Prognosis of brace-treated scoliosis

Comparison of the Boston and Milwaukee methods in 244 girls

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Totally, 244 females with adolescent idiopathic scoliosis treated by brace were followed for at least 2 years after treatment. The initial curve magnitude correlated with failure, notably thoracic curves. The Boston brace was more successful than the Milwaukee brace irrespective of initial curve magnitude and skeletal maturity.

There is general agreement that the initial curve magnitude and skeletal maturity are prognostic factors in relation to progression. Curve pattern as a predictor of progression is more controversial. Lonstein and Carlson (1984) found more double curves progressing, whereas Bunell (1986) found the poorest result in thoracic curves. Carr et al. (1980) found that the curve pattern had no effect on the response to brace treatment.

Surgery is often used as a measure of failed conservative treatment. However, the indications for surgery have been altered during the past two decades, and there are many factors influencing the decision whether or not to operate. Therefore the number of cases fulfilling the original indications for surgery (curves exceeding 45°) are a more correct assessment of brace failure.

We report the incidence of failure, particularly with reference to the initial curve magnitude, skeletal and pubertal maturity, curve pattern, and brace type used.

Patients and methods

In 1986, 2780 consecutive patients treated for scoliosis with a brace were studied retrospectively. The patients were treated between 1969 and 1983, and all had been out of their brace for at least 2 years at the time of the investigation. Only females with adolescent idiopathic scoliosis were included, 7 of whom refused to participate, leaving 244 girls for the study.

The indications for brace treatment were a) a curve of 25° or more in b) children with a skeletal age of less than 16 years or a Risser sign below 4, and c) progression of more than 5°. Failure of a conservative treatment was considered to occur when the curve exceeded 45°. Six months of daily brace wearing was a minimum requirement to be accepted as treatment. Full-time (> 22 hours) brace wearing was recommended. The time of bracing averaged 24 months ±12 months. Weaning from the brace was initiated when the skeletal age exceeded 16 or when the Risser sign was 4+. In 1978, there was a change from the Milwaukee brace to the Boston brace. Twenty-one children started their brace treatment shortly before 1978, and thus in these cases both types of brace were worn by the same patient. They were included in the Boston group. The investigation was based on a review of charts and radiographs. For each patient the type of brace used, curve pattern, menarchal status, and initial skeletal age were listed (Table 1).

A multiple factor analysis of each predictor was performed. If all the predictors were expressed by only two values, a stepwise logistic regression analysis (Afifi and Clark 1984) could be used.

The scoliotic curve was classified as double major if the difference between the two curves was less than 5° at the time when the brace treatment was started. All the other curves were classified as single curves (thoracic, thoracolumbar, or lumbar). In the statistical analysis the curve patterns were expressed as thoracic and other. Double major curves were divided according to the apex of the largest curve in double-thoracic

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Table 1. Pecentage distribution of the predictors in the 244 patients included in the study

Brace type			Curve pattern				Menarchal onset		Initial skeletal age		Initial curve		
M	B	M + B	T	TL	L	D	Post	Pre	10–12 yr	≥13 yr	25–35°	35–45°	45°–
49	42	9	55	12	12	21	40	60	33	67	56	31	13

M Milwaukee, B Boston, T thoracic, TL thoracolumbar, L lumbar, D double major, Post or Pre menarche after or before the onset of treatment.

(assigned to the thoracic group) or thoracolumbar (assigned to "other").

Because the maturity of the skeleton estimated from a hand radiograph was one of the criteria for brace treatment, skeletal age was classified according to Greulich and Pyle (1959). The Risser sign was recorded in 25 percent of the children who were divided into two subgroups, one with skeletal age 10–12 years (approximately corresponding to Risser's signs 0 and 1) and one ≥ 13 years (approximately corresponding to Risser's signs 2 and 3). The curve was measured at the beginning of the treatment, at the end of weaning, at the 2 year follow-up or (for cases operated on within 2 years) at the time of the operation, and at the last follow-up 6 (2–15) years after weaning from the brace.

The initial curve magnitude was divided into three groups with cut-off points at 35° and 45°. The two groups with the largest initial curvature were separately compared with the first group.

