Journal of Pediatric Orthopaedics
17:703-707 © 1997 Lippincott-Raven Publishers, Philadelphia

Nighttime Bracing for Adolescent Idiopathic Scoliosis with the Charleston Bending Brace: Long-Term Follow-up

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Study conducted at Orlando Regional Healthcare Systems, Orlando, Florida, U.S.A.

Summary: We report long-term experience with the Charleston Bending Brace for treatment of adolescent idiopathic scoliosis. This brace holds the patient in maximal side-bending correction and is worn at nighttime only. Patients included in this prospective multicenter study met all of the following criteria: skeletal immaturity (Risser 0, 1, or 2), curvature >25° before bracing, no prior treatment, and >1-year follow-up since completion of bracing (skeletal maturity or progression to surgery). All curves were monitored and reported. There were 149 structural curves in 98 patients. Sixty-five (66%) patients showed improvement or <5° change in curvature. Seventeen (17%) patients progressed to the point of requiring surgery for their scoliosis. Based on these long-term results and improvement of the natural history of adolescent idiopathic scoliosis, continued use of the Charleston Bending Brace is justified. **Key Words:** Adolescent—Charleston Bending Brace—Idiopathic—Part-time bracing—Scoliosis—Treatment.

We initially reported our preliminary experience with the Charleston Bending Brace for treatment of adolescent idiopathic scoliosis in 1990 (16). This was a prospective multicenter study initiated in 1984. The preliminary data on 139 patients suggested the Charleston Bending Brace was comparable to the Milwaukee (3,6,7,11) and Boston (8,10) braces with success rates ~83%. Advantages included a very high in-brace correction (73%) for all curves treated. The psychosocial advantages of nighttime bracing were readily apparent to physicians, parents, and patients. Initial concerns included progression of some compensatory curves and long-term effectiveness.

Federico and Renshaw (9) also reported their early experience with the Charleston Bending Brace in patients with adolescent idiopathic scoliosis. They had 32 patients with single curves and noted a success rate of ~85%. They too noted the advantages of nighttime bracing and had a high compliance rate.

With these initially promising results, we continued to use the Charleston Bending Brace for all our patients with adolescent idiopathic scoliosis; however, for the purposes of this study, we elected to report only the long-term follow-up on those patients who were in our preliminary study.

MATERIALS AND METHODS

To be included in this study, all patients had to be in our preliminary study. This study group was initially seen and treated for adolescent idiopathic scoliosis between 1984 and 1988 and included 139 patients. At that time, all patients had to meet the following criteria: idiopathic scoliosis, skeletal immaturity (Risser 0, 1, or 2), a curvature of 25–49° before bracing, aged 10 years or older when the brace was applied, and no prior treatment. All types of idiopathic scoliosis were treated, including double curves, hypokyphotic patients, and patients with an apex as high as T-2. At the time of the preliminary report, only 44 patients had completed treatment. All patients have now completed treatment for their scoliosis, and all patients are now skeletally mature.

One or more of the authors reviewed all patients' charts and radiographs. Independent observers also reviewed the inclusion criteria for each patient. Of the original 139 patients, five patients were subsequently found to have a neurologic condition or spinal tumor as the cause of the scoliosis, and 12 patients were lost to follow-up before completing treatment for scoliosis. Nine patients were found to be too mature (Risser >2) at the time of initial bracing to be included in the study. Five patients were found to have juvenile curves, two patients were found to have initial curves that were too

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small (curvature <25°), and eight patients had been treated with a previous brace. These patients were thus excluded from this follow-up study, leaving 98 patients (149 curves) as a basis of this report. No patient was excluded on the basis of compliance, as we believe this type of exclusion leads to bias in a report. We could not verify true compliance rates, but it was our impression that patients tolerated the brace well and were highly compliant.

There were eight boys and 90 girls. Average age at the initiation of treatment was 12 years, 9 months (range, 10 years–14 years, 9 months). Seventy-six patients were Risser 0 or 1, whereas 22 patients were Risser 2. Forty-nine patients had documented progression before bracing. These patients had their curves observed to progress ≥5° into the range required for bracing. The remainder of the patients had curvatures that were large enough to warrant immediate bracing. Patients were braced with the Charleston Bending Brace (Fig. 1), worn at night only. The average length of brace wear was 2 years, 3 months. Bracing was discontinued at skeletal maturity or at the time of surgery. All of the patients completed the course of treatment as presented. All patients then returned for follow-up evaluation an average of 1 year, 2 months (range, 1 month–6 years, 3 months) after discontinuing the brace. Follow-up from initiation of treatment averaged 3 years, 5 months (range, 13 months–10 years, 7 months).

