all patients, except those using the Charleston and Providence nighttime bending braces. Patients are encouraged to be active in sports and allowed to be out of the brace if the sport cannot be performed in the brace.

Decreased orthotic effectiveness in overweight patients has been demonstrated and may be a contraindication to bracing. O’Neill and colleagues [33] showed that individuals with body mass indices greater than the 85th percentile were three times more likely to fail brace treatment than those who were not overweight.

Brace treatment is continued until growth is completed. This is determined by a variety of indicators: typically unchanged height measurements on two successive dates 6 months apart, 18 to 24 months postmenarchal, Risser 4 status, or skeletal maturity on bone-age determination.

**Bracing results**

The use of a brace for scoliosis is complex, in part because success depends on more than just the skill of the surgeon. Quite the contrary, bracing success depends also on the dedication of the patient and family, the skill of the orthotist, the efficacy of the brace, growth, compliance with wear, regular follow-up evaluations, and an environment that encourages the brace to be worn for
what may be a prolonged period. Given this multitude of factors affecting success, it is not at all surprising that the published results of bracing span a continuum ranging from seemingly ineffective to excellent.

In general, most brace studies show a similar trend of curve magnitude improvement in the brace, followed by slow loss of correction until the end of brace treatment, when the curve is similar to that at the start of bracing [5,25,34,35]. Several studies have also identified a trend of decreasing brace efficacy with increasing curve size [8,17,28].

In most reported series, full-time Milwaukee brace treatment produces better results than natural history studies. Carr and Noonan reported failure rates requiring surgery in 39% and 42%, respectively [5,19]. While Noonan questioned the efficacy of brace treatment, surgical rates among his patients were still considerably better than natural history studies and several recent brace studies in the literature.

In one of the most complete brace studies to date, Lonstein and Winter [17] reported a 40% rate of curve progression of more than 5° and a surgical rate of 22% in a study of Risser 0-to-1 Milwaukee brace patients. The majority of patients had prebrace curves between 20° and 39°. The investigators noted a significant difference between the reported radiographic failure rate of 40% and their own natural history study predicting 68% progression. Others have reported on the use of the Milwaukee brace, but the studies are limited by incomplete follow-up, small numbers, the inclusion of nonidiopathic scoliosis and patients of ages now known to not benefit from bracing [34–36]. Patient self-image issues, non-compliance, and dissatisfaction with the cosmetic appearance of the neck ring ultimately led to the development of underarm braces [37,38].

Underarm braces include a variety of devices collectively known as TLSOs. In general, the results of TLSO treatment are similar to the Milwaukee brace studies. Several series have evaluated the results of such devices. Bassett and colleagues [39] studied a mixed population of juvenile and adolescents with curves of 20° to 39° treated with the Wilmington TLSO and found 30% progressed 5° or more. Emans and colleagues [8] reported 295 patients, 4 to 18 years of age, treated with a Boston brace. Only 12% of patients required surgery, although the failure rate was greater for curves greater than 40° when bracing was started. Emans also noted less favorable results in noncompliant patients. More recently, Spoonamore and colleagues [21] reported the results of a study using the Rosenberger brace, a front-opening TLSO. The investigators found 56% of their patients progressed more than 5° and 31% required surgery or met surgical criteria. While the investigators acknowledge that the Rosenberger brace is effective in preventing radiographic and clinical failure in some, they noted failure in others. Compliance with brace treatment was not reported. The investigators noted this as a possible explanation for the unsatisfactory results. Compared with nearly identical brace studies showing progression and surgical rates of 80%, however, the Rosenberger brace appears to produce good results. The reasons for the disparity among bracing results are unknown, but different rates of brace compliance are likely the major culprit.

Driven largely by the desire of many patients to avoid daytime and school-time bracing, nighttime-only braces have been developed that require only 8 to 10 hours of wear. The Charleston and Providence braces use bending or aggressive molding to apply corrective forces to the spine [6,20]. Several studies have reported the efficacy of these two novel braces. D’Amato and colleagues [6] found that only 21% of patients progressed using the Providence brace, provided the curve apex was caudal to T8. Katz and colleagues [16] compared the Charleston to the Boston brace. Both braces were more effective with smaller prebrace curves of 25° to 35° than with larger curves. More than 5° of progression was noted in 29% and 47% of the Boston and Charleston groups respectively. With larger prebrace curves of 36° to 45°, both braces did less well. The investigators found greater than 5° of progression in 43% of the Boston group and 83% of the Charleston patients. The investigators recommend the Boston brace for large curve magnitudes and those with thoracic curves [16]. Again recognizing that progression of 5° may be an arbitrary measure of bracing failure and that radiographic failure may not indicate clinical failure, Gepstein and colleagues [10] found no difference in surgical rates between the Charleston brace (11%) and a TLSO (13%). Surgical rates for both braces, however, are well below that expected from natural history studies.