Results

There was almost a 300 times greater risk of failure if the brace treatment was started in curves exceeding 45° than if the initial curvature was between 25° and 35°, independent of curve pattern, skeletal age, menarchal status, and brace type used (Table 2). The relative risk of initial curves in the interval between 35° and 45° was 38. The Milwaukee brace had a 5 times greater risk of failure than the Boston brace.

Concerning curve patterns, it seemed that thoracic curves had a worse outcome ($P < 0.05$). Skeletal maturity, menarchal status and age were not predictive.

A stratification of the whole material according to the initial curve magnitude (Table 3) showed few failures in curves less than 35°, but then a rapidly increasing failure. If those curves with an initial magnitude of 25° to 45°were included (n 213), two thirds of all true failures could be predicted at the time of the start of the brace treatment (sensitivity) and 92 percent of the successful treatments could be predicted (specificity).

Table 2. Relative risk for development of brace treatment failure for various predictors. The relative risk is expressed in disadvantage of the first alternative

Predictor	Alternative	Relative risk	*P*-value
Initial curve	≥45 / 25–35	299	0.0001
Initial curve	35–45 / 25–35	38	0.0001
Brace type	Milwaukee / Boston	5.1	0.0004
Curve pattern	thoracic / other	3.3	0.027
Initial skeletal age	10–13 / ≥13	1.8	0.32
Menarchal onset	postbrace / prebrace	1.5	0.45

Table 3. Correlation between initial curve magnitude (degrees) and the rates of failure and surgery

Initial curve		Failure		Surgery	
	n	n	%	n	%
25–29	63	3	5	3	5
30–34	75	2	3	1	1
35–39	44	17	39	11	25
40–44	31	19	61	11	35
45–	31	28	90	21	68

Table 4. Classification table presenting the validity of the predictors. Scoliotic curves of initial magnitude 25–45° (N 213). Positive = failure. Negative = successful treatment

Outcome	Prediction		
	Negative	Positive	Total
Negative	158	14	172
Positive	13	28	41
Total	171	42	213

Sensitivity 68%, specificity 92%, positive predictive value 67%.

The positive predictive value was two thirds (Table 4). When also the largest curves (≥ 45°) were included (n 244), the sensitivity and the predictive value both increased to 0.8.

Table 5. Correlation between brace type and initial curve magnitude (degrees) with regard to the failure rate, expressed as percentages

Initial curve	Brace type	
	Milwaukee	Boston
–35	9	0
35–45	62	31
45–	96	67

The Boston brace was more efficient than the Milwaukee brace (Table 5).

Discussion

Various predictive factors for curve progression have been suggested (Keiser and Shufflebarger 1976, Carr et al. 1980, Bigos et al. 1983, Lonstein and Carlson 1984, Bunell 1986, Emans et al. 1986, Lonstein et al. 1988). We found that the most important single predictor of brace failure was initial curve magnitude. Another factor of importance was the brace type used. In all the intervals of initial curve magnitude, the Milwaukee brace was responsible for a disproportionately large number of failures (Table 5).

We were surprised that skeletal and pubertal maturity did not correlate with brace failure. It has been stated that young children have a worse outcome of brace treatment (Moe and Kettleson 1970, Nachemson et al. 1982, Bigos et al. 1983, Lonstein et al. 1988) than older children. Rapidly progressing curves, supposedly progressing further, though not necessarily to failure, are detected at early ages. More benign, slowly progressing curves, with no tendency towards progression when braced, are detected closer to the end of growth. Therefore, maturity might correlate with the incidence of progression, but not with the failure rate. Finally, the change of brace in the course of the collection period may have interfered in this study.

Intervals of 10° is the most frequently used classification of the curve magnitude. The interval between 30° and 39° is the most interesting one, since it includes curves with different prognosis of progression. There is a trend in the policy today (Bigos et al. 1983, Winter et al. 1986) that curves of 30° hardly need to be treated. Table 3 indicates that an initial curve magnitude of 35° was a breaking off point for the incidence of failure. Almost all the patients with a prebrace curve of less than 35° had an acceptable final result, whereas a large proportion of those with an initial curve of more than 35° failed.

Further, Table 3 shows that there was a considerable difference between actually performed surgery and the number of cases fulfilling the indications for surgical intervention. The reasons for rejection varied, and were often hard to define.

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