

## SPINAL DEFORMITY IN ADOLESCENT IDIOPATHIC SCOLIOSIS AT THE END OF CHÊNEAU BRACE TREATMENT

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**Background.** Brace treatment is frequently used in adolescent idiopathic scoliosis (AIS). However, due to different brace models, long-term results on spinal deformity development at the end of Chêneau brace treatment are not often described and differ in results.

**Aim.** The aim of this work was to analyze clinical and radiological data of AIS patients treated with Chêneau braces from the beginning of treatment until the end of growth and brace therapy in order to define realistic treatment results and expectations in an everyday setting.

**Materials and methods.** 52 AIS patients with Chêneau brace treatment were followed from the beginning of treatment until the end of growth. Clinical data such as the initial Risser sign, age at treatment, gender, curve patterns and body mass index were analyzed.

**Results.** At the beginning of brace therapy, the average age was 13.1 years and patients showed a mean scoliotic curve angle of 30.9°. Four months of brace use reduced the scoliotic curve to 20.1°. Nine months after the end of brace treatment and an average treatment duration of 17 months, scoliosis has increased up to 30.3° again. In children with a lower maturity status, the initial scoliotic curve was less than in more mature patients leading to less spinal deformity at the end of treatment. In addition, obese children had less scoliosis correction during brace therapy than normalweight children.

**Conclusion.** In patients with AIS treated with a Chêneau brace, the initial curvature correction was 35%. Nine months after the end of brace treatment, scoliotic curves identical to the deformities at the beginning of treatment could be observed.

**Keywords:** Chêneau brace therapy; scoliosis; correction; conservative; spinal deformity.

## ДЕФОРМАЦИЯ ПОЗВОНОЧНИКА ПРИ ЮНОШЕСКОМ ИДИОПАТИЧЕСКОМ СКОЛИОЗЕ В КОНЦЕ ЛЕЧЕНИЯ С ПОМОЩЬЮ КОРСЕТА ШЕНО

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**Обоснование.** При лечении юношеского идиопатического сколиоза часто назначают ношение корсета. Существуют различные модели корсета Шено. Опубликованных данных об отдаленных результатах лечения деформации позвоночника с помощью корсета Шено мало, при этом результаты различаются.

**Цель** — анализ клинических и рентгенологических данных пациентов с юношеским идиопатическим сколиозом в период от начала лечения корсетом Шено и до завершения роста и лечения корсетом для определения результатов лечения и прогноза в клинической практике.

**Материалы и методы.** В период от начала лечения до завершения роста наблюдали 52 пациента с юношеским идиопатическим сколиозом, которые носили корсет Шено. Проанализированы такие клинические данные, как исходный индекс Риссера, возраст на момент лечения, пол, характеристики деформации и индекс массы тела.

**Результаты.** Средний возраст в начале лечения корсетом составил 13,1 года, средняя величина сколиотической деформации была 30,9°. За 4 мес. ношения корсета сколиотическая деформация уменьшилась до 20,1°.

Через 9 мес. после окончания ношения корсета и средней продолжительности лечения 17 мес. сколиотическая деформация достигала 30,3°. У детей с меньшей степенью созревания скелета величина исходной сколиотической деформации была меньше, чем у более зрелых пациентов, что приводило к меньшей деформации позвоночника в конце лечения. Кроме того, у детей с ожирением коррекция сколиоза во время ношения корсета была менее выражена, чем у детей с нормальной массой тела.

**Заключение.** У пациентов с юношеским идиопатическим сколиозом, носивших корсет Шено, изначальная коррекция деформации составила 35 %. Через 9 мес. после окончания лечения корсетом сколиотическая деформация была идентична таковой в начале лечения.

**Ключевые слова:** лечение корсетом Шено; сколиоз; коррекция; консервативное лечение; деформация позвоночника.

In patients with adolescent idiopathic scoliosis (AIS), brace therapy is a frequently used treatment regime in order to prevent curve progression with its negative effects and to avoid spinal fusion surgery [1]. However, results at the end of growth and after conservative treatment are difficult to compare. Treatment results are affected by the brace design, which is highly dependent on regional preferences [2]. The majority of peer-reviewed papers focus on Northern American brace therapy [3, 4]. Consequently, results for Milwaukee [5], Boston [6], Providence [7] and Charleston braces [8] were extensively described and compared in the literature.

