

Rehabilitation of adolescent patients with scoliosis—what do we know?

A review of the literature

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Summary

Different opinions exist about the efficacy of conservative scoliosis treatment. Because this divergence of opinion corresponds to a great variety of standards applied, it is also not surprising that the results of conservative treatment differ a lot. Scoliosis normally does not have such dramatic effects that immediate surgery would be indicated. Moreover, it is clear that functional and physiological impairments of scoliosis patients—including pain, torso deformity, psychological disturbance and pulmonary dysfunction—require therapeutic intervention. The triad of out-patient physiotherapy, intensive in-patient rehabilitation and bracing has proven effective in conservative scoliosis treatment in central Europe. Indication, content and results of the individual treatment procedures are described and discussed. The positive outcomes of this practice validate a policy of offering conservative treatment as an alternative to scoliosis patients, including those for whom surgery is discussed.

Introduction

Scoliosis is a term used to describe lateral curvature of the spine [1]. Most cases involve thoracic vertebrae, whose axial rotation fosters three-dimensional deformities of the torso [2–4]. A resultant loss of rib-cage–spine coupling patterns leads to restrictive lung disease secondary to reduced chest wall compliance (CCW); CCW and vital capacity (VC) are inversely correlated with curvature magnitude down to a Cobb angle of 10° [5]. Even when resting VC is found to be

normal, respiratory challenge reveals reduced exercise capacity even in children with mild curvatures [6, 7]. Symptoms of thoracic scoliosis may include shortness of breath, recurrent respiratory infection, chronic pain and psychological distress [5, 8–11]. In severe cases, death may result from right-sided heart failure; however, it does not occur in most scoliosis patients and does not occur in those patients with detection during adolescence. The impact of mild to moderate respiratory distress occurring in thoracic scoliosis has not been examined, but recent studies have shown that, in non-scoliotic adults, reduced exercise capacity is a better predictor of mortality than diabetes, heart disease and smoking [12–14]. Although there are many known causes of scoliosis, spinal deformity of unknown origin or ‘idiopathic’ scoliosis (IS), comprises 70–90% of all cases.

Once the diagnosis of IS has been made, the risk that the degree of spinal curvature will increase is of paramount clinical interest. Though it is impossible to predict with certainty whether any given spinal deformity will worsen significantly, natural histories have revealed that age, gender and curvature magnitude are the factors most likely to influence progression in children [15]. In the immature patient, the risk of progression is related primarily to growth potential [15]. Thus, in 109 children diagnosed before the age of 10 years, incidence of progression was 95% [16], and among 64 children diagnosed before the age of 12 years, 75% had progressive curvatures [17]. By contrast, in a study of older patients, 85% of whom were ≥ 12 years old, progression was only 23% [18]. In girls, the highest risk of curvature progression exists when curves are detected before the onset of menarche, which usually occurs at ≥ 12 years of age [19, 20]. After menarche, the risk for curvature progression drops significantly. For unknown reasons, males with comparable curves have approximately one-tenth the risk of progression of females. For all patients, the larger the curve at detection,

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the greater the risk of progression. Thus, in a survey of 134 patients with mild curves (more than half had minimal curvatures of 5–10° and only 3% had curvatures >20°) incidence of progression was only 5% [21]; among 839 children of whom 90% had curves from 10° to 19°, incidence of progression was 15% [22].

Evaluation of the risk of curvature progression is essential to the appropriate design of IS treatment. In the USA, school screening programmes have allowed large-scale referral of children to orthopaedic surgeons for evaluation while spinal deformity is at early stages of development and curvatures are mild (<15°, as defined by Cobb) [23]. Until curvatures progress to 25° or more, however, physicians prescribe ‘observation only’, a regime in which children are subjected to radiological exams at intervals, but are not treated [24–27]. When curvatures progress to 25° bracing has been used in efforts to stabilize progression, and its efficacy continues to be examined [28–30]. Spinal fusion surgery is recommended for skeletally immature patients when curves progress to 40–45°, and for mature patients with curvatures >50° [25–27, 31].