The only published prospective controlled brace study was performed by Nachemson and Peterson [18]. The investigators compared TLSO bracing to observation in a group of 10- to 15-year-old (skeletal age) girls with idiopathic scoliosis and single curves between 25° and 35°. Only
36% of the braced patients showed progression of more than 5°, compared with 66% in those observed. Using survival analysis, the TLSO was found to be statistically effective in altering the natural history \(P < .0001\). While the study is routinely cited as clearly and dramatically demonstrating the effectiveness of bracing, it has been criticized for not being randomized or blinded and for the inclusion of only single thoracic curves of limited size, up to 35° [21].

Unfortunately, there are many problems with most bracing studies in the literature. Juveniles, adolescents, and mature individuals are included. Different curve types, magnitudes, and lengths of follow-up are reported. Nonidiopathic scoliosis is occasionally included. Even the landmark study by Nachemson has been criticized for including thoracic curves and not including curves of greater than 35°. To assess the effectiveness of each orthosis and to compare one study to others requires consistent study parameters. The Scoliosis Research Society (SRS) has recently published a stringent, uniform set of inclusion criteria for bracing studies [29]. The standards for adolescent idiopathic scoliosis brace studies include an age of 10 years and older, Risser 0 to 2, primary curve size of 25° to 40°, no prior treatment, and, if female, either premenarchal or less than 1 year postmenarchal. The SRS also defines progression and sets standards for reporting curve patterns, curve rotation, compliance, and follow-up. It is to be hoped that additional studies using the SRS criteria will allow for an objective comparison of future brace studies.

The first and only published study using the recent, strict SRS criteria is a comparison of the TLSO to the Providence nighttime orthosis at a single institution [28]. The poor results for both braces raise interesting questions. In the TLSO group, 85% showed progression of more than 5° and 79% of braced patients required surgery. For the Providence brace, 69% progressed and 60% required surgery. The results are so similar to natural history studies that it can be argued the brace programs cited are ineffective and that the study is a natural history study of adolescent idiopathic scoliosis. Similar assumptions were made for patients treated with electrical stimulation in the past, leading those so treated to be included in “observation” rather than treatment populations [18,27,40,41]. The investigators speculate that the poor results might be due to demographics, genetics, referral patterns, or compliance, but the reasons remain unknown. The extreme variation in reported brace success rates suggests that some braces and brace programs are very good and that others have no effect on the natural history of adolescent idiopathic scoliosis. Further study is necessary to determine why one center reports a surgical rate of 79% and another 22%.

Bracing in males

Brace treatment in boys may not be as successful as in girls. For boys willing to wear an orthosis, however, brace treatment can be successful. Most studies of scoliosis orthosis treatment include both males and females, but the number of males is small, statistical power is lacking, and the results are difficult to interpret. Karol [15] reported that brace treatment in males was ineffective largely because of poor compliance. A recent study confirmed the decreased compliance in males when compared with females but found bracing useful in both genders, with progression of more than 5° in 31% of the compliant males and 21% of the compliant females [42]. Both results are two to three times better than expected from natural history and other brace studies.

Compliance

As with other medical treatments, success depends upon treatment actually being performed. In the case of bracing for adolescent idiopathic scoliosis, it is often incorrectly assumed that brace patients are compliant with their treatment. In fact, compliance with bracing may run the range from absolute nonuse to full-time bracing. The experience of wearing a brace full-time is substantially different, and more obvious to others, than that of taking daily medication or adhering to a diet. Unlike other orthopedic surgical treatments, such as surgery, braces are accessible and easily removed by the patient. Poor compliance is not surprising given the negative effects of bracing on self-image [37]. Those who do not wear their braces should be expected to have results similar to natural history studies. Compliant patients are likely to show the best results and the most significant difference when compared with natural history. Given this reality, compliance is a major determinant of bracing success. Compliance may explain the difference between brace treatment results in males and those in females [15,42].
Compliance, the ability of the patient to wear a brace for the prescribed time, has a dramatic effect on brace treatment effectiveness. Emans and colleagues [8] noted poor results for noncompliant patients in his Boston brace study. Wiley and colleagues [43] also found that brace wear of more than 18 hours per day led to less progression than if the brace was worn 12 hours per day or less. In contrast, Allington and Bowen [44] found no difference between full-time and part-time bracing using the Wilmington brace.

