Bracing scoliosis: the evolution to CAD/CAM for improved in-brace corrections

HR Weiss1*, S Seibel1, M Moramarco2, A Kleban3

Abstract

Introduction

There are a wide variety of brace applications available today with different outcomes and different characteristics. The purpose of this study is to compare in-brace corrections of the series applied today to recent Chêneau style series as presented in literature.

Methodology

All patients were registered and fulfill the Scoliosis Research Society inclusion criteria for studies on bracing from 2012. A total of 21 female patients matched with the Scoliosis Research Society inclusion criteria. These 21 girls were of an average age of 12.2 years (standard deviation = 1.1). Average Risser stage was 0.38 (standard deviation = 0.68), average Cobb angle was 31.33° (standard deviation = 6.58). In-brace correction from this sample has been compared to the in-brace corrections of other Chêneau samples as published in literature using a test for comparison of two different proportions.

Average Cobb angle in the brace was 10.66°; 34% of the initial angle was 31.33° (standard deviation = 6.58). In-brace correction when compared to symmetric braces. Asymmetric braces allow better in-brace correction when compared to symmetric braces. Asymmetric braces according to the actual, Best Practice® computer-aided design/computer-aided manufacturing standard allow for improved in-brace corrections promising the best possible radiological and cosmetic end results. Future studies on in-brace corrections and outcomes on brace treatment should use the Scoliosis Research Society inclusion criteria for bracing to improve comparability.

Conclusion

Symmetric braces are outdated. Asymmetric braces allow better in-brace correction when compared to symmetric braces. Asymmetric braces are constructed in an attempt for overcorrection with foam pads used for augmentation in the pressure areas but also for providing spaces on the opposing sides of the pressure areas. The most effective asymmetric brace is the Chêneau brace. The primary advantage of the Chêneau brace over symmetric braces is the higher in-brace correction. Its unique structure allows for a correction in three dimensions (in the sagittal, frontal and transverse planes) and allows room for corrective breathing. A recent study reveals improvement of in-brace correction of future developments should be non-surgical scoliosis management via Best Practice® based upon Schroth Method principles. The newest Chêneau brace is also manufactured using less material making the brace lighter than previously manufactured braces with the goal of improving comfort and wearability offering increased likelihood of improved patient compliance (Figure 2).

It is generally agreed that bracing outcomes are determined by the amount of in-brace correction and compliance. Therefore, the aim of future developments should be improvement of in-brace correction and comfort. A recent study reveals that not all Chêneau braces are of comparable quality or have the ability to achieve the same in-brace correction. Borysov and Borysov

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have demonstrated the capability to attain a high standard with hand-made braces using the plaster technique\(^1\), however, the outcomes of Chêneau braces created elsewhere have varied significantly; between 56%\(^{14}\) and >95% successful\(^{15}\) based on in-brace correction.

Chêneau braces made by the cast technique are at a disadvantage because they lack standardization. Even among specialists, there will always be a wide range of quality. When constructing a brace by cast, the clinician must start anew each time without a baseline standard. With each correction and alteration, the brace is vulnerable to deterioration. These deteriorations can cause the brace’s function to veer from the original intended curve pattern correction (Figure 2).

A solution is CAD/CAM technology. For 3 years, brace formulas from a library created by the first author have been used to address specific curvature patterns\(^1\). The augmented Lehnert-Schroth (ALS) classification determines which brace formula from the library is best matched to an individual patient (Figure 3). These basic patterns are key patterns. Special patterns are also available for certain presentations, such as double thoracic patterns, kyphotic patterns and adults. Furthermore, each brace (whether made from key patterns or special patterns) from the library are always customized to the individual through adjustments for comfort and function.

The baseline standard of these braces can be improved without generating new problems by adjusting unforeseen complications. Any reported problems with the braces created from the library are registered and are easily modified using CAD. After CAD modification, the problem is solved for the entire series. When compared to previously worn braces, patients have reported braces from the library (Figures 3–5) to be more comfortable.

