Standardising the treatment with Chêneau braces via CAD: Prospects and risks

HR Weiss

Abstract

Introduction

The use of a brace has become accepted as an effective way to treat idiopathic scoliosis. However, the effectiveness of today’s Chêneau treatment goes way beyond just controlling an increase in curvature during adolescence. In the meantime, it has been demonstrated that significant cosmetic corrections to torso asymmetry are possible even with curvatures above the 50° limit. According to the latest findings, the development in making Chêneau braces, from plaster models to CAD/CAM-based production, can help improve the standard of treatment. In particular, universal availability makes it possible for scoliosis sufferers to receive high-quality braces where they live even when there is no specialist in the vicinity.

Methodology

This is a selective review of the literature with respect to the outcome of Chêneau brace treatment. Additionally, the different CAD approaches as available today are presented and reviewed critically on the basis of current evidence.

Conclusion

With the CAD/CAM technique, it is possible to receive a brace of highest quality and best possible comfort within just a few days. Medical supply stores that are not very specialised will still have access to models that are standardised and tested in practice. However, individual CAD/CAM-based treatment without a time-tested brace library and without supervision by a specialist will not result in any advantages for the patients.

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Sobernheim. In these courses, Dr. Chêneau demonstrated the technique of producing braces and talked about his constantly on-going developmental work. Dr. Rigo took part in these courses as well. He learned how to produce Chêneau orthoses from a plaster cast. A collaborative effort came about that led to the book ‘Praxis der Chêneau-Korsettversorgung in der Skoliosetherapie’ (The Practice of Producing Chêneau Braces in Scoliosis Therapy) being published in 2000 by authors Hans-Rudolf Weiss, Manuel Rigo and Jacques Chêneau. In 2002, the author introduced CAD/CAM treatment at the Asklepios Katharina Schroth Clinic, which he was the head of at the time. He initially used the system on which Rigo’s plaster models were based. While Rigo contributed more and more self-produced plaster models from Barcelona, the CAD versions of the models were tested in Bad Sobernheim. It had always been the author’s desire to make braces smaller and more comfortable for patients. In the course of his own developmental work (Bad Sobernheim deflexion orthosis, see also), he started to consistently leave off one pelvic half of the brace (Figure 1) in 2001, amidst protests by Chêneau. This was later followed by the development of the Chêneau light® model. In 2009, he eventually began to develop his own CAD series (Gensingen Brace according to Dr. Weiss® – GBW) with sagittal correction that was optimised even further. Now with his own brace library, it has been possible for the author to incorporate his experiences in producing more than 30,000 braces and make further developmental steps towards braces that are ‘smaller and more comfortable with the best possible correction’ (Figure 2). Various people and health centres have played decisive roles in the history and development of producing Chêneau braces. In Germany, besides those in Sobernheim, Prof. Neff in Berlin and Freddy Hoeltzel in Offenburg deserve mentioning. However, the Chêneau principle is used in many countries. For instance, the author met a Chêneau student (Li Xiangdong) at a convention in Beijing in June 2013 and visited his workshop.

Methodology

The Scientific Principles of the Chêneau Brace Treatment

In 1985, the first study of the Chêneau brace including end results after patients were weaned off the brace was published by Hopf and Heine. While this study did not have a control group, the corrective effects of the Chêneau brace treatments at the time were described. They can be compared with those achieved today. Later, there was a series of publications on the Chêneau brace with comparable corrective results. Even back then, the corrections from the Chêneau brace were clearly superior to those with the more-or-less symmetrically constructed Boston brace. Recently, it has been possible to improve the corrective results from various Chêneau brace models even further (Table 1 from 29). The end results of the latest trials published are interesting as well: While the success rate (no evidence of progression) in a prospective study was still at 80% with the 1999/2000 standard, we can now assume a success rate of over 95% with modified Chêneau braces according to the current standard based on two...
Table 1: Publications on Chêneau brace treatment of adolescent scoliosis in Pub Med and 'Scoliosis'. The average corrective effect (\( \% \) corr) is stated in the studies and was statistically compared to the current CAD standard (Gensingen Brace according to Dr. Weiss®). This statistical analysis reveals significant differences compared to several former treatment methods\(^7,11,14\).

