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Early Brace Treatment

The New Standard for Adolescent Idiopathic Scoliosis?

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Background: No direct comparison exists between early bracing of adolescent idiopathic scoliosis (AIS) at curve magnitudes of 15° to 24° vs. observation until the Scoliosis Research Society–recommended criteria of ≥25°. We compared curve improvement and progression between early bracing vs. standard treatment with bracing starting at ≥25°.

Methods: A retrospective review was performed among patients Risser 0 to 1 with AIS curves 15° to 24° at initial visit who were followed until skeletal maturity or surgery. Patients prescribed rigid thoracolumbar sacral orthoses (TLSO) for curves 15° to 24° (early group) were compared with a control group observed until TLSO prescription at ≥25° (standard group). A subanalysis of open triradiate cartilage status (TRC) was performed. At final follow-up, patients were categorized into curve improvement ≥6°, stable (−5° to +5°), progression ≥6°, and progression to surgical magnitude (≥45°).

Results: Among 414 patients (207 early, 207 standard) matched by skeletal maturity, the early group had greater curve improvement (19% vs. 1%, $p < 0.001$, odds ratio 16.3), greater stability (50% vs. 37%, $p = 0.007$), less progression ≥6° (31% vs. 62%, $p < 0.001$), and less progression to a surgical magnitude (6% vs. 14%, $p = 0.014$) than the standard group. Patients with open TRC highlighted these differences, with the early group demonstrating greater curve improvement (18% vs. 2%, $p < 0.01$), greater stability (42% vs. 21%, $p < 0.001$), less progression ≥6° (39% vs. 77%, $p < 0.001$), and less progression to a surgical magnitude (9% vs. 20%, $p = 0.018$) than the standard group, especially those with thoracic curves 20° to 24° at initial visit (13% vs. 43%, $p = 0.001$). The number needed to treat was 3.3.

Conclusion: Early brace treatment of AIS curves 15° to 24° is superior to observation until brace initiation at 25°, with a 16-fold increased likelihood of improving curves and reducing progression to a surgical threshold by >50%.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Introduction

The gold standard treatment for adolescent idiopathic scoliosis (AIS) in skeletally immature children is thoracolumbar spinal orthosis (TLSO) wear. The Scoliosis Research Society (SRS) recommends bracing AIS curves between 25° and 40° in patients Risser 0 to 2 and female patients <1 year postmenarchal[1]. While these criteria standardize research reporting, they limit the evaluation of bracing outcomes outside these parameters. Notably, skeletally immature children with curves smaller than 25° remain at high risk of progression[2,3]. Regardless of curve magnitude, children with open triradiate cartilage (TRC) are particularly vulnerable to progressing to surgical magnitudes[4], suggesting brace initiation at lower curve magnitudes might be beneficial.

Initiating brace wear before 25° is becoming more prevalent[5-7]. Institutions participating in the BrAIST trial prescribed TLSO's starting at 20° and found that bracing halted curve progression to a surgical magnitude more so than observation[7]. This institution previously found that bracing curves <25° not only halted curve progression, but also led to curve improvement in 23% of children[5]. Still, evidence supporting early bracing as a standard AIS treatment remains limited. No direct comparison exists of bracing scoliotic curves 15° to 24° (early group) to observation until 25° at which point bracing is initiated (standard group). Opponents of early bracing argue that patients may be overtreated, as some curves may never reach 25° or progress meaningfully. Introducing an untreated control group observed until

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the SRS standardized brace treatment criteria at 25° addresses concerns regarding early brace overtreatment[8,9].

This study compared curve outcomes between early vs. standard brace treatment in children Risser 0 to 1 with AIS presenting with curves 15° to 24°. We hypothesized that early bracing would have greater curve improvement and less progression to a surgical magnitude than observation until standard bracing criteria are met.