In Europe, Chêneau or Chêneau-like braces such as Chêneau-Rigo [9] or ScolioLogiC® “Chêneau light” are mainly used [10]. Over the last decades, results with these brace models were less frequently described [1, 11, 12] than for US models and the reported results differed extremely in the achieved correction after the end of brace treatment.

Apart from the type of brace, therapy results are highly dependent on individual brace manufacturing, initial curve correction [12, 13] and wearing time of the brace [14] as well as patient related factors such as peak growth velocity, remaining growth, initial curve magnitude, curve rigidity and many others.

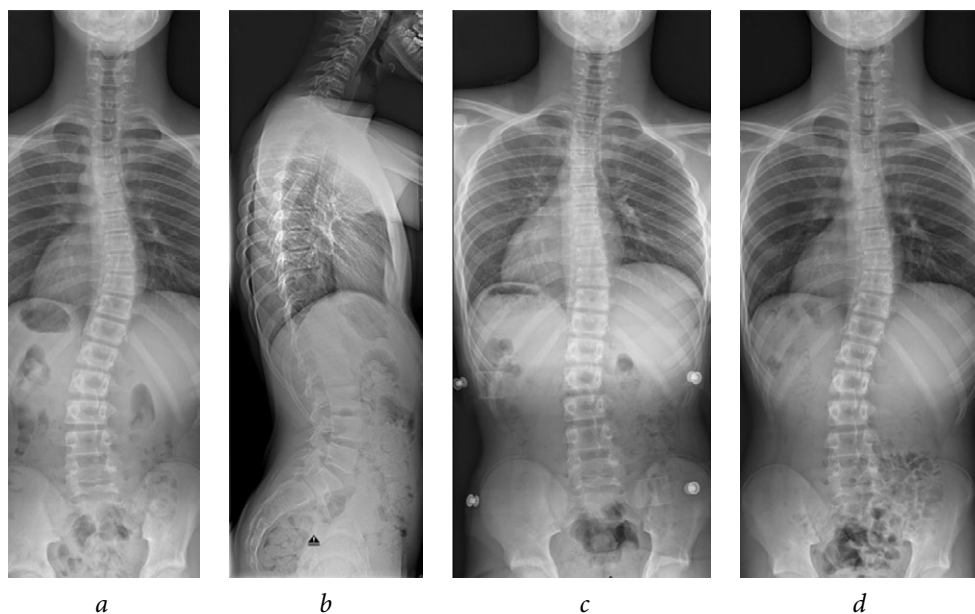
**The aim of this work** was to analyze clinical and radiological data of AIS patients treated with Chêneau braces from the beginning of treatment until the end of growth and brace therapy in order to define realistic treatment results and expectations in an everyday setting.

## Materials and methods

After approval of the institutional ethical review committee of the University Medical Center, a cohort of 52 AIS patients from a single medical university center, which were treated conservatively

with a Chêneau brace therapy were followed from the beginning of treatment until the end of growth and several months (average nine months) after brace therapy. According to Richards et al. [15] SRS (scoliosis research society) paper on brace studies, inclusion criteria at the beginning of brace treatment were the diagnosis of AIS, minimum age of ten years, Risser sign 0 to 2 (<50% ossification of the iliac apophysis on radiographs), scoliotic curve angle (Cobb degree) between 25° and 40°, less than one year after the menarche and no prior treatment. Patients who satisfied these criteria and who were treated with a Chêneau brace until the end of skeletal growth (Risser sign 5), were included into this study. Additionally, 14 patients with a scoliotic curve angle of 17°–24° were included as brace therapy is suggested at 20° of scoliosis in Germany and a measurement error of 5° should be considered using the Cobb method. Clinical data such as curve patterns and body mass index were documented. Standardized radiological standing images in the AP (anterior-posterior) and lateral projections at the first visit were performed and analyzed. In order to reduce radiation exposure, follow-up radiographs were performed as an AP standing film only (Fig. 1).

