Idiopathic Scoliosis
An 11-Year Follow-Up Study of the Role of the Milwaukee Brace in Curve Control and Trunco-Pelvic Alignment

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ABSTRACT: One hundred and fifty-two patients with idiopathic scoliosis were treated at the Alfred I. duPont Institute with the Milwaukee brace between 1961 and 1972. This study includes 94 patients and was undertaken to evaluate the effectiveness of Milwaukee brace treatment in managing various sequelae associated with idiopathic scoliosis, such as degree of curvature and trunco-pelvic alignment, and to assess the degree of spinal stability after treatment. Good results were obtained in patients with curves less 30°; in addition, there was improvement in trunco-pelvic alignment and curve correction. However, results varied considerably among patients and were unpredictable. Double major curve patterns were found to have a poor response to bracing. After bracing is stopped, rate of curve progression appears to decrease with time.

Introduction

The management of idiopathic scoliosis has always been a challenge to the orthopedic community, and the role of spinal orthoses as a means for treatment is widely accepted throughout the world. The Milwaukee brace originally was described in 1958 by Blount and Schmidt for the postoperative management of idiopathic scoliosis. This study is still the standard by which other spinal orthoses are evaluated in the nonoperative treatment of idiopathic scoliosis.

The effectiveness of the Milwaukee brace in the conservative management of idiopathic scoliosis is widely accepted and well documented in the literature. Various reports on the long-term follow up of treated and untreated patients with idiopathic scoliosis show that curve progression may occur even after a patient has reached skeletal maturity. Some investigators have suggested that the Milwaukee brace is most effective in treating curves of less than 40°. Others have shown that curves of greater than 40° have had the same percentage of improvement as those less than 40° in the brace.

Although trunco-pelvic alignment is an important factor in the treatment of idiopathic scoliosis, very little has been written on the subject and its response to bracing. One such study has been published, but it excluded the thoracic and double-major curve patterns. The purpose of this article is to study the effectiveness of the Milwaukee brace in controlling degree of curvature, as well as maintaining trunco-pelvic alignment, and to assess the degree of spinal stability achieved after treatment.

Materials and Methods

Between 1961 and 1972, 152 patients with the diagnosis of idiopathic scoliosis were treated with the Milwaukee brace at the authors' institution. One hundred and twenty-five of these patients were treated with the brace only and those with a follow up of 5 years or more after brace discontinuance were considered for this study. Of the 152 patients, 27 had to undergo posterior spinal fusion for various reasons.
Patients were asked to complete a questionnaire and undergo examination. At the time of this visit, standing posteranterior and lateral radiographs of the entire spine were obtained. Patients unable to return for an examination were asked to complete the questionnaire and have recent standing posteranterior and lateral radiographs of the spine forwarded to the investigators. Patients who could not be examined or have their films forwarded were excluded from the study. Sixty-seven brace-treated patients with a clinical and radiographic follow up of at least 5 years after brace discontinuation were analyzed separately from the 27 patients who had spinal fusion. Patients treated only with the Milwaukee brace were clinically examined and interviewed to assess physical appearance, determine incidence of back pain, and discuss the patient’s experiences in the brace.

Using the criteria of the Scoliosis Research Society, the curves were divided into thoracic, thoracolumbar, lumbar, and double-major patterns. In patients with double-major patterns, the curve with the most structural change was used for the purpose of analysis. The treatment stages were divided according to the following chronological landmarks: time of first visit, initiation of bracing, beginning of weaning from brace, completion of brace program, and current visit. In those patients who required posterior spinal fusion, the preoperative status of the curve also was recorded. All radiographs were taken with the patients out of the brace.

Radiographic evaluation consisted of measurements of the degree of curvature, trunco-pelvic alignment, and the status of the iliac crest apophysis, as graded by Risser. Cobb’s method was used to measure the degree of curvature. Trunco-pelvic alignment was determined as the horizontal distance between two vertical lines—one passing through the center of the greatest transverse diameter of the chest, and the other passing through the center of the pelvis (Fig. 1). The patient’s sex, age at initial treatment, and length of follow up were also noted.

Of the 67 patients who underwent conservative treatment, 59 were women and eight were men. The average age at initial bracing was 12 years (range, 7 to 16 years); only six patients were less than 10 years of age at the onset of treatment. There were four patients with curves under 20° at the beginning of treatment. Two had 19° curves, one had an 18° curve, and one had a 17° curve at onset of bracing. The average age at completion of the program was 16 years (range, 12 to 20 years). The average length of time in the brace was 3 years (range, 1 to 7 years). The average age at current visit was 27 years (range, 21 to 33 years). The average follow up was 11 years (range, 5 to 17 years). There were 37 thoracic, six lumbar, eight thoracolumbar, and 16 double-major patterns. There were 39 patients with a Risser grade of 0; 28 patients had a Risser grade of 1 or above at onset of treatment (Table 1).