In the USA as well as in Great Britain there has been a nearly total absence of clinical research to test the efficacy of proactive, physiotherapy-based methods to treat IS in early stages when curvatures are mild [32–35]. The rationale to justify lack of early intervention is that in natural history surveys, small curvatures of <15° often remain stable and may even improve while the child is under observation [15, 18]. Unfortunately, ‘natural history’ studies that underlie our existing knowledge base are compromised by the fact that most have included an unknown and undescribed proportion of patients who received physiotherapy including exercises and manipulation [21, 36–43]. Because the impact of such treatment has been ignored, the possibility that some curvatures stabilized or improved in response to conservative therapy cannot be ruled out [44]. We believe this situation reflects a long-standing bias against exercise-based therapies in the treatment of IS in English-speaking countries, especially the USA. This bias is reflected in statements such as

To sum up the indications for an exercise programme, you can prescribe it if you wish, as long as you understand that exercises only treat the psyches of the parents and help the muscle coordination of certain poorly muscled children, who are overweight and underexercised. [45]

Two original papers have been cited in support of the anti-physiotherapy position [46, 47]. In 1941, a committee of the American Orthopedic Association queried physicians at 16 clinics in the USA. They reported

that of 185 patients treated with ‘exercises of all types’, the deformity was stable in 35%, increased in 61%, and improved in 4%. Adequate description of patient ages, exercise regimes, supervision or follow-up, with regard to outcome of individuals, is not provided. After screening programmes allowed early detection of IS, Stone *et al.* [47] designed a controlled out-patient clinical study to examine the possibility that an exercise programme can influence progression in mild curves (Cobb angle 5–20°). Of 41 children prescribed a short daily home programme consisting primarily of five ‘pelvic tilt’ exercises, two curvatures increased, 31 stayed the same, and nine decreased; these numbers were not significantly different from those in a matched control group after a follow-up period of 3 months. Unfortunately, only four of the 41 children in the test group self-reported doing the exercises ‘daily or almost daily’ as prescribed; nearly half reported doing them ‘never’ or only 1–3 times per week. As a result, the authors concluded that ‘Based on this study, we cannot conclude that exercise has no effect on change in curvature in patients with minimal IS’ [47]. They proposed future studies with a longer follow-up, more intensive exercise, and daily supervision to ensure that the programme is carried out as prescribed.

Postural imbalance in response to factors like leg-length discrepancy, pain, tumours and psychological distress is known to cause scoliosis, which sometimes resolves when the inducing factors are removed [48, 49]. Pain-provoked scoliosis, which occurs in response to bone tumours, usually resolves if the tumour heals or is treated within a year, but otherwise may be progressive [50, 51]. The likelihood that other postural imbalance-induced curvatures will progress to a fixed deformity if inducing factors are not removed is unknown. However, Paul Harrington established that, in humans as well as in experimental animals, postural imbalance alone can induce severe scoliosis, which resolves when the imbalance is removed before growth is complete [52, 53]. In keeping with this conceptual framework, scoliosis treatment by postural-balancing physiotherapy has a long tradition in Europe. Spain, France, Italy and Germany employ physiotherapy in specialized centres. In Eastern Europe, especially in Russia, boarding schools offer an environment where scoliosis patients learn exercise-based treatment strategies in a therapeutic group setting [54].

In continental Europe [55–57], especially in Germany, a conservative treatment approach is pursued actively from the time of diagnosis [58–63]. In adolescence, this approach includes out-patient physiotherapy beginning at 15° according to Cobb. Scoliosis intensive

rehabilitation (SIR) is recommended for curvatures of 20–30°, with or without bracing, depending on prognosis. For adult IS, out-patient physiotherapy is offered for curvatures of 30–40° with moderate pain. Physiotherapists in different regions are trained so that patients have the option of continued out-patient treatment close to their home. For adult patients with curves of over 40° in association with cardio-respiratory functional impairment and pain, SIR is recommended. In-patient treatment offers structure for a daily 6-hour intensive rehabilitation treatment.