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<tr>
<td>Hopf &amp; Heine(^7)</td>
<td>1985</td>
<td>52</td>
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<tr>
<td>Rigo et al.(^14)</td>
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<td>105</td>
<td>31%</td>
<td>37\°</td>
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<td>Rigo(^16)</td>
<td>2007</td>
<td>32</td>
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<td>Weiss et al.(^22)</td>
<td>2007</td>
<td>81</td>
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<td>36\°</td>
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<td>Maruyama et al.(^11)</td>
<td>2012</td>
<td>54</td>
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<td>Weiss &amp; Werkmann(^25)</td>
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<td>34</td>
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<td>Borysov et al.(^2)</td>
<td>2013</td>
<td>92</td>
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<td>Weiss et al.(^28)</td>
<td>2013</td>
<td>21</td>
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### Methodology

Independent trials\(^4,25\). While the last two studies referred to are retrospective, they are nevertheless based on the inclusion criteria recommended by the Scoliosis Research Society (SRS)\(^13\). What is more, the end results are much better than the 72% success rate of the randomised study done in North America, which was celebrated there as proof of the effectiveness of scoliosis orthoses\(^30\). However, the effectiveness of state-of-the-art Chêneau treatment goes way beyond just controlling an increase in curvature or potentially correcting curvatures during adolescence (Figure 3)\(^26\). In the meantime, it has been demonstrated that significant cosmetic corrections to torso asymmetry are possible even with curves above the 50° limit (Figure 4)\(^27\).

**Prospects of CAD-Based Chêneau Brace Production**

Producing braces from a plaster cast is a practice that is still quite widespread today. Standardisation is practically impossible with this method, since every brace is newly modelled and constructed. As a result, there is considerable variability, with the results ranging from 'satisfactory' to 'very good' with experienced technicians, while braces made by technicians without suitable experience rarely earn a 'satisfactory' mark. And yet it is important for patients that an ideal corrective effect be achieved and, along with maximum comfort. As is well-known, the best possible treatment results can only be expected from a combination of good corrective results with optimum wearing time\(^26\). In contrast, producing Chêneau orthoses from individual measurements / scan data with CAD/CAM can be a highly reliable way to make braces under certain circumstances. The requirements for this are: 1) a fine-tuned brace library, 2) supervision by a specialist and 3) a distortion-free brace sizing programme. The corrective effect from the orthosis and patient compliance are the primary factors that determine the end result\(^26\). A pattern-optimised orthosis processed according to the latest findings determines the (three-dimensional) corrective effect. Together with adept psychological patient management, the degree of comfort and inconspicuousness of an orthosis paves the way for optimum levels of compliance. An orthosis can only be comfortable when compression effects are precluded. Due to constant product development of CAD-based orthoses, this can be guaranteed thanks to improvements to the CAD library. Minimising the orthosis size – reducing it to what is absolutely necessary – can be accomplished during the developmental phase as well. The pattern library of the Gensingen brace according to Dr. Weiss® (GBW) consists of 7 basic patterns (Figure 5). These were derived from the Augmented Lehnert-Schroth Classification\(^23\). Special forms that recur less frequently have also been added. This covers the majority of possible curvature patterns (approx. 90%). For the approx. 10% that remain, pattern selection and sizing can be followed by subsequent adjustments and optimisation using a...
special programme. In this way, highly individualised brace treatment is possible even with so few basic patterns. By basing orthosis production on CAD and through the use of a suitable brace library, cumulative and time-tested know-how is available anytime and anywhere. This kind of brace production is not dependent on the daily form or learning curve of the technician. Medical supply stores that are not very specialised will have access to models that are standardised and tested in practice.

