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Brace Wear Control of Curve Progression in Adolescent Idiopathic Scoliosis

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Background: The efficacy of brace treatment for patients with adolescent idiopathic scoliosis remains controversial, and effectiveness remains unproven. We accurately measured the number of hours of brace wear for patients with this condition to determine if increased wear correlated with lack of curve progression.

Methods: Of 126 patients with adolescent idiopathic scoliosis curves measuring between 25° and 45°, 100 completed a prospective study in which they were managed with a Boston brace fitted with a heat sensor that measured the exact number of hours of brace wear. Orthopaedic teams prescribed either sixteen or twenty-three hours of brace wear and were blinded to the wear data. At the completion of treatment, the number of hours of brace wear were compared with the frequency of curve progression of ≥6° and with curve progression requiring surgery.

Results: The total number of hours of brace wear correlated with the lack of curve progression. This effect was most significant in patients who were at Risser stage 0 ($p = 0.0003$) or Risser stage 1 ($p = 0.07$) at the beginning of treatment and in patients with an open triradiate cartilage at the beginning of treatment. Logistic regression analyses showed a "dose-response" curve in which the greater number of hours of brace wear correlated with lack of curve progression. Brace wear to school and immediately afterward was most successful. Curves did not progress in 82% of patients who wore the brace more than twelve hours per day, compared with only 31% of those who wore the brace fewer than seven hours per day ($p = 0.0005$). The number of hours of brace wear also correlated inversely with the need for surgical treatment ($p = 0.0005$). The number of hours of wear were similar for the patients who were advised to wear the brace sixteen or twenty-three hours daily.

Conclusions: The Boston brace is an effective means of controlling curve progression in patients with adolescent idiopathic scoliosis when worn for more than twelve hours per day.

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

The efficacy of bracing for the treatment for idiopathic scoliosis is controversial, with some authors reporting control of curve progression with bracing[1-23] and others reporting that bracing fails to alter the natural history[5,24-28]. Accurate monitoring of brace wear is now possible with use of heat sensors in the orthosis[29,30]. Rahman et al. showed a relationship between monitored brace compliance and lack of curve progression in a group of thirty-four patients who were managed with the Wilmington brace[31]. Morton et al. showed that when brace wear is accurately monitored, the estimates of wear by the patient, the parent, the treating physician, and the orthotist are unreliable[32]. In the first year of bracing, for example, physicians failed to identify 25% of patients who were noncompliant with bracing. Other authors have shown similar inaccuracies of estimated compliance with treatment[29,33]. The unreliability of estimates of compliance with brace treatment brings into question the validity of unmonitored studies of brace treatment of scoliosis.

The purpose of the present study was to determine the relationship between the measured number of hours of brace

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wear and the control of curve progression in patients with adolescent idiopathic scoliosis. Our hypothesis was that a greater duration of brace wear will prevent curve progression, whereas the null hypothesis was that the duration of brace wear is unrelated to curve progression in patients with adolescent idiopathic scoliosis.

Materials and Methods

Study Overview

To be enrolled into this prospective study, each patient had to have a diagnosis of idiopathic scoliosis, had be skeletally immature (Risser 0, 1, or 2), had to be ten years of age or older at the time of brace prescription, had to have a curve with a Cobb angle of between 25° and 45°, and had to have no history of previous treatment. All patients were managed at the same pediatric orthopaedic hospital in which treatment was provided without cost to the family. Patients were assigned sequentially to one of seven scoliosis services by appointment clerks, with each clinic receiving the same number of new patients each week. Each service included a pediatric orthopaedic surgeon (J.A.H., J.G.B., and others), an orthopaedic nurse, an orthotist (D.K. and others), and an orthopaedic resident or fellow. At the outset of the study, each team chose to use one bracing protocol for all patients, recommending brace wear either sixteen or twenty-three hours daily, according to the team's usual practice. All teams used the Boston brace (Boston Brace International, Avon, Massachusetts); four teams elected to prescribe twenty-three hours of brace wear per day (the Boston-23 group), and three teams elected to prescribe sixteen hours of wear per day (the Boston-16 group).

Description of Temperature Monitoring

To measure actual brace wear objectively, a temperature data logger was installed within each orthosis (Fig. 1). However, it was not small enough for its existence to be concealed from the patient. To reduce the chance that the patient's awareness of the device would alter his or her wear pattern, we informed each patient that the device would monitor the temperature within the orthosis so that we might be able to correlate temperature with the reported levels of comfort. The institutional review board approved this approach.

The temperature data logger was programmed to continuously sample the temperature on the inside of the orthosis every fifteen minutes. We performed a field trial in which the lead author (D.K.) and two persons without scoliosis wore monitored braces. They maintained a precise log of actual wear to which the algorithm's estimated wear could be compared. The total number of hours of actual wear by the three subjects was 1072.84 hours, and 2900 hours of samplings were taken under environmental temperatures varying between 22°F and 100°F (−5.6°C and 37.8°C). The sensor was insulated from the environment, and even extreme environmental temperatures did not affect the readings of body temperature. The algorithm interpreted the actual wear to be a total of 1072.1 hours (average accuracy, 99.93%). We concluded that this method was effective for insulating the data logger from ambient air temperature while ensuring accurate thermoconductivity between the skin and the temperature sensor. The device has a storage capacity of 32,520 data points and a battery life of five years. At our sampling rate, the device could store data for 338 days. This capacity was more than adequate because the patients in the present study were evaluated in the clinic at intervals of three to four months, at which time the raw data were downloaded and then the sensor was reset for continuing data collection. All patients were monitored for wear throughout the entire duration of treatment. The chronologically stamped data points included the date, time of day, and temperature. These data were used to formulate a clinically accurate algorithm to calculate brace wear. All team members were blinded to all of the wear data.