Of the 27 patients who had a spinal fusion, nine had thoracic curves, two had lumbar curves, two had thoracolumbar curves, and 14 had double-major curve patterns. Three of these patients were men and 24 were women.
### TABLE 1

**DEGREE OF CURVATURE BASED ON RISSE R GRADE AT INITIAL VISIT**

<table>
<thead>
<tr>
<th>Risser Grade</th>
<th>Number of Patients</th>
<th>Initial Visit</th>
<th>Beginning of Weaning From Brace</th>
<th>Completion of Treatment</th>
<th>Current Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>39</td>
<td>32</td>
<td>25 (17-70)</td>
<td>28 (5-70)</td>
<td>32</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>36</td>
<td>30 (18-66)</td>
<td>31 (4-56)</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>35</td>
<td>33 (20-47)</td>
<td>35 (17-47)</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>34</td>
<td>28 (19-49)</td>
<td>28 (16-37)</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>32</td>
<td>31 (31-33)</td>
<td>31 (22-42)</td>
<td>40</td>
</tr>
</tbody>
</table>

**Fig. 2:** A poor result in an 11-year-old girl (Risser 1) at the onset of treatment, as seen in this radiograph demonstrating a 31° right thoracic curve and a 32° left thoracolumbar curve (A). At 12 years old, these curves progressed to 50° and 45°, respectively, in spite of compliant brace wear and required posterior spinal fusion (B).

### Results

Results of the conservative and surgical treatment groups are discussed separately. Responses to bracing varied significantly, as demonstrated in two cases (Figs. 2-3).
Fig. 3: A good result in a 16-year-old girl (Risser 0) at the onset of treatment, as seen in this radiograph demonstrating a 32° right thoracic curve with significant trunco-pelvic shift to the right (A). When she was 16 years old, the brace was stopped, the curve measured 25°, and there was improved trunco-pelvic alignment (B). At follow-up approximately 10 years later, the curve measured 27° and there was acceptable trunco-pelvic alignment (C).

Conservative Treatment Group

The results of Milwaukee brace treatment were evaluated according to the following factors: curve pattern, curve magnitude, Risser grade, trunco-pelvic alignment, and loss of correction. Table 2 summarizes the response to bracing in all 67 patients.

Of the 37 patients with thoracic curve patterns, 15 had initial curves of less than 30°. At the time bracing was stopped, 10 of the curves had decreased, 3 were unchanged, and 2 showed progression. Any increase over the original curve was considered progressive. For this group, the average rate of progression after the brace was discontinued was 0.2° per year. Those patients whose curves either progressed, improved, or remained unchanged were included for calculating the rate of progression for this group. Ten patients presented with thoracic curves of 30° to 39°. At the time bracing was discontinued, 7 curves decreased

<table>
<thead>
<tr>
<th>TABLE 2</th>
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<tbody>
<tr>
<td>DEGREE OF CURVATURE IN 67 PATIENTS TREATED WITH MILWAUKEE BRACE</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Pretreatment</th>
<th>Beginning of Weaning from Brace</th>
<th>Completion of Treatment</th>
<th>Current Visit</th>
<th>Rate of Progression (°/year)</th>
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<tr>
<td>Total Group</td>
<td>Average</td>
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<td>29</td>
<td>31</td>
<td>35</td>
</tr>
<tr>
<td>(n = 67)</td>
<td>Range</td>
<td>17-70</td>
<td>3-60</td>
<td>5-70</td>
<td>8-72</td>
</tr>
<tr>
<td>Thoracic</td>
<td>Average</td>
<td>34</td>
<td>27</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>(n = 37)</td>
<td>Range</td>
<td>19-70</td>
<td>3-60</td>
<td>5-70</td>
<td>10-72</td>
</tr>
<tr>
<td>Double-Major</td>
<td>Average</td>
<td>34</td>
<td>30</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>(n = 16)</td>
<td>Range</td>
<td>18-48</td>
<td>4-50</td>
<td>13-52</td>
<td>8-59</td>
</tr>
<tr>
<td>Thoracolumbar</td>
<td>Average</td>
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<td>27</td>
<td>26</td>
<td>31</td>
</tr>
<tr>
<td>(n = 8)</td>
<td>Range</td>
<td>17-49</td>
<td>16-40</td>
<td>15-44</td>
<td>17-46</td>
</tr>
<tr>
<td>Lumbar</td>
<td>Average</td>
<td>33</td>
<td>30</td>
<td>30</td>
<td>36</td>
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</table>

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and 3 showed progression. The average rate of progression after brace discontinuance was 0.5° per year.