All patients were prescribed a Chêneau brace, which were manufactured at different companies throughout the country. After completion of the brace, a period of adjustment was recommended with increasing wear duration. If necessary, an adaptation of the orthosis was performed by the manufacturing company. An outpatient visit was scheduled three to five months after the initial visit to check on the brace and to perform AP radiographs in the brace to proof deformity correction. All adolescents and their parents were instructed to wear the brace for 23 hours/day [14] and only to take it off during sports and showers. Physiotherapy was prescribed with a given preference to the Schroth method



**Fig. 1.** A 12-year old boy with scoliosis (a) and a normal sagittal profile (b). Scoliosis could be well corrected by a Chêneau brace (c). At six months follow-up after the end of brace treatment, spinal deformity was similar to the initial values (d)

to de-rotate, stabilize and elongate the spine in a three-dimensional plane [16]. Objective data on real brace time wearing and physiotherapy efforts were not collected. Therefore, the reported data represent a typical everyday situation in a large pediatric spine clinic.

In addition to clinical data, radiological measurements of scoliosis were performed on X-rays with and without Chêneau brace. Data were analyzed according to the degree of maturation (Risser sign). The Lenke classification was used to describe which of the three regions of the spine (proximal thoracic, main thoracic and thoracolumbar/lumbar) was structural or non-structural and scoliosis could be divided into six different types with the help of X-ray images [17]. The obtained data were reviewed statistically with Student's *t*-tests using Excel. All data are presented as mean  $\pm$  standard deviation. Statistical significance was determined with  $p < 0.05$ .

## Results

Data and radiological images of 52 children with idiopathic scoliosis according to the SRS criteria [15] were evaluated. 88% of the collective ( $n = 46$ ) were female and 12% ( $n = 6$ ) male. The mean age at diagnosis was 13.1 years (range 11.1–14.3 years, SD = 1.63). The average body height at the time of diagnosis and start of brace treatment was 162 cm with a mean weight of 49 kg. 87% of the study group ( $n = 45$ ) had a single scoliotic curve, whereas

the others ( $n = 7$ ) were diagnosed with a S-shaped double curve, so that a total of 59 curves could be analyzed in this work.

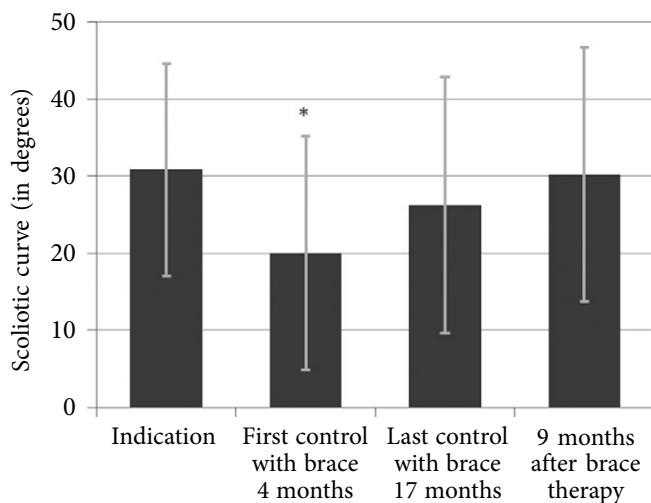
Using the Lenke classification [17], scoliotic deformity was divided into six different types. Lenke 1, the right convex thoracic scoliosis, was predominantly present for the majority of patients (Table).

The degree of maturation of the patients differed. In 48% of girls ( $n = 22$ ), the menarche had already occurred. Risser signs  $\geq 1$  were found in 75% of this group at primary diagnosis. In 2% of the radiographs, the Risser sign could not be assessed due to technical reasons.