When the brace is applied, the sensor warms (or cools, should a hot brace be donned) quickly and gradually equilibrates within a few degrees of body temperature. Temperatures are recorded every fifteen minutes, and the temperature may fluctuate for as long as an hour. We recorded a wear time once the temperature had stabilized between 90°F and 99°F (32.2°C and 37.2°C), giving the patient credit for the "warm up time." The wear time for an episode was stopped when the temperature dropped below 90°F (32.2°C). Several safeguards to

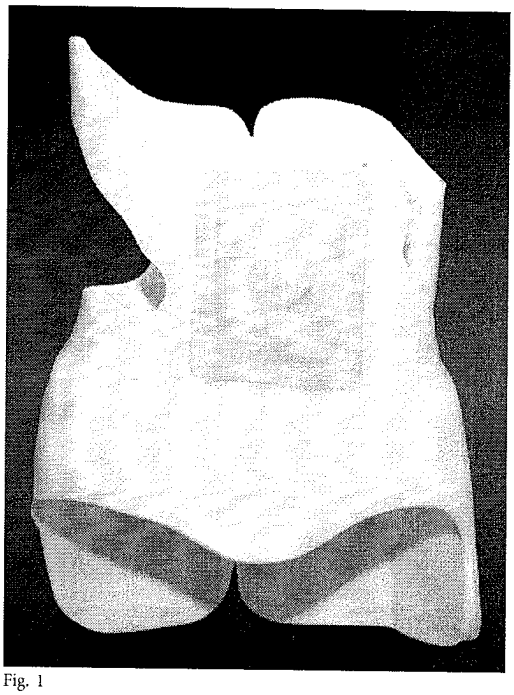

Fig. 1

A commercially produced data logger (TidbiT; #TBI32-05+37; Onset Computer, Bourne, Massachusetts), attached to a Boston brace, worked within a large temperature sampling range (−4°F to 158°F) (−20°C to 70°C), was completely self-enclosed and thus was waterproof, and was small enough so as to not be obtrusive or objectionable to the patient (1.2 in [3.0 cm] wide × 1.6 in [4.1 cm] tall × 0.65 in [1.7 cm] thick; 0.8 oz [24.9g]).

minimize the risk for both false-positive and false-negative readings were employed (Fig. 2).

A patient's compliance, defined as his or her adherence to a prescribed wear schedule, was calculated by determining the ratio of hours in which the orthosis was worn to the hours of prescribed wear, multiplied by 100 in order to express the quotient as a percentage. This calculation was performed on a visit-by-visit basis for each patient in order to account for any minor alterations in prescribed wear, typically toward the end of treatment.

Brace Management Protocol

A hospital staff orthotist (D.K. and others) fit all orthoses. Each Boston brace was customized to the patient from a premanufactured thermoplastic module, which was modified relative to each patient's body measurements. A newly prescribed orthosis was fitted to the patient no more than four weeks after the initial prescription. After approximately four weeks of wear, each patient returned to the clinic for an in-brace, standing posteroanterior spine radiograph that was used to document the amount of curve correction while the orthosis was being worn. The appropriate application and fit of the orthosis were confirmed by a staff orthotist (D.K. and others) immediately prior to each in-brace radiograph to ensure an accurate reflection of the application of forces that were employed to reduce the size of the curve in each patient.

Skeletal maturity was noted and brace treatment was discontinued when two of the following three criteria were reached: (1) a Risser scale of 4 or 5, (2) at least eighteen months since the onset of menstruation (for girls), and (3) two consecutive visits over a time period of at least six months with no more than a 1-cm increase in height.

Data Collection and Analysis

Clinical and radiographic data were collected prospectively for each patient at every four months. At each visit, a standing posteroanterior spine radiograph was made with the patient out of the brace. The clinical data included the age, menarchal status, height, weight, and any other relevant treatment observations from the patient's medical record. Radiographic data included the curve type (single thoracic, thoracolumbar, lumbar, double major, double thoracic, and triple major), the triradiate cartilage status (open or closed), and the Risser grade. In-brace correction was measured as the percentage of improvement of the major curve on the standing posteroanterior spine radiograph made with the brace on as compared with the most recent standing posteroanterior spine radiograph without the brace. One author (D.K.) measured the Cobb angle on all radiographs to avoid interobserver variability in the readings. The mean number of hours of brace wear over the entire bracing period was compared with the presence or absence of ≥6° of progression. When a patient discarded a brace prior to

