Spinal Surgery

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Critical review

Remodelling of trunk and backshape deformities in patients with scoliosis using standardized asymmetric computer-aided design/computer-aided manufacturing braces

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Abstract

Introduction

In the literature, there are papers on scoliosis reporting improvements of spinal curvatures under brace treatment, but this predominately relates to results revealed on X-ray, not clinically. Therefore, it is worthwhile to review the literature showing improvements after brace treatment and to show what can be done conservatively via bracing in curvatures exceeding 45° Cobb.

Materials and methods

- A PubMed review of the literature with a keyword search for 'scoliosis', 'brace treatment' and 'improvement' and alternatively for 'scoliosis', 'orthosis' and 'improvement' was conducted.
- Additionally, a case series of patients is demonstrated, with curvatures exceeding 45° clinically and radiologically.

Results

Ninety-two papers were displayed in the keyword search for 'scoliosis', 'brace treatment' and 'improvement' and 79 papers were displayed in the keyword search for 'scoliosis', 'orthosis' and 'improvement'.

A case series of three patients with curvatures exceeding 45° is demonstrated within this paper, revealing radiological and clinical improvements when using the recent Chêneau standard of bracing with a reliable computer-aided design library of braces and an experienced team.

Discussion

The solution for the high variability of bracing outcomes is standardization. Braces can be standardized when applying well-tested, standardized brace models from computer-aided design libraries. In comparison, manually-made braces cannot be standardized, resulting in unpredictable outcomes. In addition, there is future advancement potential of baseline quality in braces produced using computer-aided design/computer-aided manufacturing technology.

Conclusion

Trunk and backshape can be improved conservatively even in patients with curvatures exceeding 45°. Modern concepts of bracing may improve even scoliotic deformities exceeding 45° Cobb, radiologically. Clinical improvements, with modern bracing concepts, are comparable to clinical improvements via surgery. For the majority of scoliosis patients with curvatures exceeding 45°, surgery is not indicated, considering the long-term detrimental effects as shown in the literature.

Introduction

Scoliosis is regarded as a three-dimensional (structural) deformity of the spine and trunk, which may deteriorate during growth[1–5]. Currently, treatment indications can be calculated reliably[6,7], but there is a debate about treatment protocols[8]. Conservative management of scoliosis has long been questioned[9–13]. The rate of success of brace treatment has been reported to be relatively low[9–13]. In international literature, the results achieved have been generalized and as for the conclusions, 'Bracing does not work'[9–13]. However, there are a variety of braces available with different approaches and outcomes. Outcome of brace treatment is dependent upon in-brace correction, hours worn and patient compliance[14]. Biomechanically, correction may vary according to brace type, and each brace is tolerated differently, which may affect compliance. We may also assume that bracing outcomes will differ when comparing symmetric braces to asymmetric ones[14–20].

One problem in the literature regarding bracing is the comparison of patient samples with different prognoses, for example varying Risser classification and/or curve magnitude. Another problem is the type of brace must be differentiated, especially in consideration of the completely different philosophies of hard vs. soft braces. The hard brace allows for elongation, thereby decreasing compressive forces. In contrast, a soft brace augments compressive forces, contraindicated with scoliosis, perhaps contributing to the conclusions of a study on hard vs. soft braces[19]. Soft braces certainly allow for more spinal and trunk mobility; however, when applied to a moderate or severe curve, with significant rotation, evidence is lacking that the rotational component of scoliosis improves. Finally, it should be under consideration that brace distributors state beneficial effects,

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while independent studies do not corroborate this claim[18,19].

Scoliosis is a three-dimensional deformity of the spine and trunk, sometimes leading to a drastic increase in the curvature during growth, a process known as curvature progression[1–5]. A characteristic of scoliosis is increased stiffening of the major curvature, which is not overcorrected easily. This is why scoliosis cannot be satisfyingly corrected using unspecific symmetric braces or soft braces, allowing mobility[18,19].

In the past, when bracing standards were in question, braces had been applied in the range of 20° to 40°. In the literature, it has been stated that a curve exceeding 40° cannot be halted using the Boston brace, and surgical management with spinal fusion has been proposed for larger curves[15,16]. Today, it is known that surgical treatment has a high rate of long-term complications estimated to exceed 50% with no proven beneficial effects on patients' health in terms of improving vital capacity, and under discussion recently, the uncertainty of the long-term effects of metallosis[21–29]. Currently, brace treatment has advanced (Figure 1), with success rates exceeding 95% when the SRS criteria for inclusion are applied[30].