Radiographs of patients with AIS demonstrated an average curve of  $30.9^\circ$  at the beginning of treatment, which could be reduced to  $20.1^\circ$  four months after initiation of Chêneau brace therapy. This equals an initial curve correction of 35%. At the last radiological control during brace treatment, the average scoliotic curve had increased to  $26.3^\circ$  during an average of 17 months of treatment. However, this difference was not statistically significant (Fig. 2). Nine months after the end of brace treatment, the

AIS ( $n = 52$ ) classified according to Lenke [17]

| Lenke classification |          |     |
|----------------------|----------|-----|
| 1                    | $n = 27$ | 52% |
| 2                    | $n = 0$  | 0%  |
| 3                    | $n = 7$  | 13% |
| 4                    | $n = 3$  | 6%  |
| 5                    | $n = 14$ | 27% |
| 6                    | $n = 1$  | 2%  |

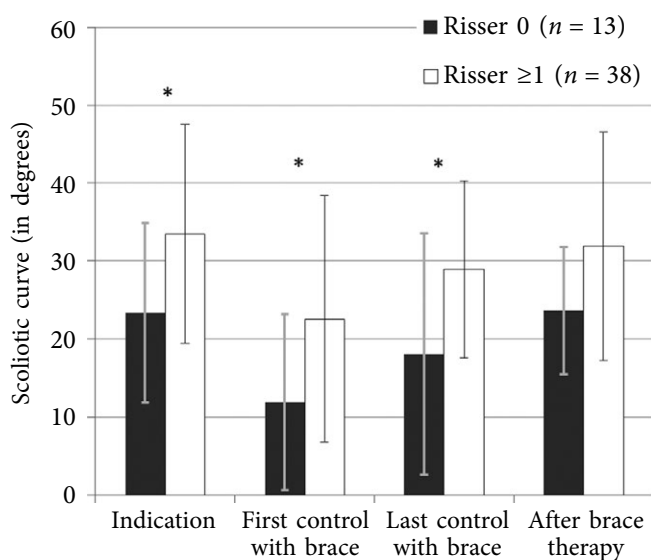


**Fig. 2.** Scoliotic angle (in degrees; mean  $\pm$  standard deviation) of the main curves of all patients ( $n = 52$ ). Values at the time of indication for brace treatment, four months after wearing a brace, last control in the brace (17 months) and nine months after the end of brace therapy. The significances ( $*p < 0.05$ ) calculated with Student's  $t$ -test are referred to the initial value (indication for brace therapy)

scoliotic curves presented with the same degree as the initial curve.

Looking at the remaining growth, patients after the peak growth velocity (Risser sign  $\geq 1$ ) started with more severe scoliotic curves ( $33.5^\circ$  versus  $23.4^\circ$ ,  $p = 0.005$ ), but showed the same curve pattern during the treatment course as skeletally more immature patients (Fig. 3).

Data analysis was able to show that overweight was a negative predictive factor for spinal deformity



**Fig. 3.** Scoliotic curve pattern (in degrees; mean  $\pm$  standard deviation) differentiated between skeletally immature (Risser 0) and skeletally more mature patients (Risser  $\geq 1$ ). 51 patients were analyzed. The significances calculated with Student's  $t$ -test ( $*p < 0.05$ ) relate to the difference between the two groups

control with a Chêneau brace. Overweight patients ( $n = 4$ , body mass index [BMI]  $> 90^{\text{th}}$  percentile) presented with higher initial ( $41^\circ$  versus  $31^\circ$ ) and final scoliotic curves ( $46^\circ$  versus  $26^\circ$ ) and less deformity control than normal weight adolescents during brace therapy ( $p = 0.039$ ).

## Discussion

The effect of brace treatment in children with AIS still remains controversial. A systematic review [3] of only English literature showed that there was no difference of curve degrees which classified for surgical interventions in observed AIS patients, versus children with a brace treatment. Contrary to this, the same group found a higher rate of treatment success after bracing compared to observation only in patients with AIS [18]. De Giorgi et al. [1] reported a permanent 59% scoliosis correction with an average  $11^\circ$  scoliosis five years after completion of Chêneau brace treatment, thus showing no curve angles within the range of surgical treatment.