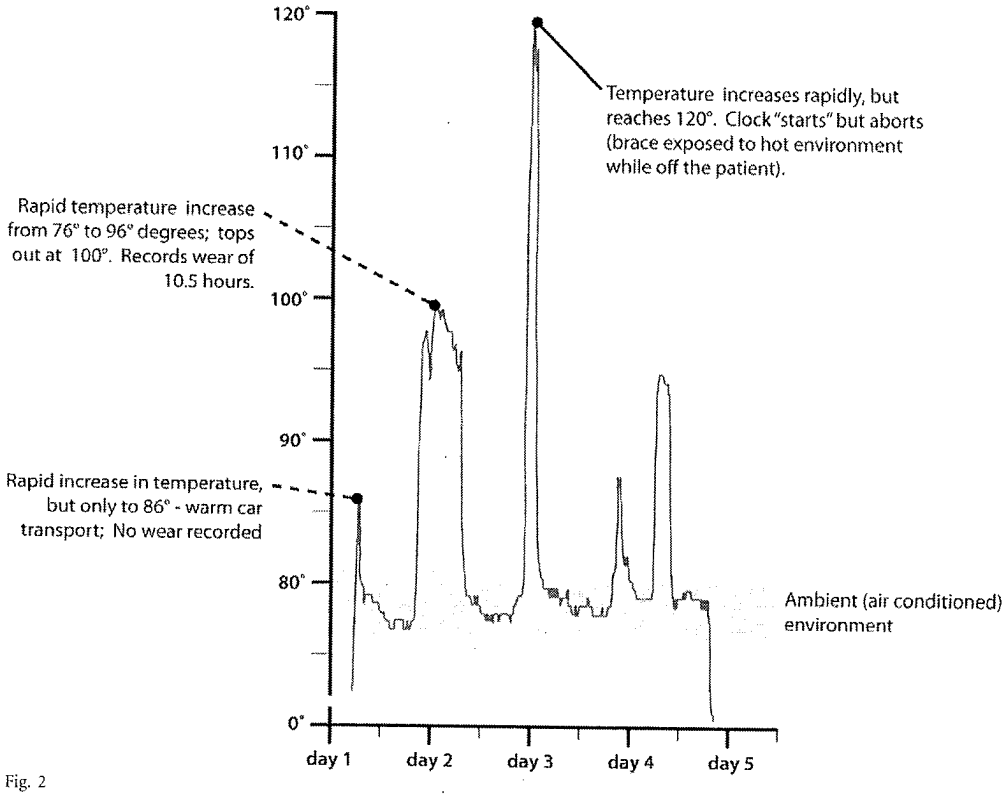

Fig. 2

Graph of temperature readings and our interpretations of the data. All temperatures are given in Fahrenheit (Celsius value = [Fahrenheit value − 32]/1.8).

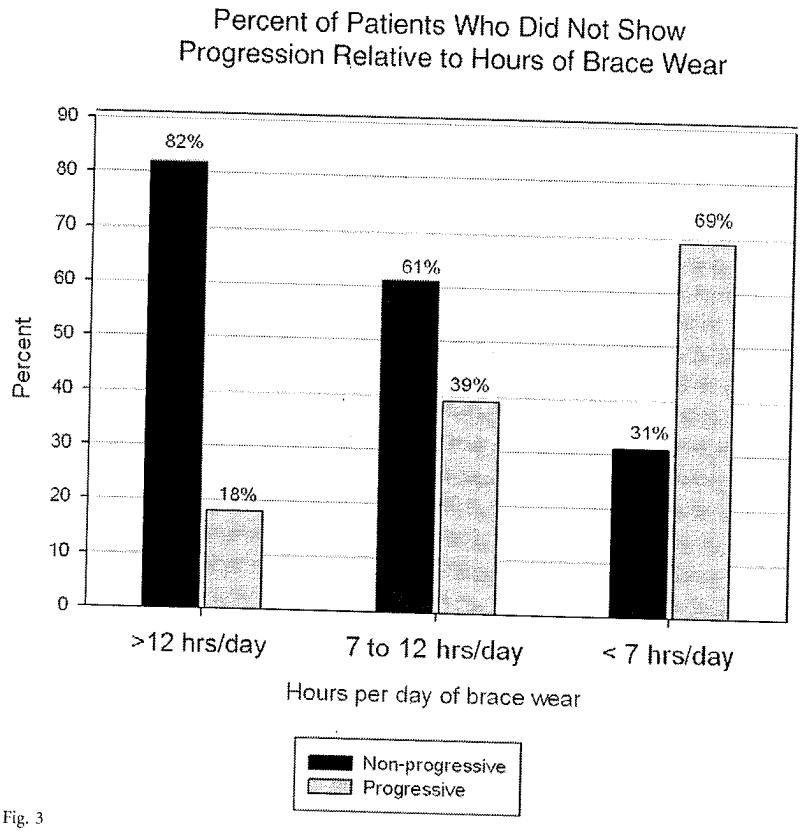

Fig. 3

Bar graph showing the percentage of patients with a nonprogressive curve who wore the brace for the number of hours indicated.

skeletal maturity, the number of days between the date of stopping the brace and the date of skeletal maturity were counted as zero wear days.