Another advantage of the state-of-the-art CAD/CAM technique has to do with how quickly braces can be provided. Foreign patients (from Italy, England, the Netherlands, Russia, Malaysia, China, South Korea, USA, New Zealand) are regularly treated at the author’s practice. Using the CAD/CAM technique, we can offer ‘overnight’ service. The patients are fitted with the brace on the day following the examination. In the practice of Dr. Moramarco in the USA (Scoliosis 3DC), the GBW is also fitted the next day, and sometimes even on the same day. Patients come to him from all 50 states.

Discussion
Risks of CAD-Based Chêneau Brace Production
Despite all of its advantages, even the CAD/CAM method of producing braces has a few remaining sources of errors, usually attributable to an improper design (e.g. flat back design), to faulty modelling or simply to selecting the wrong pattern.

The significance of the sagittal profile when producing braces for idiopathic scoliosis – what factors speak against a ‘flat back design’?
There are CAD models in Germany that neglect sagittal profile correction or even increase the tendency of flat back syndrome and lumbar kyphosis (flat back design). For this reason, such orthoses are only truly recommendable for thoracic kyphoscoliosis (Figure 6). The majority of scoliosis cases are idiopathic (80-90%) and are identified as such when thoracic curvatures develop into flat back syndrome. Lumbar curvatures lead to a reduction of lumbar lordosis and even to lumbar kyphosis. The flattening of the sagittal profile therefore needs to be counteracted in the orthosis by accentuating the sagittal profile if the deformity is to be consistently corrected in all three planes. Several studies have demonstrated that forced lordosis of the upper lumbar region alone contributes towards correcting lateral curvature. A case study19 and a small series study21 successfully documented the fact that it is possible to improve scoliosis simply by means of forced lordosis of the upper lumbar region. Recently, van Loon and associates17 have confirmed these findings with a more comprehensive radiographic study. This is reason enough to rule out the treatment of idiopathic scoliosis with orthoses that counteract lumbar lordosis. An aggravating factor is the fact that reducing lumbar lordosis correlates closely with the incidence of chronic back pain in adulthood5,6.
Faulty Modelling

The modelling of a brace has to do with how pronounced a brace model’s individual zones are. The prospects of success of a brace library also harbour risks with respect to modelling: Systematic errors that go unrecognised are passed on from brace to brace. The author has come across one example of a systematic error again and again: poor rotational stability of a CAD-series brace. Horizontal rotational instability (brace twist) is usually due to a stop point that is incorrect or even non-pronounced (point 37 according to Chêneau) or because of an improper balance between other pressure zones. In such cases, the brace usually twists towards the back on the side of the rib hump. The rib hump is then inside the free space that was originally in ventral position and is now in lateral position (see also Figure 5 lower right), thus losing the corrective effect that was good at the outset. This problem occurs regularly in some treatment series and is attributable to a systematic modelling defect (Figure 7). Side shift that is insufficient or completely lacking or forms with not enough curve or ‘mirroring’ will result in a poor corrective effect. Even if all pressure zones are at the proper height, it will be necessary to replace such an orthosis or at least alter it considerably. At times, the opinion of a medical specialist may be required to optimise an existing brace (Figure 8).

Curvature Pattern and Brace Selection

Chêneau braces were originally produced taking the simple classification according to Lehnert-Schroth9, 10 as a basis. Chêneau initially published a brace type for curvatures with a main thoracic curve (triple-curve or functional 3-curve pattern) and one for double-curve curvatures or lumbar-dominant curvatures (quadruple-curve or functional 4-curve pattern). This simple classification according to Lehnert-Schroth is still sufficient today for findings-oriented

Figure 5: The seven basic models of the Gensingen library. First row from the left: Model 3BH, Model 3BTL, Model 3BN, Model 3BL. Second row from the left: Model 4B, Model 4BL, Model 4BTL. Far right: a view of Model 4B from above, showing the extensively protruding ventral free space. (3B = functional 3 curve pattern / 4B = functional 4 curve pattern).