Examples for conservative management of scoliosis in Germany

OUT-PATIENT PHYSIOTHERAPY (SPECIFIC EXERCISES)

Specific exercises are performed on an out-patient basis for patients with curvatures of 15–20°. On the

one hand, curvatures of less than 10° are very common and principally have a good prognosis [15]; on the other hand, physiotherapy is more effective in bigger curvatures than in small ones [58, 59]. In Germany, the Schroth programme (figure 1) [2] and exercises following the principles of Vojta [64] are commonly performed [58, 59]. Internationally, side shift exercises are in use [65].

SCOLIOSIS INTENSIVE REHABILITATION (SIR)

SIR employs an individualized exercise programme combining corrective behavioural patterns with physiotherapeutic methods, following principles described by Lehnert-Schroth [2]. The three-dimensional scoliosis treatment is based on sensomotor and kinesthetic principles and its goals are (a) to facilitate correction of the asymmetric posture, and (b) to teach the patient to maintain the corrected posture in daily activities.



Figure 1 Idiopathic scoliosis-associated torso asymmetry (a) and its correction (b) by posture-balancing physiotherapeutic methods. The goal of SIR is to facilitate development and maintenance of the corrected posture, by teaching the patient to raise herself as far as possible by using active trunk muscle force only. A clear 3D corrective effect is visible performing the exercise with correction of pelvic prominence and lumbar hump as well. (Reproduced with kind permission of Pflaum Company, Munich.)

Referrals are from spine centres, general orthopaedic surgeons, paediatric physicians and general practitioners. A 4-week minimum is required for the first treatment, and may be up to 6 weeks; return treatments are 3–6 weeks in length, depending on symptoms and prognosis. Patients are admitted in groups, with the first day of the programme devoted to diagnosis and evaluation of the three-dimensional deformity, supervised by nine staff physicians (2 orthopaedic surgeons, and 6 general practitioners or specialists for physical medicine and rehabilitation), who also provide oversight for each patient's programme. On the second day, instruction in basic human anatomy, spinal deformity and principles of postural balancing therapy is provided to the group. Each patient receives a detailed summary of his/her own condition, and those with matching diagnoses (based on age, degree and pattern of curvature) work together in groups. Evening social activities provide a sense of community and foster development of psychological support systems that can be maintained after treatment is complete.

The treatment programme consists of correction of the scoliotic posture with the help of proprioceptive and exteroceptive stimulation, and begins on the third day after admission. Each weekday, after a 20-min group warm-up session, the patients exercise in matched groups for 2 hours in the morning and 2 hours in the afternoon and receive shorter, more individual training sessions in between. Central to the individual and group exercise programmes is therapist assistance, by a staff of 20 physical therapists and sports therapists who supervise all exercises and provide exteroceptive stimulation needed to obtain desired correction. Depending on individual curve patterns, the patients are assigned to special exercise groups for an additional 2 hours daily. Development and maintenance of the corrected posture is facilitated using asymmetric standing exercises designed to employ targeted traction to restore torso balance and mobility. Rice-bag bolsters provide localized sustained pressure during floor exercises for mobilization of rib prominences or other torso and lumbar asymmetries. Bracing (since 1992) and passive transverse forces are applied as needed (depending on curvature pattern, flexibility and magnitude) using a vertical frame with adjustable belts.

The correction is supported by 'rotational breathing' exercises, an integral part of the regime: by selective contraction of convex areas of the trunk, the inspired air is directed to the concave areas of the chest and the ribs to lengthen and mobilize soft tissues in these regions [62]. Female patients wear bikini tops during all sessions, and ceiling and wall mirrors enable the

patients to self-monitor progress at all times to facilitate optimum correction. Four full-time massage therapists provide bi-weekly mobilization therapy for each patient, using myofascial release, manual traction, ischemic pressure and pressure-point therapy. Two full-time respiratory therapists are available to meet individually with each patient to monitor vital capacity weekly and to provide training in corrected breathing patterns. Psychological counselling is provided by three staff psychologists to help patients cope with feelings about the diagnosis of deformity as well as the impact of treatment, as needed; patients can request individual psychotherapy in response to anxiety, depression, or other psychological distress. Optional evening group sessions devoted to relaxation therapies including meditation and visualization approaches also are available. Osteopathic manipulation and acupuncture by staff therapists are available to treat pain, as needed.