To determine the effect on outcome related to the time (or times) of day that the brace was worn, logistic regression analyses were done with use of the following approach. We considered hours worn in six time periods: (1) twenty-four hours per day, (2) from 4:00 P.M. to 10:00 P.M. (after school and before bedtime), (3) from 10:00 P.M. to 7:00 A.M. (in bed), (4) from 7:00 A.M. to 4:00 P.M. (school hours), (5) from 4:00 P.M. to 7:00 A.M. (not in school), and (6) from 7:00 A.M. to 10:00 P.M. (all hours except bedtime). To put the hours on a common scale, we computed the percentage of time that the brace was worn during each period, relative to the length of the period. For example, from 4:00 P.M. to 10:00 P.M. is six hours, so if the subject wore the brace for four hours during that time, we would record 66% as the wear, rather than four hours.

Outcome Definitions

Brace treatment was considered to have failed if a mature patient had ≥6° of progression of the main curve on a standing posteroanterior spine radiograph made with the patient out of the brace. For double curves, the curve with the largest Cobb angle was termed the primary curve. Failure was also noted when the secondary curve progressed to a value that was ≥6° greater than the primary curve. Progression to surgical treatment was noted as a failure as well. Patients who had surgical treatment without having ≥6° of progression were eliminated from the study.

Institutional Review Board Approval

Institutional review board approval was obtained, and, from July 1998 to July 2000, all patients who met the criteria for inclusion were given the opportunity to give informed consent and to participate in the study.

Statistical Methods

Comparisons of two means were made with use of the usual independent group t test, assuming unequal variances in the two groups. Comparisons of three or more means were made with use of standard analysis-of-variance methods, with Tukey multiple comparison methods being employed if a significant overall result was seen. Comparisons of rates and proportions were performed with use of the Fisher exact test. To estimate the probability of nonprogression of the curve, logistic regression methods were used. To find the best set of variables to predict the probability, backward elimination methods were used. A p value of ≤0.05 was considered significant.

Source of Funding

There was no external source of funding for this study.

TABLE I Correlation of Brace Wear to Curve Progression

	Daily Brace Wear* *(hr)*		
	Nonprogressive	Progressive	P Value†
All patients (n = 100)	9.1 (0 to 21.0) [n = 50]	5.0 (0.01 to 16.1) [n = 50]	<0.0001
Risser 0 patients (n = 75)	9.9 (0.3 to 21.0) [n = 33]	5.2 (0 to 16.1) [n = 42]	0.0001
Risser 1 patients (n = 15)	8.3 (0.1 to 17.6) [n = 10]	3.5 (0 to 7.0) [n = 5]	0.0701
Risser 2 patients (n = 10)	6.4 (0 to 18.2) [n = 7]	4.9 (0.2 to 9.8) [n = 3]	0.702
Total no. of hours of brace wear	5321 (1 to 15,224)	3312 (2 to 14,542)	0.0097
Open triradiate cartilage (n = 42)	10.6 (1.7 to 17.5) [n = 12]	5.8 (0.1 to 16.1) [n = 30]	0.0040
Closed triradiate cartilage (n = 53)	8.1 (0 to 21.0) [n = 35]	3.8 (0 to 10.8) [n = 18]	0.0015

*The values are given as the mean, with the range in parentheses. The number of patients is given in brackets. †T test.

Results

Exclusions

Two hundred and sixty patients were fitted with a Boston brace during the study period. One hundred thirty-four patients failed to meet the inclusion criteria and were excluded. Of these, sixty-four did not have a diagnosis of adolescent idiopathic scoliosis, forty-three had a history of orthotic treatment, eighteen were at Risser level 3 or greater at the time of brace prescription, eight had a Cobb angle outside the range defined as a criterion for inclusion, and one declined to participate.

One hundred and twenty-six patients were prospectively enrolled into the study, and informed consent was provided by both the patient and his or her legal guardians. Of these patients, fourteen were lost to follow-up, eight had less than sixty days of brace use or had technical problems with sensors, and four were excluded because surgery was performed without progression of the initial curve. As a result, twenty-six patients were excluded from the final analysis, leaving a total of 100 patients for this review.

Characterization of Patients and Wear Variables

Of the 100 patients, ninety-one (91%) were female and nine (9%) were male. Forty-three patients (43%) were in the Boston-16 group, and fifty-seven patients (57%) were in the Boston-23 group. Sixty-two patients (62%) had a double-major curve pattern, twenty-six (26%) had a single thoracic curve, three had a double thoracic curve, eight had either a lumbar or thoracolumbar curve, and one had a triple-curve pattern. At the onset of treatment, seventy-five patients were at Risser 0, fifteen were at Risser 1, and ten were at Risser 2. Thirty-six (40%) of the ninety-one female patients started bracing before menarche, and fifty-five (60%) started treatment after menarche. The triradiate cartilage was open in forty-two patients and closed in fifty-three; the status was unknown in five patients because of radiographic shielding. At the onset of treatment, the mean age was 12.7 years (range, 10.1 to 15.6 years), and the mean magnitude of the primary curve was 33.9° (range, 25° to 45°). Thirteen patients discontinued the brace before skeletal maturity, and the days between discontinuance and skeletal maturity were counted as no wear days. The eighty-seven patients who did not discontinue the brace had an average total wear of 18.8 months (range, 2.3 to 41.8 months). Braces were routinely adjusted for comfort and were replaced as often as necessary to accommodate growth. No patient complaints about the prominence of the sensor were noted. All patients were followed to skeletal maturity.