The purpose of this study is to compare in-brace correction of the CAD/CAM series as currently applied to the Chêneau series as presented in literature previously\(^1\).
Methodology

In accordance with Scoliosis Research Society (SRS) inclusion criteria for studies on bracing all patients fulfilled the following criteria.7

The SRS inclusion criteria for bracing studies:

1. Age at bracing = 10 years and older
2. Primary curve = 25–40°
3. Risser sign = 0, 1 or 2
4. No prior treatment
5. Females—premenarchal or one-year postmenarchal
6. Include all patients regardless of compliance (‘intent to treat’)

The 21 females who matched the criteria were of an average age of 12.2 years [standard deviation (SD) = 1.1] with the following distribution of curve patterns:

Thoracic: \( n = 11 \)
Double major: \( n = 4 \)
Lumbar: \( n = 4 \)
Thoracolumbar: \( n = 2 \)

Average Risser stage was 0.38 (SD = 0.68) and average Cobb angle was 31.33° (SD = 6.58).

In-brace correction from this sample has been compared to the in-brace correction of other Chêneau samples as published in literature.11,13,15,18–21

Results

Average Cobb angle in brace for our sample was 10.66° (SD); 34% of the initial angle resulting in an in-brace correction of 66%.

The results in comparison to others are demonstrated in Table 1. A significant difference is revealed showing that the application of CAD/CAM braces leads to better in-brace corrections than cast-made braces, and also better in-brace corrections than previous results for CAD/CAM braces as previously published (RSC).19

Discussion

During growth, it is of vast importance that brace treatment is established immediately and with the most effective brace available. To attempt

Figure 3. ALS classification as used for the selection of the appropriate brace from our Gensingen library. (From left to right) 3CH, 3-curve with hip prominence; 3CTL, 3-curve with hip prominence thoracolumbar; 3C, 3-curve balanced; 3CL, 3-curve with long lumbar countercurve; 4C, 4-curve double; 4CL, 4-curve single lumbar; 4CTL, 4-curve single thoracolumbar.

Figure 4. Brace from a patient of this series with a full correction of the single thoracic curve pattern. This patient, from New Zealand, was 12 years old with Tanner II–III and therefore still rather flexible.

the protocols of these studies have been approved by the relevant ethics committees related to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in these studies.

In 2011, a prospective trial commenced using the referenced CAD/CAM approach. Patients included were from November 2011 to December 2012.

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Figure 5. Clinical result of a 15-year-old patient with a 42° Cobb angle at the start of treatment with marked progression within a few weeks. Right: Clinical result following 6 months of treatment after outgrowing her first brace. Pelvic width has increased as compared to the photo at far left revealing skeletal immaturity at the start, age 15, although normally 15-year-old girls are nearly fully grown (to 99%).

Table 1. Papers on the Chêneau brace treatment of patients with Adolescent Idiopathic Scoliosis as can be found in PubMed and the journal ‘Scoliosis’ where the average in-brace correction (φ corr) is documented (φ corr and Φ Cobb angle have been rounded). Statistical analysis revealed significant differences of the in-brace correction achieved when the results from this sample (Weiss et al., 2013) were compared to previous studies11,18,21 (t = 2.4 and 3.64, respectively, in a statistical test to compare two different proportions)

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>n</th>
<th>φ Corr</th>
<th>Φ Cobb</th>
<th>Significance</th>
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<tr>
<td>Hopf and Heine11</td>
<td>1985</td>
<td>52</td>
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<tr>
<td>Rigo et al.18</td>
<td>2002</td>
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<td>37°</td>
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<tr>
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<td>2007</td>
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<tr>
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<td>81</td>
<td>51%</td>
<td>36°</td>
<td>ns</td>
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<tr>
<td>Maruyama et al.21</td>
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<td>54</td>
<td>36%</td>
<td>37°</td>
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<tr>
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<td>31°</td>
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<tr>
<td>Borysov et al.13</td>
<td>2013</td>
<td>92</td>
<td>56%</td>
<td>29°</td>
<td>ns</td>
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<tr>
<td>Weiss et al. (this study)</td>
<td>2013</td>
<td>21</td>
<td>66%</td>
<td>31°</td>
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</tbody>
</table>

Methodology


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Methodology

Competing interests: declared in the article. Conflict of interests: declared in the article.