Therefore, clinicians should strive to improve in-brace correction and patient compliance[14] through comfort, since bracing today offers the best documented mode of treatment with an acceptable 'cost/effect relation' for the patient during growth[21–29] and is non-invasive. In the literature, there are papers showing improvement of curvatures under brace treatment, but this mainly relates to results revealed on an X-ray, not clinically[30]. Therefore, it appears worthwhile to review the literature revealing improvements after brace treatment and to show what can be done conservatively via bracing in curvatures exceeding 45° Cobb.

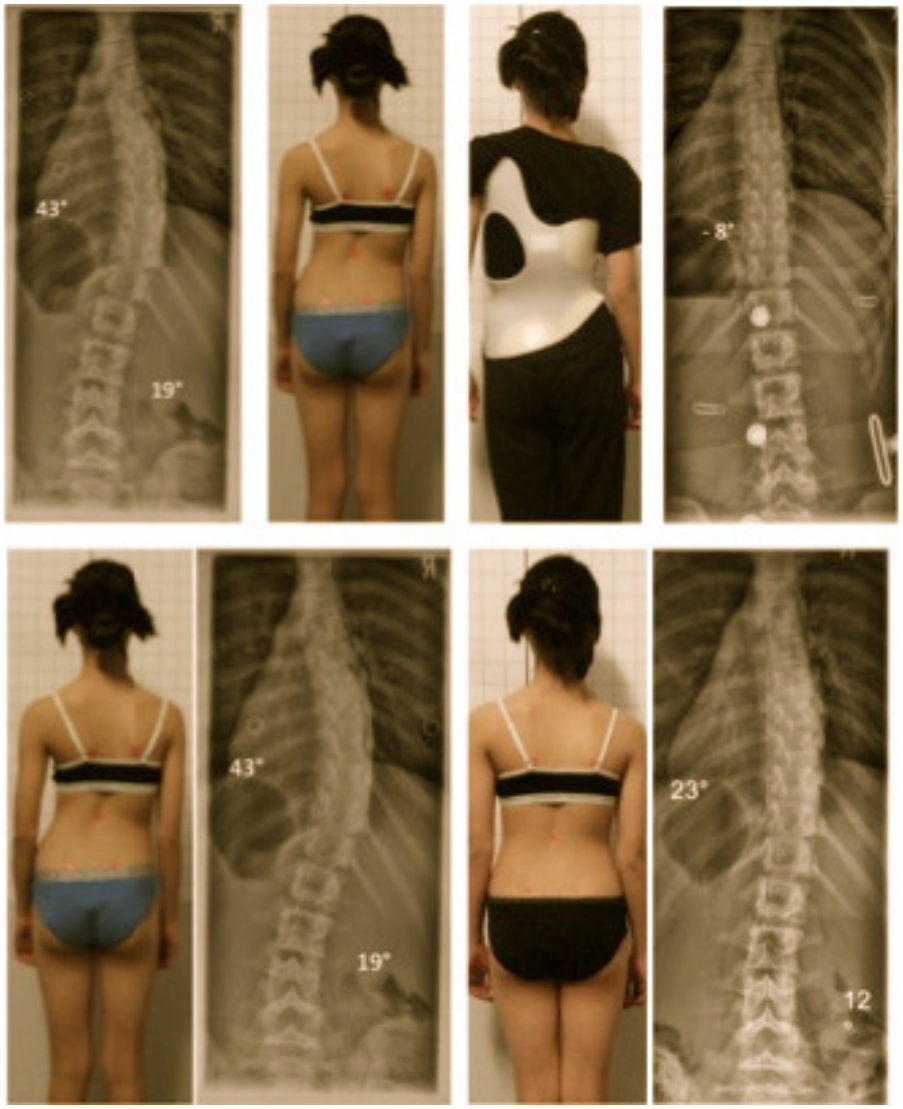

Figure 1: Skeletally immature female presenting with 43° before CAD/CAM Chêneau brace. In-brace correction to –8°. After 6 months, this patient had outgrown the initial brace: intermediate result 23° without brace and a significant improvement of clinical appearance. (With kind permission by Pflaum, Munich, taken from Weiss HR: Best Practice in conservative scoliosis care 2012.)