Outcomes

We stratified brace wear (in hours per day) to determine a threshold for likely successful treatment. We found that 82% of patients who wore the brace for more than twelve hours per day had a successful outcome (defined as <6° of curve progression). Patients who wore the brace for seven to twelve hours per day had a success rate of 61%, and those who wore the brace for fewer than seven hours per day had a success rate of only 31% ($p = 0.0005$) (Fig. 3). The average number of hours of brace wear per day was strongly associated with a successful outcome (Table I). The associations were strongest in the immature patients (those at Risser 0 and those with an open triradiate cartilage). Logistic regression analysis showed that the variables best capable of correctly predicting nonprogression were the average number of hours of brace wear per day and the status of the triradiate cartilage and the Risser sign at the beginning of treatment. Figures 4 and 5 show the relationship between the greater number of hours of brace wear and the likelihood of nonprogression of the scoliotic curve. A greater number of hours of wear was necessary for curve control in patients with an open triradiate cartilage.

The patients with a higher percentage of compliance with the hours of prescribed wear had less curve progression. Patients without curve progression wore the brace for an average of 46.1% of the prescribed hours throughout the course of treatment, whereas those with curve progression wore the brace for an average of 28.6% of the recommended hours ($p = 0.0022$). The overall rate of compliance with prescribed brace wear was 35% and 27% in the sixteen-hour and twenty-three-hour groups, respectively ($p = 0.28$). Patients for whom

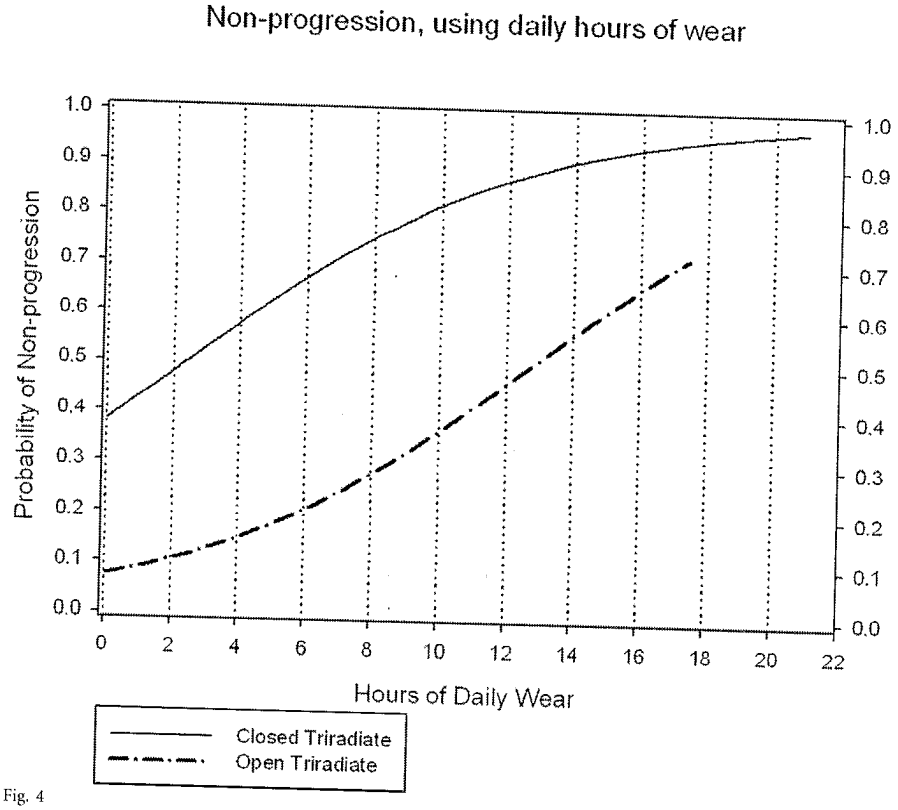

Fig. 4

Logistic regression relating hours of brace wear to the probability of prevention of curve progression for patients with open or closed triradiate cartilage.