Material and Methods

This retrospective cohort study was approved by the hospital and university institutional review boards. No funding was obtained. Patients were identified from 2 retrospective datasets from the same pediatric orthopaedic tertiary care institution and were followed until skeletal maturity or progression to ≥45°. The historical "standard brace" dataset (1990-2005) included all children with AIS Risser 0 to 1 with curves 15° to 24° at initial visit who were braced once their curve reached 25°. Race and ethnicity were not included. The "early brace" dataset (2015-2019) included all children with AIS who were braced for curves measuring 15° to 24°. Children in this dataset were only included if they were Risser 0 to 1 at brace prescription, had AIS, and were followed until skeletal maturity or surgical magnitude to match the inclusion criteria of the "standard brace" dataset. Exclusion criteria included initial Risser >1, non-AIS diagnosis such as juvenile idiopathic scoliosis (JIS), and lost to follow-up before skeletal maturity.

Radiographic data included Cobb angle, primary curve location, Risser stage, and TRC status at initial visit, before bracing or planned surgery, and/or skeletal maturity. Clinical data included biologic sex, age, menarchal status, body mass index, and growth. Measurements were obtained from the medical record. Less than 1% of the data was missing.

Standard institutional practice since the 1990s entails custom full-time bracing for thoracic curves incorporating detorsion and 3 point, 3-dimensional, monocot ventral or dorsal closure and prescribed for 16 to 23 hours/day, and nighttime bracing for thoracolumbar/lumbar curves for ≥8 hours/night. The primary curve is defined by the location of the largest Cobb angle. Patients are followed every 6 to 12 months until skeletal maturity (≥Risser 4). Outcomes were measured from initial visit at brace prescription for the early group and at presentation for the standard brace group until the final visit of skeletal maturity or surgical threshold for both groups. Primary outcomes were selected for clinical significance: Curve improvement (continuous) and progression ≥6° (categorical) accounted for measurement error, and progression to ≥45° (categorical) indicates a surgical threshold[1]. Stable curves remained within 5°. A secondary outcome, progression to 30° (categorical), was used due to concerns of continued progression and degenerative changes in adulthood[10-13].

Six hundred ninety-three patients (283 early, 410 standard) were reviewed. Since the early brace dataset had broader inclusion criteria than the standard brace dataset, children Risser 2, follow-up before skeletal maturity, and JIS entailing bracing before age 10 were excluded (Fig. 1). Preliminary analysis revealed that the early group had a greater percentage of open TRC and therefore a higher progression risk, so the larger standard group was propensity score–matched at a 1:1 ratio with the smaller early group by TRC status and Risser sign. Patients were compared between groups by open TRC status and further subanalyzed by initial curve magnitude 20° to 24° and thoracic curve location to evaluate radiographic outcomes by these specific progression risk factors. Normality of continuous variables was assessed with the Shapiro-Wilk test, followed by *T*-tests or Mann-Whitney tests for between-group comparisons as appropriate. Categorical variables were compared using χ^2 or Fisher exact tests. Logistic regression analysis was performed to determine odds ratios with 95% confidence intervals (CIs). The number needed to treat (NNT) for early bracing was derived from the absolute risk reduction. Analyses were performed using R (4.2.3) and SAS (9.4).

Results

After matching, 414 patients (207 early, 207 standard) were included. Patients averaged 3.1 years of follow-up from

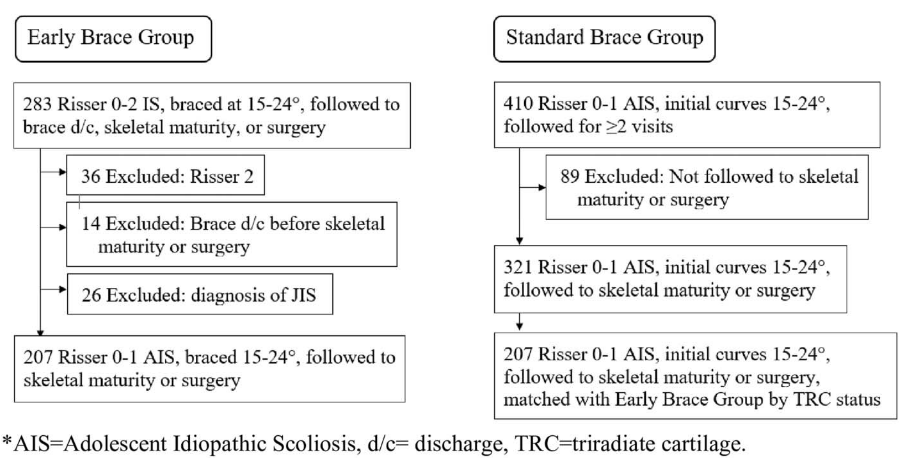

Fig. 1

Participant flow of Early Brace Group and Standard Brace Group.