Materials and methods

- A PubMed review of the literature was undertaken with a keyword search for 'scoliosis', 'brace treatment' and 'improvement' and alternatively for 'scoliosis', 'orthosis' and 'improvement'.
- Additionally, a case series of three patients is demonstrated, with curvatures exceeding 45° clinically and radiologically.

Results

Ninety-two papers were displayed when using the keyword search for 'scoliosis', 'brace treatment' and 'improvement'. Seventy-nine papers were displayed when using the keyword search for 'scoliosis', 'orthosis' and 'improvement'. Nine papers from the list were of interest for our research and are discussed in the next section of this paper[31–39]. There is

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a limited body of evidence demonstrating clinical improvements[33,35,37] via bracing, and even less research showing trunk-shape improvements.

Two papers demonstrated that clinical and radiological development may be different[33,37] and one paper with a case report demonstrated clinical and radiological improvement with a brace[35].

A case series of three patients with curvatures exceeding 45° is demonstrated here, showing that radiological and clinical improvement is possible when using the recent Chêneau standard of bracing with a reliable computer-aided design/computer-aided manufacturing (CAD/CAM) library of braces and an experienced team.

Case 1 (Figure 2): Initial Cobb angle was 48° in an immature girl (Risser 0; age 11 years in 2008). Final result after brace treatment: 24° at weaning of brace (Risser 4, 16 years old, November 2012).

Case 2 (Figures 3–5): Skeletally immature boy with a decompensated thoracic curvature of 56° Cobb having had a progression in the brace worn prior to treatment in the department of the first author. Curvature was reduced at weaning to 43°; however, drastic clinical improvement has been achieved. The single thoracic curve has been transferred into a double major curve, which clinically improves cosmetic appearance since the spine is more balanced (Figure 5). An added benefit is that double curves progress less after cessation of growth as is well known in the literature[4].

Case 3: (Figures 6–8): Skeletally immature 13-year-old girl with a decompensated thoracic curvature of 54° Cobb at the start of treatment. Curvature was reduced at weaning to 33°. Therefore, clinical improvement has also been achieved. The single thoracic curve has been transferred into a double major curve, which clinically improves cosmetic appearance since the spine is more balanced (Figure 7). Again, double curves progress less after cessation of growth as is well known in the literature[4].

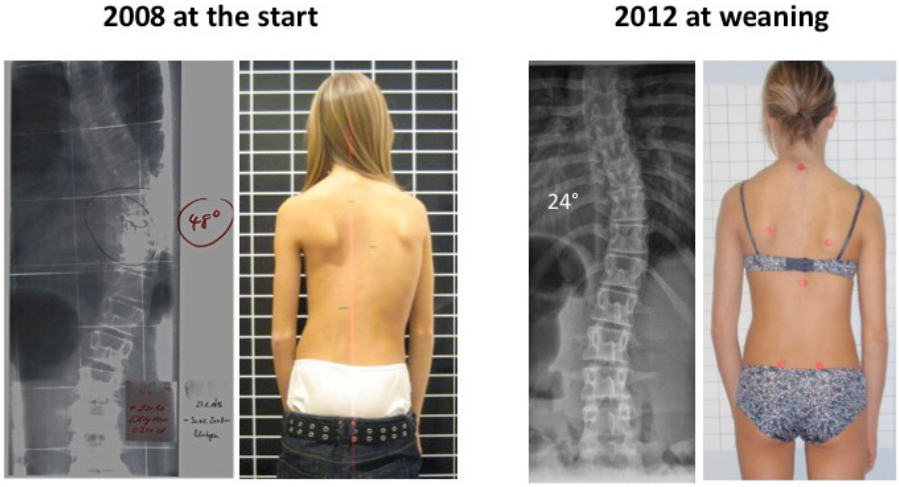

Figure 2: Skeletally immature 11-year-old female starting treatment with 48° Cobb in 2008. Final result at brace weaning 24° Cobb, with a significant improvement of trunk symmetry and alignment.

Figure 3: Skeletally immature male with a decompensated thoracic curvature of 56° Cobb having progressed in the brace worn prior to starting treatment in the department of the first author. First in-brace result achieved with a cast-made Chêneau brace.