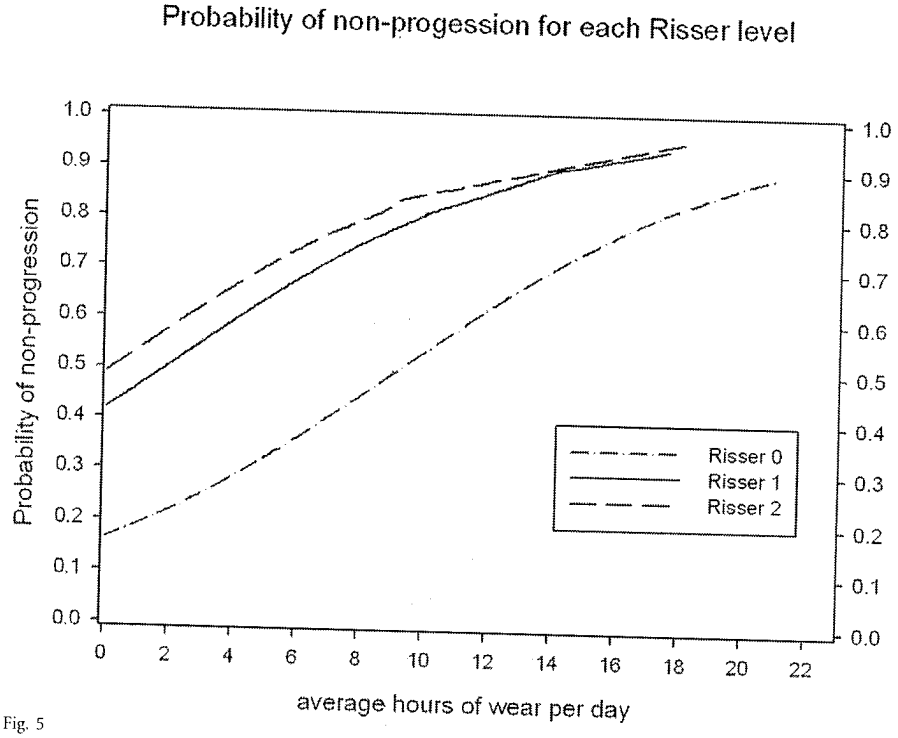

Fig. 5

Logistic regression relating hours of brace wear to the probability of prevention of curve progression for patients with Risser signs of 0, 1, and 2.

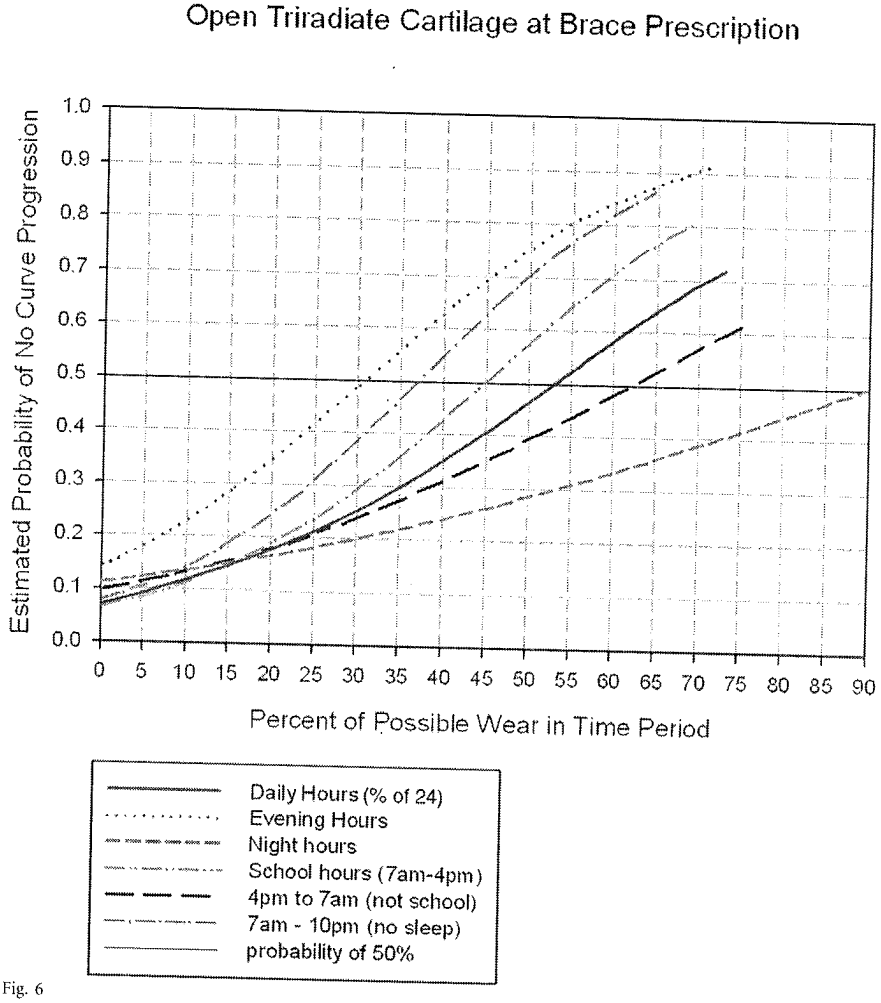

Fig. 6

Line graph illustrating the hours of brace wear during certain daily periods relative to curve non-progression in the open triradiate cartilage group.

twenty-three hours of wear was prescribed did not wear the brace for more hours than those for whom sixteen hours of wear was prescribed (7.6 compared with 6.3 hours per day; $p = 0.23$). Only 33% of the patients who complied with 75% or more of the recommended wear had curve progression, whereas 54% of the rest of the patients had progression. With the numbers available, we found no significant differences between boys and girls in terms of the number of hours of wear per day ($p = 0.79$), the total hours number of hours of wear ($p = 0.98$), or the probability of progression ($p = 1.0$).