There were 17 single thoracic curves, 24 thoracolumbar curves, six lumbar curves, and 51 double curves; thus there was a total of 149 structural curves in the 98 patients. Average curvature immediately before bracing was 31° (range, 25–49°).

Results were analyzed in a similar fashion as before, according to the total number of patients, total number of curves, curve types, magnitude of curves, and Risser sign (16). Treatment was considered excellent if there was improvement or ≤5° progression at the end of treatment. This included secondary and compensatory curves. The remainder of patients have been classified as brace failures. However, as we were not totally dissatisfied with all results listed as brace failures, the patients with brace failure were subdivided into good, fair, and poor results. Treatment was considered good if there was >5° and ≤10° progression. Treatment was considered fair if they progressed >10° while in the brace but avoided surgery or the need for an alternate brace. Poor result was defined as any patient who required surgery, had surgery recommended to them, or changed to a different brace. For surgical patients, the value of the scoliosis curvature used was that immediately before surgery.

Indications for surgery were curvature >50°. Our indications for change to conventional brace wear was curve progression of >10° while in the brace with growth remaining (Risser 0, 1, or 2).

RESULTS

Length of brace wear for patients completing bracing averaged 2 years, 4 months (range, 1 year, 5 months–4 years, 10 months). The length of follow-up past brace wear was 1 year, 2 months (range, 1 month–6 years, 3 months). Scoliosis curvature measured 32° at follow-up (range, 11–60°). Sixty-five (66%) patients showed improvement or ≤5° change in curvature at the end of brace wear and were considered to have an excellent result. Eight patients had good results, whereas five patients had fair results. Twenty patients were considered to have poor results. Overall the brace wear was found to have acceptable results in 79% of patients. Fifteen of the 20 patients who had a poor result required surgery to correct the scoliosis. Two other patients were offered surgery but declined, and three patients were changed to an alternate brace system after progression of the scoliosis curvature.

Analysis with regard to individual curves indicates that 94 (63%) of the 149 curves had excellent results. Fourteen curvatures had good results, whereas nine cur-

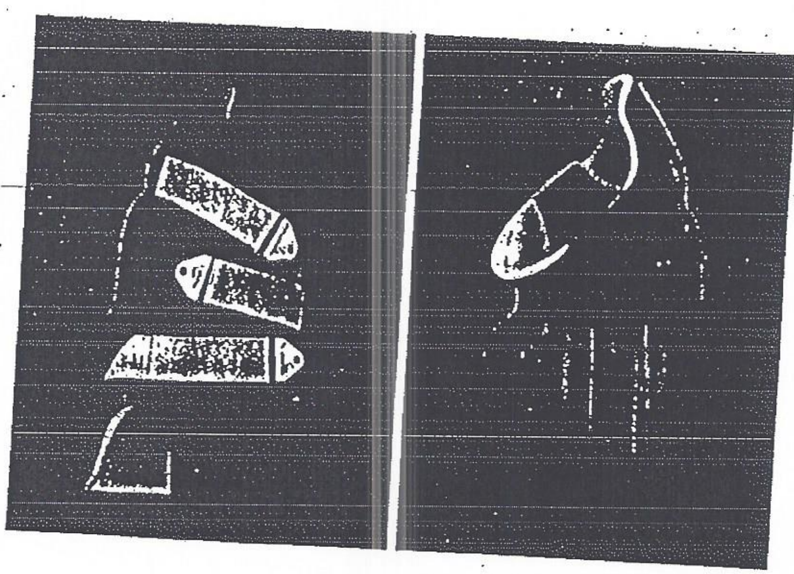

FIG. 1. Anterior (left) and posterior (right) views of Charleston Bending Brace.

TABLE 1. *Results by major curve type*

Curve type (No. of pts.)	No. of curves	Excellent ≤5°	Good 6–10°	Fair >10°	Poor
Single thoracic (17)					
25–29°	4/1	4/1	-/-	-/-	-/-
30–39°	7/2	4/2	-/-	-/-	3/-
40–49°	2/1	-/1	-/-	-/-	2/-
Single thoracolumbar (24)					
25–29°	11/2	8/2	2/-	-/-	1/-
30–39°	5/5	3/4	-/1	-/-	2/-
40–49°	1/-	1/-	-/-	-/-	-/-
Single lumbar (6)					
25–29°	4/1	4/1	-/-	-/-	-/-
30–39°	1/-	1/-	-/-	-/-	-/-
40–49°	-/-	-/-	-/-	-/-	-/-
Double thoracic (6)					
25–29°	3/4	2/4	1/-	-/-	-/-
30–39°	3/2	-/2	1/-	-/-	2/-
40–49°	-/-	-/-	-/-	-/-	-/-
Double major lumbar primary (24)					
25–29°	37/2	19/2	5/-	4/-	9/-
30–39°	7/-	6/-	-/-	-/-	1/-
40–49°	2/-	-/-	-/-	-/-	2/-
Double major thoracic primary (21)					
25–29°	11/4	6/1	-/-	3/2	2/1
30–39°	17/7	9/6	4/-	-/-	4/-
40–49°	12/1	-/1	-/-	-/-	2/-