Discussion

The authors have referenced some of their own studies in this review. These referenced studies have been conducted in accordance with the Declaration of Helsinki (1964) and 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.

It has been demonstrated that improvements can be achieved during growth when high corrective braces are applied[14,29,30,33,35].

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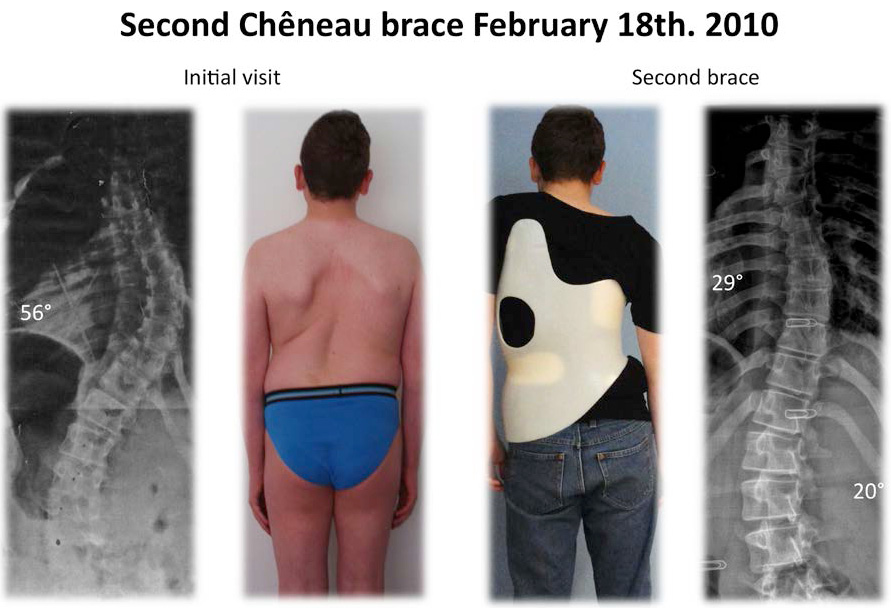

Figure 4: Skeletally immature male with a decompensated thoracic curvature of 56° Cobb initially (Figure 3). Second in-brace result achieved with a CAD/CAM Chêneau brace clearly mirroring the deformity.

Figure 5: Curvature was reduced at weaning to 43°; however, significant clinical improvement has been achieved. The single thoracic curve has been transformed into a double major curve, which clinically improves cosmetic appearance since the spine is more balanced (Figure 7). Also, double curves progress less after cessation of growth as is well known in literature[4].

Radiological improvements have been demonstrated, but little is known about the effects of specific bracing on the trunk and backshape of the patients. Previously, one paper was published showing an increase of curvature radiologically with a drastic clinical improvement. This indicates that curvature and backshape sometimes may develop differently[33].

Adolescent idiopathic scoliosis (AIS), in principle, is a benign disease with little impact on a patient's health[40]. Improvements of backshape may be considered more important than Cobb angle on an X-ray[30]. It is known that after surgery, the rib hump sometimes reappears within 12 months[21]. At this time, there is no current published evidence that backshape and trunk deformity are stable after brace treatment in patients with curvatures exceeding 45°. However, there are cases where it has been shown that a stable correction, 18–24 months after brace weaning, is attainable for patients with initial curvature angles of less than 45°[30].

In future studies, clinicians should strive for an improved positive long-term bracing outcome while considering the patient's appearance, social participation and satisfaction.

Many papers found in the literature do not define the brace investigated, but nonetheless conclude 'brace treatment does not work' rather than designating and demonstrating the specific brace action[9–13].

Furthermore, competing conclusions have been drawn. One paper stated that bracing would affect the outcome of surgery[31], and one study found that braces do not affect the surgical outcome[34]. The authors of both papers generalized the presented results, but in reality, only one brace type had been investigated. Obviously, it is not the name of the brace that is important, but the specific corrective effect a brace potentially has on different patterns of curvature[14,30]. For instance, there are studies showing that the Chêneau brace corrects better than other brace types[14,30], but the standard of Chêneau bracing may differ among practitioners (Figure 9). The solution for the high variability of all braces is standardization. Braces can be standardized when applying well-tested and standardized brace models from CAD libraries. Braces made manually cannot be standardized and bear the risk of gaining unpredictable results, while standardized braces