At the end of in-patient treatment, the primary goal is for patients to be able to assume their personal corrected postural stereotype, independent of the therapist and without mirror control, and maintain this position in their daily activities. Recommended at-home follow-up treatment includes three to four exercises for 30 min daily in order to maintain the improved postural balance. In case of pain, curvature progression, or pulmonary symptom development repeat SIR treatment is available by referral from primary care physicians.

HIGH-CORRECTION BRACING

Two factors have emerged as the main parameters of successful brace treatment. Goldberg and co-workers [29] cited two references in which good patient compliance with bracing corresponded with favourable outcomes [66,67]. However, the actual extent of the corrective effect is also described as an essential criterion in successful bracing. Based on a review of the literature, we confirmed that there exists a direct positive correlation between the primary corrective effect of an orthosis and the end result [68]. The importance of this effect is supported by a study from Mellerowicz *et al.* [69] and by a study from Landauer [70], in which they independently concluded that compliance and the primary correction effect in the brace are the two most important variables associated with good brace outcomes.

The treatment of adolescent idiopathic scoliosis (AIS), however, serves to change not only the secondary symptoms of scoliosis and the X-ray (figure 2) but—most important to the adolescent—also aims at an



Figure 2 X-rays of a 13-year-old girl with (left) 37° at start of conservative treatment, overcorrection of -16° in the brace, 14° at the start of weaning and 16° two years after weaning (right). No more treatment will be necessary because of scoliosis. (Reproduced with kind permission of Pflaum Company, Munich.)

improvement of the cosmetic signs of the deformity (figure 3) [15, 29]. Thulbourne and Gillespie [71] may be right in saying that, even if the progression can be reduced by bracing, cosmetic appearance and the rib hump may not always be influenced positively, nor may a successful course as shown by X-ray always be appreciated as a successful treatment by the patient. Rigo, however, has demonstrated that the application of the Rigo-System Chêneau brace (RSC-Brace) leads to significant improvements of the cosmetic deformations [72] and to a significantly reduced rate of progression [73]. The frontal corrections in the RSC brace were on average about 30–40% for the major curve but also showed a significant reduction of vertebral rotation (22%). So, not only compliance and correction in frontal plane but also 3-D correction plays an important role in the conservative management with the help of braces.

Treatment of scoliosis with the Chêneau brace is currently the most practised conservative method in Germany, Austria and Spain, as well as in Poland. It is also used in France and Italy. The Chêneau brace is defined as a thermoplastic brace modelled on a hypercorrected positive plaster mould of the patient. Specific pad areas are designed to provide detorsional forces through the trunk. Expansion rooms are also built, in order to allow active correction by breathing movements. Clinical histories of individuals enjoying excellent corrective effects and favourable outcomes with the Chêneau brace are encouraging its use in many places in central Europe.

Most of the braces applied worldwide have a common plan of construction and do not address curve pattern enough to be called specific [66, 74, 75]. Mathematically, there is an unlimited number of curve patterns, all with individual 3-D properties. So, just to distinguish between thoracic, lumbar, double major or thoracolumbar curves and to apply one single construction plan [66–68] will not be sufficient for most of the curve patterns. To make the brace longer or shorter is not the way to make fine adjustments to correct different curves.