Figure 6: Comparison of two CAD models. Left: on the side panel, harmonic sagittal profile with lumbar lordosis and mildly accentuated thoracic kyphosis, a profile that is also perceived as comfortable by patients. The pelvis can extend out the back (arrow). Right: on the side projection, the obsolete flat back form promoting lumbar kyphosis can be recognised (flat back design). As early as 2003, it was indicated that promoting lumbar lordosis should invariably be a corrective component for treating idiopathic scoliosis15. Moreover, there is a pronounced compression effect between the pelvic section blocking lordosis and the heavily accentuating point 37 (arrows). Abdominal problems (increased pains during monthly periods) have been described (source: Scoliosis Info Forum).
physiotherapy. For the pattern optimised production of corrective trunk orthoses, however, it is necessary to further differentiate this system of classification. The more growth that is anticipated for a patient, the more optimised the brace pattern has to be in order not to cause the progression of secondary curvatures. The brace model needs to perfectly mirror the curvature pattern during times when intense growth is anticipated in order to reliably prevent the progression also of secondary curvatures (Figure 9). In Figure 10, we see a course of treatment that was originally good, but which was nullified by improper treatment later on. The more mature a patient is, the more important it is to focus on correcting the main curvature as much as possible. In some cases, the secondary curvature is intentionally neglected. Such treatment control presupposes a wealth of treatment experience, and only an experienced specialist can guarantee its success. Towards the end of the growth period, it is essential to mirror the static misalignment of the torso (decompensation). Only in this way will a balanced end result be achieved. Such a result 1) is the most cosmetically pleasing, 2) has the least risk of curvature increasing after adolescence, and, in the author’s experience, 3) has a lower probability of pain in adulthood.24, 29. If the CAD method is individually applied when no fully developed library is available, it provides no advantages over providing a brace produced from a plaster cast – other than that the patient does not have to endure the unpleasant plaster cast procedure. Neither the design nor the modelling nor the pattern selections are standardised. Each brace constructed this way is like a game of chance. The learning curve to produce braces of above-average quality takes years to master. Any individual brace of average or below-average quality cheats patients of the best possible treatment currently available, usually with unpleasant results for the patients. Reports of such experiences are reproduced in the author’s scoliosis guidebook.24, 29. Nowadays, the regular occurrence of below-average results, pain from the orthosis, unnecessary prolongation of the wearing time, reduced comfort, and needless limitations in day-to-day life can easily be avoided.

**Conclusion**

According to the latest findings, the development in making Chêneau braces, from plaster models to CAD/CAM-based production, can help improve the standard of treatment. In particular, universal availability makes it possible for scoliosis sufferers to receive a high-quality brace where they live even when there is no specialist in the vicinity. Nowadays, the regular occurrence of below-average results, pain from the orthosis, unnecessary prolongation of the wearing time, reduced comfort, and needless limitations in day-to-day life can easily be avoided.
Methodology

Conflict of interests
HR Weiss is advisor of Koob GmbH & Co KG

Competing interests
HR Weiss is advisor of Koob GmbH & Co KG

References

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Figure 9: Depiction of mirroring various curvature patterns in the brace. Brace 4BTL was fitted for a physically handicapped boy. Of note is the feature for restoring lumbar lordosis, which gave the patient good stability when sitting.

Figure 10: Left: immature patient with 51° at the beginning of her treatment. Centre: After 9 months, slight curvature correction with noticeable recompensation after treatment with a 3BH brace. A new brace was produced according to the same principles. In 2009, the patient was then had outgrown the second brace and received the centre right brace from a different technician. The heavily protruding lumbar pad continued to cause decompensation of the thoracic curvature by press against the 11th rib. Right: The author saw the patient again with 75°. The experience report is reproduced in the author’s guidebook, I Have Scoliosis24.
Methodology

Competing interests: declared in the article.

All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

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