The problems of brace therapy in AIS are numerous: type of brace, individual manufacturing, uncertain wearing time [19, 20], different additional physiotherapy, individual curve progression and rigidity, remaining growth and many other factors. As described by De Giorgi et al. in 2013 [1], excellent Chêneau brace treatment results can probably be achieved with careful patient selection, a single treating doctor, who personally controls all braces and supervises wearing time, as well as physiotherapy and only one experienced brace manufacturer. However, this situation does not reflect the usual routine in most patient settings. This paper reports results of a normal everyday outpatient routine administered in a single large pediatric spinal center.

After patient selection according to the SRS criteria [15], adolescents were prescribed a Chêneau brace, which is commonly used in Europe [10]. The braces were manufactured close to home as many families lived far away. Brace fitting was controlled by radiographs at an average of 4.3 months after the beginning of treatment. According to the literature, curve corrections of 50% and higher are favorable [12,13], but only 35% could be achieved in this studied population. One reason might be different techniques by different

manufacturers who were involved into creating the Chêneau braces. The families were advised to adjust the Chêneau brace at their local manufacturers according to radiographic findings to improve correction. Follow-up medical visits were advised every six months and earlier if problems were noted.

Administering this standard procedure, a gradual but not statistically significant increase of the scoliotic curves could be observed during the Chêneau brace treatment over time. Nine months after completion of brace therapy, the scoliotic angle was identical to the initial spinal deformity. Similar findings have been reported by Hopf et al. [11] and Zaborowska-Sapeta et al. [21], who described a stop of scoliotic curve progression in 48% of patients. Long-term results after completion of bracing are extremely heterogeneous. While some report of permanent excellent results [1], others demonstrated a gradual curve progression over time [21, 22].

In our patient population, skeletally immature patients at the beginning of treatment (Risser <0) and therefore longer treatment periods did not show more severe curves than initially older patients at the final results (Fig. 3). A reason might be that the patients have been selected according to the SRS criteria [15], which exclude younger patients below the age of ten, whose curve progression normally deteriorates more severely. A negative factor associated with poor Chêneau brace effectiveness was clearly overweight, which has been described in the literature before [23].

### Limitations of the study

The limitation of our study was that also patients with a Cobb angle below 25°, which is described in the SRS criteria, were included as brace therapy is suggested at 20° of scoliosis in Germany and a measurement error of 5° should be considered when using the Cobb method.

### Conclusion

Our patient group of 52 AIS children according to the SRS criteria, who were treated with a Chêneau brace, which was manufactured at different locations throughout the country, showed an overall initial curvature correction of 35%. At the end of growth as well as an additional nine months follow-up after cessation of brace treatment, scoliotic curves

identical to the deformities at the beginning of treatment could be observed. These results were better than the reports in many US studies [4, 6–8], but worse than results reported for Chêneau brace treatment with a careful patient selection, single doctor, close monitoring and single experienced brace manufacturer [1].

Concluding, brace therapy in AIS children prevents the progression rather than correct or reverse the deformity leaving the scoliotic curve at the end of the treatment on initial degrees.

### Additional information

**Source of funding.** No funding was received for this study.

**Conflict of interests.** All authors declare that they have no conflict of interests.

**Ethical statement.** Approval of the Local Ethics Committee was given at 05th December 2013 with the number DOK\_125\_2013. As this study evaluates radiological pictures solely, the ethics committee waived the need for informed consent for the study. The participants were informed about the purpose of the study and informed consent was obtained for all patient images from a parent and/or legal guardian.

#### Author contributions

*K. Tsaknakis, A.K. Hell* — contribution to study concept and design, acquisition of data, analysis and interpretation of data, drafting of the manuscript, revision of the manuscript.

*H.M. Lorenz* — acquisition of data, revision of the manuscript.

*L. Braunschweig* — analysis and interpretation of data, drafting of the manuscript, revision of the manuscript.

All authors made a significant contribution to the research and preparation of the article, read and approved the final version before publication.

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