The Chêneau brace includes two different construction plans for two different functional curve patterns [30]. More recent bracing concepts in central Europe use the King classification [76] in order to achieve a more specific distribution of correction force for different individual curve patterns [30], which, however, is an incomplete classification that does not address thoracolumbar and lumbar curves. The results of brace treatment following the described principles were good on average [30, 68, 270, 73, 77–80]. However, in some cases,



Figure 3 Girl with early onset scoliosis before pubertal growth spurt. Upper left: before first rehabilitation with 49° having a brace of bad quality from outside—operation seemed indicated; correction to less than 20° in the first brace from our centre, and a good clinical correction after first SIR as can be seen on upper right-hand picture. Lower left: the second brace from our centre; lower right: balanced appearance and undisturbed cosmesis after pubertal growth spurt (Risser 3). Surgery will not be necessary. (Reproduced with kind permission of Pflaum Company, Munich.)

also the described advanced bracing concept failed. The problem is that no one can tell why in one case the brace is effective and in the other not. The solution at the moment is sought in bracing regimes that are even more specific.

Progression of curvature angle mainly is recognized during the pubertal growth spurt between the first pubertal signs (Tanner 1–2) and the bony maturation [81]. Lonstein and Carlson [18] have described a relation between initial Cobb angle and age at onset. In curvatures between 20° and 29° diagnosed before the age of 11 years, the risk for progression is 100%, while in a curve between 20° and 29° at the age of 15 years only 16% of the cases were progressive [18]. Peterson and Nachemson [82] documented that prognosis of scoliosis depends on skeletal maturity, chronological age but also on the curve pattern.

The fact that most bracing concepts fail to address different curve patterns, although different curve patterns have different prognoses [82] and different biomechanical properties, demands consideration.

Today it is possible to design specific braces for individual curve patterns without plaster. For the treatment with a Chêneau brace using the CAD-technique according to the Rigo-system, certain static and also dynamic measurement values describing the deformity and the correction are necessary, as well as new X-rays (full spine in standing position) and pictures of the trunk (view of the back, frontal and lateral view, if possible).

After this procedure, the data are sent via e-mail to the experts who first determine the curve pattern according to the Rigo-classification (figure 4) in order

to choose the appropriate model (out of 45 different moulds) considering the curve pattern, the patient's age and curve severity. Based on the static and dynamic measurements of the patient a foam model is produced according to which the brace is finally constructed (figure 5).

Notwithstanding the promise of the Chêneau brace as a viable conservative treatment, we continually strive to offer patients a balanced perspective on treatment options. In our experience, many patients, even those with curvatures of over 40°, nevertheless opt for conservative treatment, although this may affect quality of life for a certain time frame.

Results of conservative management

PHYSIOTHERAPY/SCOLIOSIS IN-PATIENT REHABILITATION (SIR)

Case report series have demonstrated that measurable positive changes in the signs and symptoms of IS are correlated with SIR treatment [57, 59, 60, 62]. Among > 800 patients, nearly every case revealed a small but significant improvement in chest expansion and a 14–19% improvement in VC after SIR treatment [62]. Among 794 adult patients with severe scoliosis, 55% exhibited at least one sign of right ventricular strain at admission, and by the end only 12% exhibited signs of impairment; VC improved by 250 ml in the same population [83]. Among 107 patients, mean Cobb angle decreased from 43° to 39°, with improvements of up to 20° in individual patients after SIR [84]. Studies also have demonstrated significant

Anatomo-Radiological Patterns. Rigo Classification.

Thoracic

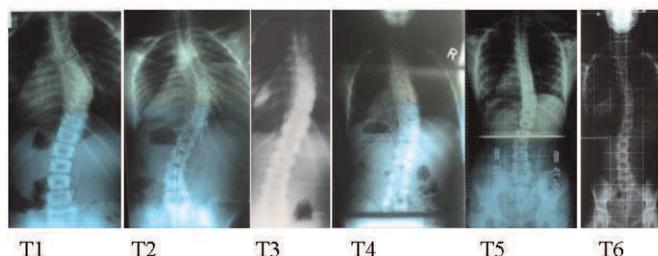


Figure 4 The Rigo classification consists of 15 different curvatures with individual radiological and biomechanical properties, which have to be respected in brace construction to gain a good radiological and a good clinical (cosmetic) correction effect regarding the sagittal profile as well as the frontal plane correction. Those braces are usually comfortable to wear although correction is clearly visible (figure 5). The six thoracic curve patterns are presented here as an example, but there are additionally three thoracolumbar, two double major, three double thoracic and one lumbar curve pattern used for curve specific bracing.