The logistic analyses of the time of day during which the brace was worn are shown in Figure 6 and the Appendix. Wear during school and in the afternoon and evening between school and bedtime was more strongly associated with successful treatment than were total daily wear and wear at night, both for patients with an open triradiate cartilage and for those with a closed triradiate cartilage.

In the group of patients at Risser 0 or 1 with curves of 25° to 35°, the seventeen patients with a nonprogressive curve wore a brace for an average of 10.3 hours per day, whereas the eighteen patients with a progressive curve wore a brace for an average of 4.38 hours per day ($p = 0.0004$). In patients at Risser 0 or 1 with curves of 36° to 45°, the patients with a nonprogressive curve wore a brace an average of 8.5 hours per day, whereas the patients with a progressive curve wore a brace 5.7 hours per day ($p = 0.046$). Curve flexibility as measured on the basis of the in-brace correction was similar for both the patients with progressive curves and those with nonprogressive curves (47% compared with 43%; $p = 0.25$). Brace wear also was not associated with the degree of in-brace correction ($p = 0.126$).

Six patients who exhibited consistent brace wear (defined as wearing the brace >80% of the prescribed days) had curve progression. All had an open triradiate cartilage and a somewhat larger curve at the start of treatment (mean, 36°), and only one patient wore the brace for more than twelve hours per day.

Compliance with prescribed brace wear declined over the duration of treatment to a small degree in the patients whose

TABLE II Correlation of Brace Wear to Need for Surgical Treatment

Wear Variables	No Surgery* (N = 72)	Surgery* (N = 28)	P Value
No. of hours of wear per day over all days when brace was indicated	8.1 (0 to 21.0)	4.3 (0.01 to 12.1)	0.0005
No. of hours of wear per day when brace was worn	10.6 (0.5 to 21.1)	7.2 (0.8 to 12.5)	0.0002
Total no. of hours of brace wear	5002 (1 to 15,224)	2552 (1.5 to 10,611)	0.0033
Percent compliance	42.4% (0.1% to 99.1%)	24.4% (0.1% to 75.6%)	0.0025

*The values are given as the mean, with the range in parentheses.

curves did not progress and to a larger degree in those whose curves progressed. Patients with a nonprogressive curve wore a brace for an average of 10.2 hours per day in the first year of treatment and for an average of 7.1 hours per day in the subsequent years. The patients with a progressive curve wore the brace for an average of 6.0 hours per day in the first year of treatment and for an average of 4.5 hours per day in subsequent years. Thirteen patients discontinued the brace. Of these thirteen patients, eight had a curve that had progressed ≥6° at the time of discontinuation (with seven of the eight having surgery), three had a curve that never progressed, and two had a curve that progressed between the time of brace discontinuation and the time of the latest follow-up.

The number of hours of brace wear was inversely related to the avoidance of surgical treatment ($p = 0.0005$). Those who did not have surgery ($n = 72$) wore the brace for an average 8.1 hours per day, whereas those who had surgery ($n = 28$) wore the brace for an average 4.3 hours per day (Table II). The mean change in the main curve Cobb angle was 19.0° (range, 8° to 44°) for those having surgery and 2.4° (range, −14° to 25°) for those not having surgery ($p < 0.0001$). At the time of surgery, the average curve was 54.2° (range, 41° to 80°). Surgery rates were higher for patients with an open triradiate cartilage at the onset of the treatment.

Of the seventy-two patients who did not have surgery before brace discontinuance, six were followed for less than six months after the completion of brace treatment, leaving sixty-six patients for follow-up analysis. The average duration of follow-up between skeletal maturity and the last visit was 2.4 years (range, 0.5 to 6.3 years). Seven patients had spine surgery in this time period, and all had previously been classified as having had a failure of bracing. We compared curve measurements at the onset of treatment, at the time of initiation of the brace, at the time of discontinuance of the brace, and at the time of the latest follow-up (see Appendix). Patients with more than twelve hours of brace wear per day had significantly less progression and the Cobb angle at the time of the latest follow-up was not significantly different from the initial Cobb measurement.

For the entire cohort, brace treatment was considered successful for fifty patients who had <6° of progression of the major curve. Brace treatment was considered to have failed in fifty patients who had ≥6° of curve progression. Of the seventy-five Risser 0 patients, thirty-three patients (44%) did not have curve progression and forty-two (56%) had curve progression. Success rates were higher in the more mature patients, with ten successes among fifteen patients at Risser 1 maturity and seven successes among ten patients at Risser 2 maturity. Patients with an open triradiate cartilage had lower success rates than those with a closed triradiate cartilage, with success of treatment in twelve (29%) of forty-two patients with an open triradiate cartilage and thirty-five (66%) of fifty-three patients with a closed triradiate cartilage ($p < 0.001$).

Discussion

The direct correlation between the number of hours of brace wear and the lack of curve progression confirms that brace wear can be an effective treatment for progressive adolescent idiopathic scoliosis. The less-mature patients (Risser 0 and 1), who are the most likely to have curve progression, showed the strongest treatment effect in comparison with the more-mature patients (Risser 2). We believe that these findings refute the null hypothesis that brace wear does not influence the progression of scoliosis. An increased likelihood of progression in patients at Risser 0 or 1 maturity has been documented in many studies[14,34,35]. Ylikoski, in a recent study of 535 untreated girls with adolescent idiopathic scoliosis, showed that curves (mean magnitude, 23.4°) in patients at Risser 0 progressed at a rate of 7° per year, those in patients at Risser 1 progressed at 4.6° per year, those in patients at Risser 2 progressed at 3° per year, and those in patients at Risser 3 and 4 progressed at <1.5° per year[36].