Of the patients treated conservatively at initial evaluation, there were 12 with thoracic curves of greater than 40°. At the time bracing was stopped, 9 curves improved, 2 curves progressed, and 1 remained unchanged from original magnitude. The average curve progression after completion of brace treatment was 0.7° per year. The overall progression after completion of treatment was 0.5° per year.

In the double-major curve group, four patients had initial curves of less than 30°. At the time bracing was stopped, 3 curves improved and 1 progressed from original magnitude. For this group, the average rate of curve progression after the brace was stopped was 0.2° per year.

Seven patients presented with curves ranging from 30° to 39°. At the time bracing stopped, 2 curves improved, 4 curves progressed, and 1 remained unchanged. In this group, average curve progression was 0.3° per year.

Five patients with double-major patterns had initial structural curves of over 40°. At the time bracing was stopped, 2 patients improved, 2 patients progressed, and 1 remained unchanged from original magnitude. Average annual curve progression in this group was 0.3°. The overall progression rate after completion of bracing for the double-major group was 0.3° per year.

In the thoracolumbar and lumbar curve series, 8 patients had thoracolumbar curves, whereas 6 patients had lumbar curves. In the thoracolumbar group, the average degree of curvature was 30° at initial visit, 26° at brace discontinuation, and 30° at follow up. In the lumbar group, the average degree of curvature was 33° at initial visit, 29° at brace discontinuation, and 36° at follow up. The rate of progression after discontinuing the brace was 0.3° and 0.6° per year for the thoracolumbar and lumbar curves, respectively. All pertinent data for these particular curve patterns can be found in Table 2.

In those patients treated by bracing alone, curves showed an average improvement of 12% at the beginning of brace weaning, 6% improvement at treatment completion, and 12% worsening at current visit, in comparison with the initial curve measurement (Fig. 4).

A comparison was made between the 33 patients with curves measuring 30° to 39° and the 15 patients with curves of 40° to 49° at presentation (Fig. 5). The groups were similar in regard to patient age at the beginning of treatment, curve patterns, Risser grade, and length of follow up. Sixty percent of the patients with curves of 30° to 39° were within 5° of their
initial curves at follow up, as compared with 66% in the 40° to 49° group. The groups had comparable lengths of full-time brace wear; however, the 40° to 49° group had a weaning period of 2.17 years, as compared with 1.19 years in the 30° to 39° group. This result is statistically significant, with a P value of less than 0.005, and shows that the 40° to 49° group required more time to stabilize the curve.

To assess the influence of the degree of curvature at completion of treatment on curve progression, a comparison was made between curve measurements at the time bracing was discontinued and those calculated at the time of the current visit (Fig. 6). Thirty-one of the 67 conservatively treated patients had curves of less than 30° when treatment was completed. At follow up, 83% of these curves were within 5° and 90% were within 10° of the measurements that were taken at the end of treatment. Twenty-two patients had curves of 30° to 39° after bracing. At follow up, 65% of these were within 5° and 95% within 10° of the posttreatment measurement. Sixteen patients had curves of greater than 40° when bracing was discontinued. Of these, 62% were within 5° and 88% were within 10° of the end-of-treatment curves at latest follow up.

The correlation between percentages of correction of trunco-pelvic alignment and the degree of curvature for the 67 patients is shown in Figure 4. The average initial trunco-pelvic alignment was 1.44 cm (range, 0.1 to 4.1 cm). The average improvement in trunco-pelvic alignment was found to be 24.6% at the beginning of weaning from the brace and 14.6% at the time treatment was completed. At the time bracing was stopped, 58% of patients showed improvement of trunco-pelvic alignment (Fig. 7). At follow up, there was an overall 4.8% worsening when compared with the trunco-pelvic alignment at the initial visit; 49% of patients maintained an improved trunco-pelvic alignment. An analysis of trunco-pelvic alignment in various curve patterns showed that the thoracic, thoracolumbar, and lumbar curve patterns displayed more improvement during the treatment period than the double-major curves.

In order to assess the average amount of curve correction lost after treatment was discontinued, the patients were divided into two groups; group A, with follow up of less than 12 years after completion of treatment and group B, with more than 12 years of follow up (Table 3). There were 43 patients in group A and 24 patients in group B. The average follow up for these groups was 9 years and 14 years, respectively. The average rate of progression was 0.5° per year for group A and 0.3° per year for group B.

Clinical evaluation of the patients showed that 23 patients (34%) complained of some back pain or
discomfort at the level of the curve, although no patient took medication for pain relief on a regular basis. Most of the patients who had back pain complained of low back pain without any radiation into their legs.