Until recently, compliance was difficult to measure and often relied upon patient or parent self-reporting. With the availability of pressure transducers and temperature sensor loggers, reliable brace wear records may be recorded. Using instrumented braces, several studies have determined that brace wear varies from 8% to 90% of the prescribed time, averaging only 65% to 75% of the time prescribed [45,46]. Patients and parents over-reported their hours of brace wear by 150%. Additionally, there was an inverse correlation between age and compliance. Ten-year-olds wore their braces 84% of the prescribed time compared with only 77% for 12-year-old patients and 60% for 14-year old patients.

Rahman and colleagues [47] reported on the association between brace compliance and outcomes using a temperature sensor and data logger in Wilmington TLSO braces. The investigators found striking differences between the compliant and non-compliant patients. Among those with radiographic progression more than 5°, patients wore their braces only 62% of the time prescribed. For those who did not progress, compliance was better, logging 85% of the prescribed time (P=.004). Additionally, in those who wore their brace more than 90% of the time prescribed, progression of more than 5° was seen in only 11%, better than any other group in the literature. The results indicate that those who are compliant with brace treatment have significantly more favorable outcomes.

Factors affecting brace compliance are not well understood and have not been adequately studied. The role of the treating physician, orthotist, and parents require additional attention. Finally, while the SRS has recommended that all noncompliant brace patients be included in further brace studies, it will be important to distinguish between brace failure, and failure of the patient or brace program to use the brace. There is a tendency to label bracing as “ineffective” when noncompliant patients raise the average radiographic progression rates in some studies. Similar standards are not routinely applied elsewhere in medicine or in orthopedics. As an example, patients who refuse antibiotics for the treatment of osteomyelitis are not usually included in studies of antibiotic efficacy, nor are they cited as “failures” of drug treatment. While it is useful to know how often brace patients wear their orthosis, the question that physicians, patients, and parents want to know is, “If this brace is worn, what will the back look like and can surgery be avoided?”

Summary

Brace treatment is the treatment of choice for some, but not all, patients with adolescent idiopathic scoliosis. Indications for bracing include curve magnitudes of 20° to 40° in growing individuals with Risser 0 to 2 skeletal maturation and, if female, either premenarchal or less-than-1-year postmenarchal status. Natural history and brace studies suggest that 68% to 79% of these individuals show progression of their scoliosis and similar numbers require surgery if untreated. In contrast, those that are compliant with brace treatment show radiographic progression of more than 5° in just 11% and rarely require surgery. The importance of wearing the brace—so-called “compliance”—cannot be overstated. Poor compliance is the most likely source of many poor bracing results but it is difficult to measure as patients and their parents routinely report more brace time than they actually achieve.

Bracing is less effective in obese patients and in those with curve magnitudes greater than 40°. Bracing is not effective in skeletally mature individuals or in those with nonidiopathic scoliosis. Good results have been reported with Milwaukee, TLSO, and bending braces.

Successful brace treatment prevents radiographic progression of scoliosis and avoids the need for spine surgery. In general, if brace treatment is not effective for a patient or group of patients, one or more of the following problems is likely present:

- The brace does not fit or is not effective.
- The patient is not wearing the brace.
- The time-in-brace is insufficient.
- The diagnosis is incorrect.

It becomes the role of the treating physician and orthotic specialist to sort these issues out and to make appropriate changes.

Brace treatment is a team activity that requires the active, willing participation of the prescribing physician, orthotist, patient, family, and friends.
If the physician does not prescribe and follow up, if the orthotist does not properly fit the brace, if the patient does not wear the brace, and if the family and friends are not supportive, the treatment will not be effective. The literature discussion about "bracing efficacy" assigns far too much credit or blame to the orthosis and not nearly enough responsibility to those involved with the prescribing, manufacturing, and, most importantly, the wearing of the brace.

References