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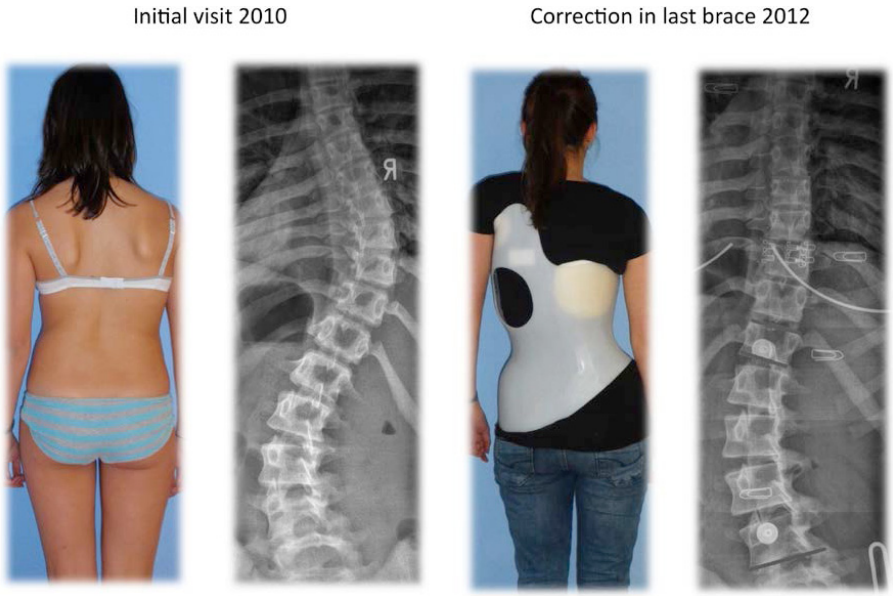

Figure 6: Skeletally immature 13 year-old female with a decompen sated thoracic curvature of 54° Cobb at the start of treatment and with the intermediate result before weaning off the brace, visible on the right.

Figure 7: Curvature was reduced at weaning to 33°, however, significant clinical improvement has been achieved.

today may provide a high baseline quality with the potential for future improvement.

Case results, as demonstrated within this paper, are attained with standardized braces. Recent technology developed using CAD/CAM enables a high standard of bracing, worldwide, to be distributed via email files for local brace creation.

AIS is the most common form of scoliosis. In the skeletally immature patient with Cobb angles in excess of 40° and in more mature patients where Cobb angle measures in excess of 45° or 50°, spinal fusion surgery is the most common intervention. However, long-term studies have revealed outcomes concluding that the risks of surgery are many[21–27]. In contrast, bracing of the highest standards now offers an alternative for the patient, leading to improved outcomes, without surgery. Brace advancements must be fostered to provide patients with curvatures greater than 50° with beneficial clinical and radiological outcomes, without the associated risks[21–29].

The role of exercises in the treatment of progressive curvatures is still debated till date[41] as it was in 1985[38]. However, there is growing evidence that curve pattern scoliosis-specific exercises, learned via instruction by a specially trained practitioner, may be beneficial. Furthermore, in an inpatient rehabilitation setting, the patient may benefit from the psychological support[42–44].

Finally, it has been demonstrated that the trunk and backshape can be modified, and corrected somewhat, using an asymmetric standardized CAD/CAM brace, as presented in the case series of three AIS patients with curvatures exceeding 45° Cobb. Previously, another case report, also using the Chêneau brace concept, demonstrated improvements in one patient with a curvature exceeding 45°[35]. In consideration of this case series, and the aforementioned study, it can be stated that improvements of scoliotic deformities are attainable when trained clinicians apply braces of the highest standards. Admittedly, conclusive evidence is lacking regarding the long-term effects of bracing and regarding the stability of curvature, when improvements are achieved. However, the same may be stated regarding surgical outcomes since it is not unheard of for a deformity to