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 Rather low. In addition, only selected single patterns of curvature have been included. The average Cobb angle of the subset of patients with thoracic curvatures is only 24°, and thus is not comparable to the other samples in Table 1. Unlike in the other studies, double curvatures obviously have been excluded. Despite these limitations, the final results, as reported, must be regarded as far above average.

In-brace correction is more easily and more safely achieved with braces from the standardized CAD library developed by the first author. In comparison, cast braces do not offer the same basis of standardization that can allow the patient the potential for improved in-brace corrections and outcomes. Unfortunately, there are a few individuals skilled enough to reproduce the standard of CAD technology via casting.

Since November 2011 when the prospective study was started, we have applied more than 600 CAD/CAM Chêneau braces in Gensingen. Many of these patients before the study start have been treated elsewhere or in first author’s clinic; many patients’ age exceeded the limits of the SRS inclusion criteria. Many patients had curvature angles exceeding 40°. Therefore, we were able to include only this small number (21 patients) into the current study.

This exactly is the problem that many patients come late to be braced, at an age and with a Cobb angle that no longer fit within the margins of the SRS inclusion criteria.

Many patients with scoliosis, therefore, are needed to start such an endeavour of a prospective cohort complying with these criteria.

Cobb angle, on the other hand, certainly cannot be regarded as the most important outcome measure for the patient. As has been demonstrated, our new series of CAD/CAM Chêneau braces is able to improve trunk asymmetry significantly even in curves exceeding 40° Cobb angle. Maybe in the future we will be able

Figure 6. Rib hump of the patient from Figure 5 left at the start and right after 6 months of brace treatment.

Figure 7. Immature patient initially treated for a curve of more than 30° at the age of 8 (left). During the growth spurt, part-time treatment is enough as the curve is below 20° as illustrated in the intermediate result (far right). The 2nd, 4th and 6th x-rays from the left are in-brace x-rays showing that there was no further improvement possible with respect to in-brace correction.

Figure 8. A 14-year-old girl from the US with a 53° curve thoracic to the right. As she is still skeletally immature (Risser 2), the first author decided to brace her pattern specifically with a 3CL Chêneau brace from the Gensingen CAD/CAM library. In the end, the curve corrected minimally in the thoracic area (to 40°) and the apical area in the x-ray seems quite stiff. Nevertheless, a slight correction can be expected upon outgrowing the brace. The next brace will be of the 3CH model (see Figure 5) shifting the decompensated trunk even more to achieve an improved good cosmetic outcome.

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Methodology

to change the measure for outcome from the Cobb angle to cosmetic issues, which might be more important for the patients themselves.

Symmetric braces will not allow the best possible in-brace correction and therefore are outdated today and should no longer be used as these do not promise the best possible percentage of beneficial outcomes and final corrections especially in curves exceeding 45° have never been demonstrated using symmetric braces27.

Conclusion

• Symmetric braces are not of the same standard as asymmetric braces.
• Asymmetric braces allow better in-brace correction.
• Asymmetric braces according to the Best Practice® CAD/CAM standard allow for optimal in-brace correction that in turn yields the best possible end result.

Competing interests

HR Weiss is advisor of Koob GmbH & Co KG

Conflicts of interests

HR Weiss is advisor of Koob GmbH & Co KG, M Moramarco is a US provider of the Chêneau Gensingen Brace™.

Abbreviations list

ALS, augmented Lehnert-Schroth; CAD, computer-aided design; CAM, computer-aided manufacturing; SD, standard deviation; SPORT, symmetric, patient-oriented rigid trunk orthosis; SRS, Scoliosis Research Society.

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All patients visible on the pictures and their parents have kindly agreed to the publication of their photos within this article. The authors are thankful to Kathy Moramarco for copyediting the manuscript and for her precious suggestions.

References


Methodology

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