Spinal Fusion Group

Of the 27 patients who had a posterior spinal fusion, the indications for surgery included true brace failure (13 patients), poor brace compliance (seven patients), poor patient selection (six patients), and chronic back pain (one patient). Patients with curves over 50° at initial visit were considered poor candidates for bracing. Patients with curve progression in spite of compliant brace wear were considered as part of the true brace failure group. If only the true brace failure group is considered, then the percentage of patients in this series who required spinal fusion was 8.5%.

In this group, 19 patients had surgery while undergoing active brace treatment; eight patients had surgery after brace treatment had been discontinued. The average curvature prior to brace treatment was 40° and the average curvature prior to surgery was 48°.

In the surgically treated group, curve patterns included 14 double-major curves, nine thoracic curves, and two each of the lumbar and thoracolumbar types. There was a striking difference in the curve patterns between the conservatively treated and surgically treated groups. The double-major curve pattern accounted for 52% of the patients in the surgically treated group, compared with only 23% in the brace-treated group. The two groups were comparable in chronological age and Risser grade at the onset of treatment. The average curve in the braced group was 33° at initial visit, compared with 40° in the spinal fusion group, demonstrating a higher curve magnitude in the spinal fusion group. The compliance rate was 92% in the conservatively treated group and 70% in the spinal fusion group.

Discussion

In our series, the standard response to the Milwaukee brace was achievement of moderate improvement during the time the brace was being worn, with some increase in curvature after bracing was discontinued. At follow up, 73% of patients were within 5° of their initial curve.

An evaluation of the various curve patterns showed that double-major deformities experienced the least amount of correction upon completion of treatment, with an average correction of 0°. This compares with 5° of correction for thoracic curves, 4° of correction for thoracolumbar curves, and 3° for lumbar curves. At follow up, the thoracic and thoracolumbar curves were of equal magnitude to the initial curves, whereas the double-major curves had an overall increase of 3°. There was an average progression of 3° in the lumbar curves from the initial curvature; however, the number of patients in this group (6) was too small to draw definite conclusions. The relatively poor response of the double-major curve patterns to bracing also was demonstrated by the fact that 52% of the patients who underwent spinal fusion had double-major curves.

Our study is consistent with previous reports in that it shows that both thoracic and double-major curves of less than 30° tend to have much better outcomes than curves greater than 30°. However, contrary to other findings, we discovered that on long-term follow up, the brace produced similar results in curves of 30° to 39° and 40° to 49°.

The rate of curve progression after skeletal maturity has recently been studied in patients with untreated scoliosis. The overall progression reported was 0.8° per year for those curves between 30° and 39° and 1.9° per year for those between 40° and 60°. In our study, the rate of progression for curves under 30° was 0.3° per year; for those between 30° and 39°, the rate of progression was 0.5° per year; and for those over 40°, the rate of progression was 0.3° per year.

Other studies also have shown that no predictable
improvement in spinal decompensation can be expected.\textsuperscript{17} Previous authors have suggested some improvement in trunko-pelvic alignment due to Milwaukee brace treatment.\textsuperscript{5,10} Of the 67 patients in our study, we found an average 14.5\% improvement in trunko-pelvic alignment when bracing was discontinued. At long-term follow up, there was an overall 4.8\% worsening of trunko-pelvic alignment. Fifty-eight percent of patients had an improved trunko-pelvic alignment at the time bracing was stopped. Forty-nine percent of patients had an improved trunko-pelvic alignment at follow up as compared with their initial visit.

The relationship of Risser grade to the amount of curve correction showed that patients with Risser 0 or 1 had comparable responses to bracing. Curves in the Risser 4 group had the worst response.

The study of the length of follow up after completion of treatment showed a progression rate of 0.5° per year for those patients under 12 years old and 0.3° per year for those patients over 12 years old after completion of brace treatment. There appears to be a tendency for a gradual decrease in the rate of progression with time as the spine achieves stability. Patient compliance is an important factor in successful treatment, as shown by the fact that in the spinal fusion group, the compliance rate for Milwaukee brace wear was considerably lower than in the conservatively treated group.

**Conclusion**

The response to Milwaukee brace treatment varies considerably between patients. In light of the recent studies that have measured the degree of spinal stability achieved after discontinuing the brace,\textsuperscript{3,5,8,16,17} wide variability in the response to brace treatment should be anticipated. The best results are seen in curves of less than 30°. If the patient's cosmetic appearance is acceptable, curves in the 40° range also can be treated successfully by the Milwaukee brace. Double-major curve patterns tend to have a poor response to brace treatment. The brace did improve the trunko-pelvic alignment in addition to curve correction; however, the results are unpredictable and the rate of curve progression decreases with time after brace treatment.

**References**