Data expressed as Risser 0–1/Risser 2.

vatures had fair results. Twenty-two curvatures had poor results. Overall 85% of curves had acceptable results. In-brace curve correction averaged 87% for major curves and 33% for compensatory or secondary curves. Twenty compensatory or secondary curves progressed >5°. These patients were listed as brace failures regardless of the primary curve outcome. Four patients required surgery because of an increase in their compensatory curve alone.

Table 1 gives results by major curve type. Single lumbar curves fared the best with 100% excellent results and no brace failures. Single thoracolumbar curves also fared well with 75% excellent and only 12% poor results. The single thoracic curves had 71% excellent results and the highest percentage of poor results (29%). The double curves with lumbar primary (King type I) had 56% excellent results and 25% poor results. The double curves with thoracic primary (King type II) had 55% excellent and 24% poor results. Double thoracic curves had 67% excellent results with only 17% poor results.

The rate of poor results was increased as the magnitude of the initial curve increased in size. The rate of poor results for initial curve between 25 and 29° was 15%. The rate of poor results for initial curves between 30 and 39° was 23%. The rate of poor results for initial curves between 40 and 49° was 67%.

The risk of progression for the more immature patients (Risser 0–1) was greater. Table 2 gives results of immature patients (Risser 0 and 1) by major curve type. There were 76 (78%) patients who were Risser 0–1. The 13 patients who had a single right thoracic curvature had 62% excellent results and 38% poor results. The 17 patients who had a thoracolumbar curvature had 71% excellent results and only 18% poor results. The five patients who had a lumbar curvature all had excellent results (100%). Forty-one immature patients had double curvatures, and 21 (51%) had excellent results, whereas 11 (27%) had poor results.

Risk of progression for the 76 more immature patients (Risser 0 and 1) increased as the magnitude of the curve increased (Table 3). The 37 patients with curves of 25–29° had 78% excellent results and 18% poor results. The 32 patients with curves of 30–39° had 50% excellent results and 33% poor results. The seven patients with curves of 40–49° had 14% excellent results and 86% poor results.

The results of the more mature patients (Risser 2) were more favorable. Tables 4 and 5 give result of Risser 2 patients only. There were 22 (22%) patients who were Risser 2. Nineteen (86%) patients had excellent results, and one patient (5%) had a poor result. The four patients with single thoracic curves and the one patient with a single lumbar curve all had excellent results (100%). The seven patients with thoracolumbar curves had 86% excellent results and 0% poor results. The 10 patients with

TABLE 2. *Risser 0–1 (76 patients)*

Curve type	No. of patients	Excellent result	Brace failure
Single thoracic	13	8 (62%)	5 (38%)
Thoracolumbar	17	12 (71%)	3 (18%)
Lumbar	5	5 (100%)	0
Double	41	21 (51%)	11 (27%)

TABLE 3. *Risser 0–1 (76 patients)*

Curve	No. of patients	Excellent result (<5° change)
25–29°	37	29 (78%)
30–39°	32	16 (50%)
40–49°	7	1 (14%)

TABLE 5. *Risser 2 (22 patients)*

Curve	No. of patients	Excellent result (<5° change)
25–29°	9	7 (78%)
30–39°	11	10 (91%)
40–49°	2	2 (100%)

double curves had 80% excellent results and 10% poor results.

All patients returned for a follow-up evaluation an average of 1 year, 2 months after discontinuing the brace. At this follow-up, 37% of all the curvatures had noted some progress, whereas 38% of the curvatures had shown continued improvement, and 25% of the curvatures had shown no change since the end of brace wear. There was an overall average increase of 0.8° per curvature at last follow-up since discontinuing the brace.

Three complications were associated with brace wear; all were reported in the preliminary study. Transient neuropathy developed in one patient from axillary pressure. This was relieved by trimming the brace. Two patients had local skin erythema. No patients had skin breakdown.

DISCUSSION

Our preliminary study suggested that 8 h of nighttime bracing with the Charleston Bending Brace may be as effective as other methods of orthotic management for scoliosis. This longer term study confirms that observation. Reports of the natural history of scoliosis indicate that 60–80% of patients in this study group would have progressed without treatment (5,12–15,17,18). Although lower than our initially reported 83%, we believe that our 65 (66%) patients in this report with excellent results is an improvement of the natural history of untreated scoliosis.