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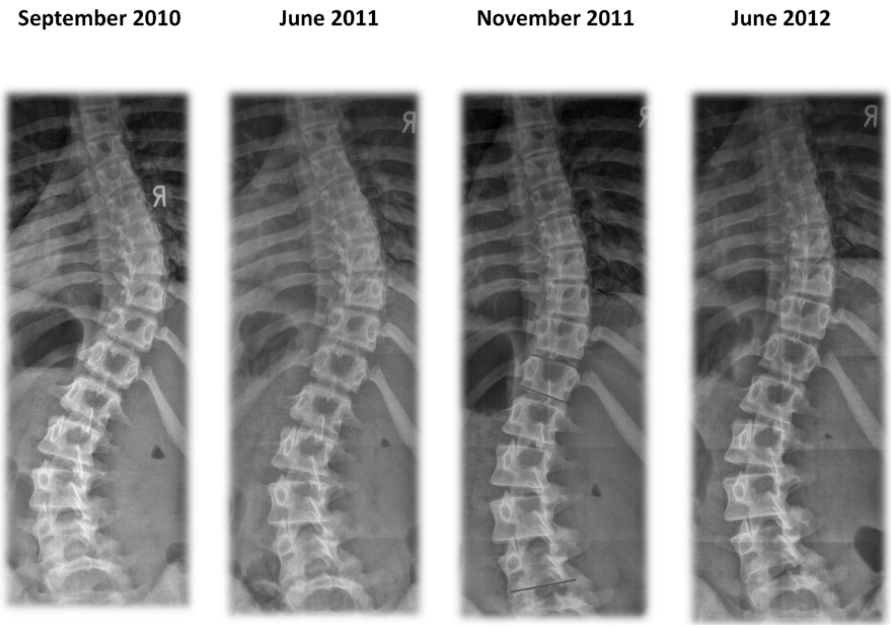

Figure 8: The single thoracic curve has been transformed into a double major curve, which clinically improves cosmetic appearance since the spine is more balanced (Figure 7). Also, double curves progress less after cessation of growth as is well known in literature[4].

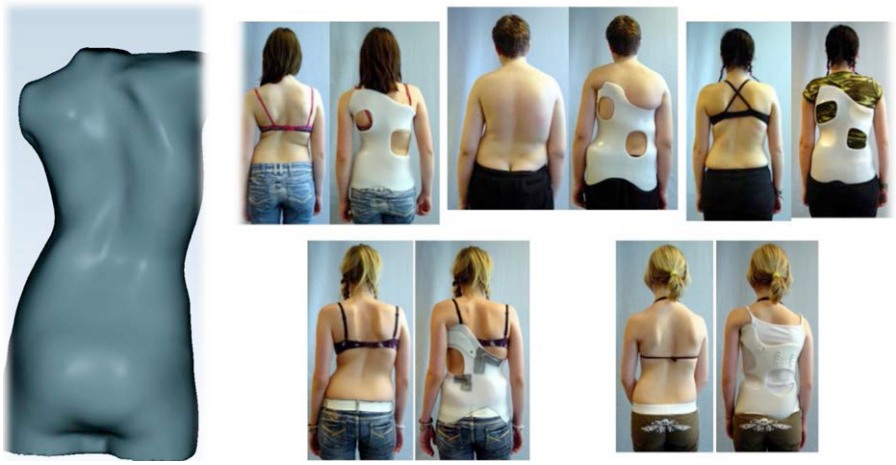

Figure 9: A thoracic curve decompensated to the right (*see left*) affords static overcorrection to the left to achieve a good in-brace correction and a beneficial clinical outcome as illustrated in Figures 1–8. On the right, the so-called 'Chêneau braces' made by cast do not change the decompensation and will not be able to improve curvature or clinical appearance. This kind of bracing is inferior and, therefore, not optimal for the patient.

reappear as early as 1 year postoperatively[21]. Therefore, results demonstrating stable corrections of 18–24 months, via bracing[30], make indications for surgery questionable.

Conclusion

1. Trunk and backshape can be improved, conservatively, even in patients with curvatures exceeding 45°.
2. Some current bracing concepts may improve scoliotic deformities exceeding 45° Cobb, radiologically.
3. Clinical improvements attained with current bracing concepts are comparable to the clinical improvements of surgery, without the risks.
4. For the majority of scoliosis patients, with curvatures exceeding 45°, surgery should not be indicated, considering that a large percentage of long-term effects are detrimental, as shown in the literature.

Competing interests

HR Weiss is advisor of Koob GmbH & Co KG, M Moramarco: none declared.

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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.

Abbreviations list

AIS, adolescent idiopathic scoliosis

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