initial to final visit. At initial visit, 85% were Risser 0, and 63% had open TRC among both groups. The early group had larger curves (22° vs. 19°, p < 0.001, Table I), while age, sex, curve location, and menarchal status were similar. In the standard group, 37% eventually initiated bracing at ≥25°. At brace prescription, the standard group had larger curves (30° vs. 22°, p < 0.001) and a smaller percentage of open TRC (45% vs. 63%, p < 0.001) than the early group.

At final visit, the early group had similar growth, but smaller curves (25° vs. 29°, p < 0.001), and less curve progression (3° vs. 10°, p < 0.001), exceeding the 6° measurement error. The early group demonstrated an increased rate of improvement ≥6° from brace initiation (19% vs. 1%, p < 0.001), more stable curves remaining within 5°, reduced rate of curve progression ≥6°, reduced rate of progression to 30°, and reduced rate of progression to a surgical magnitude (6% vs. 14%, p = 0.014) than the standard group (Table II). The early group averaged 12.6 ± 6.2 hours of full-time brace wear and 7.0 ± 2.8 hours of nighttime brace wear.

A subanalysis of patients with open TRC revealed similar findings (Table III). The early group demonstrated greater curve improvement ≥6° (18% vs. 2%, p < 0.001), greater stability, less curve progression ≥6°, and progression to a surgical magnitude (9% vs. 20%, p = 0.018). A further subanalysis of those with open TRC and thoracic curves 20° to 24° at brace initiation revealed even more striking between-group differences: The early group progressed on average 6°, with a final curve magnitude averaging 28°; in contrast, the standard group progressed on average 20°, with a final curve magnitude averaging 42°. No curves in the standard group improved, whereas 11% of curves in the early group improved (p < 0.001). The rate of progression to a surgical magnitude in the early group was 13% compared with 43% in the standard group (p = 0.001, Table III). Those with open TRC and thoracolumbar curves 20° to 24° at brace initiation averaged 5° curve progression in the early group (n = 55) vs. 14° in the standard group (n = 12, p < 0.001).

Logistic regression analysis showed the early group had a 16-fold increased likelihood of curve improvement ≥6° (odds ratio [OR] 16.29, 95% CI 5.78-68.16), a 70% decreased risk of curve progression ≥6° (OR 0.28, 95% CI 0.18-0.41), and a >50% decreased risk of progression to a surgical magnitude (OR 0.43, 95% CI 0.21-0.84, Table II). Those in the early group with open TRC had a similar decreased risk of curve progression to a surgical magnitude (OR 0.42, Table III). Patients in the early group with open TRC and thoracic curves 20° to 24° at brace initiation had an even more pronounced decreased risk of curve progression to a surgical magnitude (OR 0.20, Table III).

The NNT for early bracing compared with standard bracing (control) to prevent curve progression ≥6° is 3.1 (1/[62%-30%]). The NNT for early bracing among open TRC and thoracic curves 20° to 24° is 3.3 (1/[43%-13%]).

Discussion

This study compared radiographic outcomes between early and standard bracing in children with AIS Risser 0 to 1 at initial visit. Bracing at 15° to 24° produced higher rates of curve improvement (19% vs. 1%) and reduced rates of progression to a surgical magnitude (6% vs. 14%) than observation until the standard bracing criteria. Among the highest-risk subgroup (open TRC thoracic curves 20°-24°), early bracing demonstrated even greater benefit, with far fewer progressing to a surgical magnitude (13% vs. 43%), strengthening the notion that standard brace treatment in this demographic is too late, and that "early brace" treatment is the preferred approach.