The results of this study compared favorably with the Milwaukee brace results reported by Lonstein and Winter (14). At completion of treatment with the Milwaukee brace, 57% of patients (187 of 329) who had a Risser sign of 0 or 1 and a 20–39° curve had an excellent result. This deteriorated to a 48% excellent result at follow-up. The Charleston brace produced 61% excellent results in 69 patients who had a Risser sign of 0 or 1 and a 25–39° curve. The results reported by Lonstein and Winter may have been less favorable if noncompliant patients had been included in their analysis.

TABLE 4. *Risser 2 (22 patients)*

Curve type	No. of patients	Excellent result	Brace failure
Single thoracic	4	4 (100%)	0
Thoracolumbar	7	6 (86%)	0
Lumbar	1	1 (100%)	0
Double	10	8 (80%)	1 (10%)

Higher success rates of ~80% were reported by Emans et al. (8) with the Boston brace (8). However, that study included patients up to age 18 years with Risser sign of 0–4. Their results in immature patients were not analyzed separately. No reports of the Boston brace analyzed results by curve magnitude and maturity. Andersen et al. (2) stated that their results with the Boston brace questioned whether Boston bracing alters the natural course of a scoliotic curve.

Bassett et al. (4) reported 72% excellent results with the Wilmington brace for patients who had a Risser sign of 0 or 1 and a curve of 20–39°. However, they eliminated noncompliant patients from their study. Also, curves with an apex above the seventh thoracic vertebra were not included, and they reported an unusually low number of double major curves (16 of 79 patients).

Allington and Bowen (1) reported 59% excellent results in patients with curves <30° and 41% excellent results in patients with curves 30–40° with part-time bracing with the Wilmington brace. They also eliminated noncompliant patients from their study. They noted that part-time and full-time bracing were equally effective in preventing progression of immature curves of ≤40°.

In this Charleston Bending Brace study, we included all curves and noncompliant patients. It is our opinion that treatments that patients reject should be reported. We found the Charleston Bending Brace to be well accepted by patients and family. However, some patients are still noncompliant with their treatment. As in any brace study, it is often difficult to judge noncompliance or partial compliance. Because we feel that this is a large source of bias, no patient was excluded from the study on the basis of noncompliance or partial compliance.

Green (10) reported a group of 44 patients selected in a manner comparable with those in this Charleston Bending Brace study. Green used part-time bracing with either the Boston or Milwaukee brace. Noncompliant patients were included. All patients had a ≥25° curve, and all had a Risser sign of 0, 1, or 2. Green reported 89% excellent results with this bracing protocol for 44 patients. This is the best success rate in the literature for a group of immature patients with curves of 25–49°.

In this study, as in the preliminary report, double curves had the poorest response to brace treatment. This has been reported by other authors using conventional braces. However, it is possible that poorer response of double curves to the bending brace is related to the difficulty in "unbending" two opposing curves. This may be reflected by the in-brace correction of 87% for major curves and only 33% for compensatory or secondary curves. This lower percentage of correction may also explain the 13% incidence of progression of the compensatory curves. Current techniques of bending-brace application have been modified to address the problem of double curves, and additional clinical trials are now in progress using these newer methods.

As in any multicenter study, we noted problems with data collection and control. We tried to overcome this by one or more of the authors collecting and reviewing all follow-up data for this study. During this review, we were surprised to find a number of patients who did not fit our initial inclusion criteria and thus were excluded from this follow-up report. We have learned that multicenter studies should be strictly controlled and reviewed independently from the outset by one or two primary authors.

In an effort to be self-critical, our reported results may be skewed in the direction of poorer results. For double curves, the worst curve at follow-up was reported for individual patient analysis. For any patient for whom the treatment failed because of one curve, the other curve was automatically reported as a failure. We also reported as poor results those patients in whom surgery was recommended but refused and those patients who had a brace change. We also monitored and reported all curves, including secondary and compensatory curves, and if any secondary or compensatory curve increased >5°, it was reported as a brace failure. Other authors have published examples of increases in secondary curves of >5° that they did not report as failures because there was no increase in their primary curve (14).

In conclusion, the long-term results of nighttime treatment of scoliosis with the Charleston Bending Brace continue to be encouraging. It is possible that full-time conventional brace wear would improve results, but compliance is difficult and burdensome for many patients. Part-time wear has been demonstrated to be just as effective as full-time wear, but this may reflect failure of full-time compliance as much as it reflects success of part-time wear. It is our opinion that the Charleston Bending Brace improves the natural history of idiopathic scoliosis and is as effective as other reported brace-management programs.

Acknowledgment: This study was funded in part by a grant from the Charleston Bending Brace Company.

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