Brace treatment is traditionally compared with the natural history study by Lonstein and Carlson, in which 68% of curves between 20° and 29° in patients at Risser 0 or 1 progressed[35]. Only one of our thirteen patients at Risser 0 who wore the brace for more than twelve hours per day experienced curve progression. This benefit continued between the completion of brace wear and the latest follow-up. Those wearing the brace for seven to twelve hours per day had progression 39% of the time, whereas those who wore the brace fewer than seven hours per day had progression 68% of the time, which is the same as the natural history[35]. If we were unaware of actual brace wear, our report would resemble other "intent-to-

treat" reports with progression in 52% of our patients at Risser 0 or 1 with curves between 25° and 45°, a modest improvement over the natural history, but the perspective changes substantially when we accurately quantitate brace wear. Our data reflect a dose-response relationship between brace wear and lack of curve progression.

Even our most compliant patients only wore the brace a fraction of the number of hours prescribed by the clinicians. When twenty-three hours of brace wear was prescribed, the hours of wear were not significantly different from when sixteen hours of brace wear was recommended. The patients who were most likely to have successful outcomes were those who wore the brace for more than twelve hours per day, regardless of the number of prescribed hours of wear. The most successful patients were those who wore the brace between school and bedtime and those who wore the brace during school hours, whereas those who wore the brace only at bedtime were the least successful. These time correlates were more predictive of success than the total hours of wear. It is likely that the successful outcome in those wearing the brace beyond nighttime hours simply identifies the more diligent brace-wearers.

We found no relationship between curve flexibility in the brace and the number of hours of brace wear or outcome. This finding differs from those of other studies, which have shown a direct correlation between radiographic in-brace correction and successful brace treatment[11,27]. The lack of such correlation in the present study may relate to the fact that measured number of hours of brace wear is a much stronger factor than the measure of radiographic in-brace correction.

On the basis of this information, how much brace wear should we recommend? With an informed patient approach, the treating team may be more likely to achieve an exact "dosage" and timing of brace wear. Perhaps the "homework assignment" of sixteen or twenty-three hours seems impossible to a teenager, whereas he or she might be able to conceive of a way to achieve a "real wear time" of twelve hours, including some time at school and afterward. More than twelve hours of brace wear may be necessary when the patient is at the peak of the adolescent growth spurt.

Brace wear declined over the duration of treatment, more so in the patients in whom the curve progressed than in those in whom the curve did not progress. There was a linear relationship between the number of hours of brace wear and the lack of curve progression in the Risser 0 and 1 patients but not in the Risser 2 patients. However, there were only ten patients who started treatment at Risser 2, and additional studies of monitored brace wear are needed to clarify the appropriate duration of treatment in this subgroup. At the present time, we recommend that brace treatment be continued until maturity, which is defined as Risser 4 in a patient who has not grown >1 cm over the preceding six months or in a girl who is at least eighteen months beyond menarche.

Previous studies have found that boys are frequently poor brace-wearers. While the present study found no differences between boys and girls in terms of the number of hours of brace wear, this finding should be interpreted with caution as there were only nine boys in the study.

Many previous investigators have argued for or against the effectiveness of bracing for the treatment of adolescent idiopathic scoliosis. They have shown that prospective brace wear reporting by the patient, the parent, the physician, and the orthotist bear little relationship to actual brace wear. These studies must be viewed in light of the data in the present study and that by Morton et al.[32]. In the present study, we also found that prescribed hours of wear do not predict actual wear, which is highly variable among patients. When patients wear the brace so inconsistently and so unpredictably, and when the investigators cannot accurately estimate the actual wear rate, studies performed without monitoring of wear cannot provide firm conclusions about efficacy.

It could be argued that our patients were different from other cohorts as they came from all economic strata and from several ethnicities. They received braces for which they did not pay, and this could have a negative effect on the likelihood of brace wear. On the other hand, they were aware that they were entered into a study and might, therefore, have been inclined to wear the brace for more hours and to report their wearing habits more honestly.

One limitation of the present study is the inclusion of only one variety of brace. The Boston brace has been widely used and is similar in design to other thoracolumbosacral orthoses. Braces with different designs should be studied in a like manner to refine our conclusions. We would strongly recommend that these studies include monitoring of wear hours for the studies to be of value. Another limitation of the present study is the lack of interobserver error determinations as only one observer measured the Cobb angle on all radiographs.

In conclusion, greater number of hours of wear of a Boston brace is associated with improved control of progression of adolescent idiopathic scoliosis. The less mature patients had the greatest benefit from brace wear. Successful outcomes are most likely when the patient wears the brace more than twelve hours per day.

Appendix

(eA) Figures depicting hours of brace wear are available with the electronic version of this article on our web site at jbjs.org (go to the article citation and click on "Supporting Data"). ■

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