While SRS bracing criteria include reporting progression ≥6° and progression to ≥45°, they do not include improvement

TABLE I Early Brace vs. Standard Brace Patient and Radiographic Characteristics

	Early brace (n = 207)	Standard brace (n = 207)	p
Biologic sex			
Female	81%	79%	0.713
Male	19%	21%	
Initial age (yrs)	12.4 ± 1.2	12.4 ± 1.2	0.548
Initial primary curve			
Thoracic	43%	52%	0.062
Lumbar/thoracolumbar	57%	48%	
Initial menarchal status			
Pre	76%	78%	0.807
Post	23%	22%	
Initial BMI (kg/m^2)	18.2 ± 2.5	18.5 ± 3.6	0.957
Initial curve magnitude (°)	22 ± 2	19 ± 3	**<0.001**

BMI = body mass index, and initial = at brace prescription for the early group and at presentation for the standard brace group. Bold indicates significance.

TABLE II Early Brace vs. Standard Brace Outcomes

	Early brace (n = 207)	Standard brace (n = 207)	p	OR (95% CI)
Growth (cm)	10.2 ± 5.9	13.7 ± 19.1	0.052	NA
Curve, brace initiation (°)	22 ± 2	30 ± 4 (n = 76)	**<0.001**	NA
Final curve magnitude (°)	25 ± 11	29 ± 12	**<0.001**	NA
Total curve progression (°)	3 ± 11	10 ± 11	**<0.001**	NA
Curve improved ≥6°	19%	1%	**<0.001**	16.29 (5.78-68.16)
Curve stable (−5° to 5°)	49%	37%	**0.007**	1.71 (1.16-2.53)
Curve progressed ≥6°	30%	62%	**<0.001**	0.28 (0.18-0.41)
Final curve ≥30°	26%	43%	**<0.001**	0.46 (0.30-0.69)
Final curve ≥45°	6%	14%	**0.014**	0.43 (0.21-0.84)

CI = confidence interval, NA = not applicable, and OR = odds ratio. Bold indicates significance.

≥6° as an outcome. Therefore, the literature typically omits curve improvement[4,6,7,14] although it can occur[15,16]. Only one US study from 1986 of braced patients Risser 0 to 4 with curves 20° to 59° included improvement as an outcome[17]. The remaining studies originate from outside of the United States[16,18-22], potentially reflecting lower brace treatment expectations from the United States than other countries[23]. Given the meaningful potential for curve improvement, we recommend that future studies include this measure. Shifting expectations from stabilization to possible improvement offers more informed, family-centered decision-making.

The bracing literature more often evaluates progression to surgical thresholds of 45° or 50°[4,7,8,14]. Among BrAIST braced patients Risser 0 to 2 with curves 20° to 40°, 28% progressed to a surgical magnitude; though TRC status and specific curve range data were not provided[7,13]. Another study found that 63% of patients with open TRC progressed to surgery, including 33% of those braced at only 25° to 29°[4]. In our standard group, 26% of patients with open TRC with curves 20° to 24° progressed to a surgical magnitude, compared with only 10% in the early group, confirming open TRC and curves 20° and 24° remain high-risk and are ideal candidates for early bracing.

Even if curves do not progress to surgery, many families are still concerned about progression ≥ 6°. Lonstein and Carlson (1984) found that 68% of curves 20° to 29° progressed ≥5° in patients Risser 0 to 1, similar to our standard group progression ≥6° rate (60%), but still twice that of our early group (30%)[3]. Knowing these risks supports individualized brace counseling. Keeping curves <30° may prevent degenerative changes, back pain, and continued progression throughout adulthood[8,12]. A recent systematic review and meta-analysis found an alarming incidence of pain and curve progression in curves 30° to 45° after 20 years of follow-up[11]. Our standard group's final curve magnitude of 42° among open TRC thoracic curves initially 20° to 24° highlights this subgroup's substantial lifetime risk.

TABLE III Early Brace vs. Standard Brace Outcomes by Open Triradiate Cartilage Status and by Open TRC Thoracic Curves 20° to 24°

	Open TRC				Open TRC Thoracic curves 20°-24°			
	Early brace (n = 130)	Standard brace (n = 128)	p	OR (95% CI)	Early brace (n = 54)	Standard brace (n = 35)	p	OR (95% CI)
Final curve magnitude (°)	26 ± 13	33 ± 12	**<0.001**	NA	28 ± 13	42 ± 12	**<0.001**	NA
Total curve progression (°)	5 ± 13	14 ± 11	**<0.001**	NA	6 ± 13	20 ± 12	**<0.001**	NA
Curve improved ≥6°	18%	2%	**<0.001**	14.26 (4.11-90.06)	11%	0%	**<0.001**	NA
Curve stable (−5° to 5°)	42%	21%	**<0.001**	2.58 (1.60-4.80)	46%	11%	**<0.001**	6.68 (2.26-24.78)
Curve progressed ≥6°	39%	77%	**<0.001**	0.19 (0.11-0.32)	43%	89%	**<0.001**	0.10 (0.03-0.28)
Final curve ≥30°	33%	60%	**<0.001**	3.06 (1.85-5.11)	39%	83%	**<0.001**	7.60 (2.84-23.14)
Final curve ≥45°	9%	20%	**0.018**	0.42 (0.19-0.86)	13%	43%	**0.001**	0.20 (0.07-0.54)

CI = confidence interval, NA = not applicable, OR = odds ratio, and TRC = triradiate cartilage. Bold indicates significance.

Both groups were comparable by key progression risk factors including TRC status, Risser stage, curve location, and initial curve magnitude (15°-24°). Although the early group had curves 3° larger than the standard group due to an increased likelihood of brace initiation as curves increase, this difference was within measurement error. While the standard brace group dataset did not include whether a nighttime brace or full-time brace was prescribed, we do not believe that brace type affected outcomes. A recent study from this institution previously found no significant differences in outcomes between nighttime bracing and full-time bracing for Risser 0 to 2 curves 15° to 24°[5]. Similarly, a previous study from this institution from the 1990s also found no significant differences between nighttime bracing and full-time bracing for Risser 0 to 1 curves 25° to 35°[24]. We have consistently prescribed full-time rigid TLSOs for thoracic curves and overcorrective night-time TLSOs for thoracolumbar/lumbar curves. Others have corroborated favorable outcomes in nighttime bracing compared with full-time bracing for Risser 0 to 2 with curves 25° to 40°[25].

The first limitation is that this single-institution retrospective review may not be generalizable to the entire AIS population, underscoring the need for prospective multicenter studies, including younger patients. Second, JIS was excluded to maintain cohort homogeneity, though prior work shows infantile and JIS curves can also improve from early bracing[26-28]. Third, time-dependent confounders may have influenced group differences, since we used a historical control group. Brace counseling using temperature sensors was initiated only for the early brace group. However, while brace counseling reduced curve progression ≥6° in larger curves than our study (33° vs. 20°), counseling did not reduce curve progression to a surgical magnitude[14]. Bracing techniques have evolved, such as implementing CAD/CAM technology for brace design and fabrication. Yet, we continue to use the same TLSO measurement, fabrication and classification according to rigidity, primary corrective plane and action, and construction[29]. The fabrication and fitting of the orthoses have been standardized at our institution and remain similar between groups. In addition, one brace design has not been found to be superior[30]. Fourth, Sanders staging and objective adherence data were unavailable, since the historical group was treated before these parameters. Fifth, patient-reported outcomes were not collected. Finally, patients had variable follow-up durations for outcome evaluation.

In conclusion, early brace treatment of AIS curves 15° to 24° is superior to observation until 25°, with a 16-fold increased likelihood of curve improvement in children with Risser 0 and 1 when matched with a standard brace group. Progression of curves to a surgical magnitude was reduced by more than half. Early brace treatment is recommended as the new standard of care for Risser 0 to 1 AIS.

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Ethics Approval

IRB approval was received from Scottish Rite for Children and from University of Texas Southwestern. ■

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