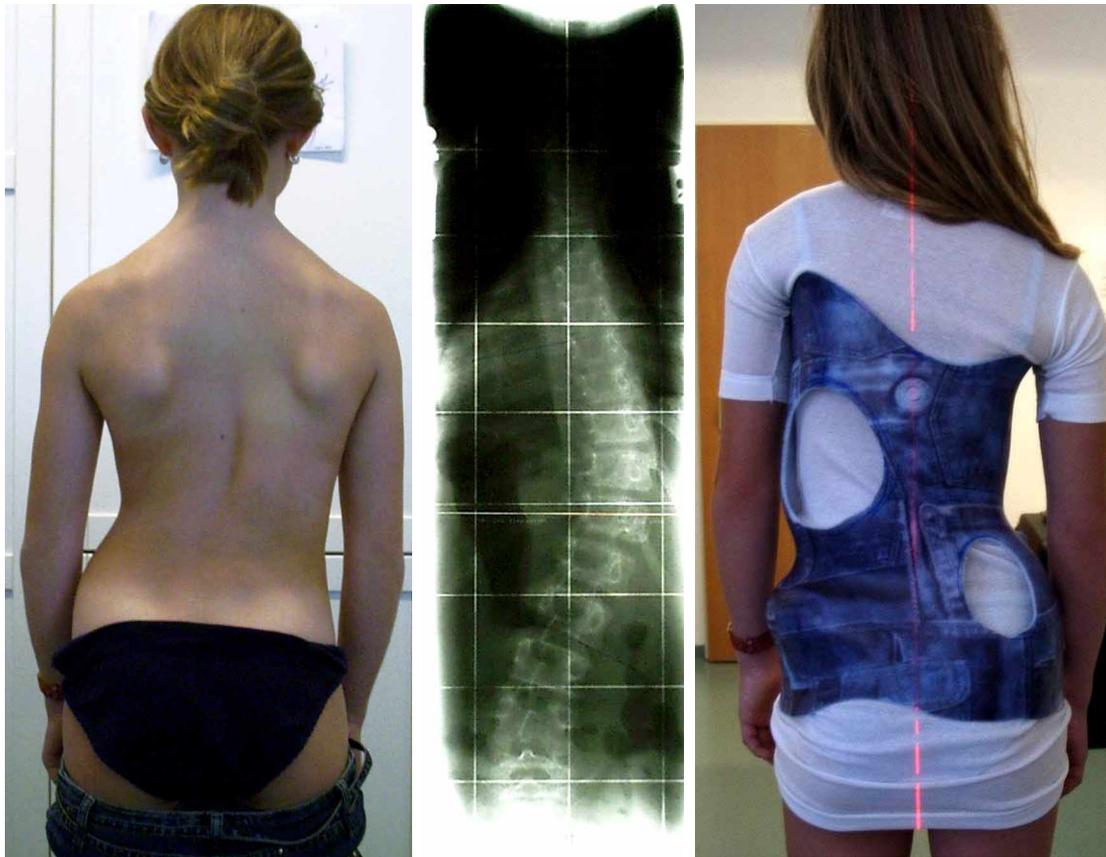


Figure 5 Patient with a low thoracic curvature and a clear imbalance with a decompensation to the right. The X-ray of this patient shows the apical vertebra at Th 10/11. Right: in the RSC-brace the imbalance seems to mirror the clinical picture on the left, while C7 is centred (red line). Pelvic prominence clinically to the left, in the brace to the right.

improvement in pain [63, 85, 86] and psychological distress [87, 88] in response to SIR. Results of a preliminary study were consistent with the possibility that incidence of progression among 181 patients treated with physiotherapy during the late 1980s was significantly less than the incidence that would be expected based on natural history surveys [59].

Another study to test the hypothesis that physiotherapy-based intervention can reduce incidence of progression in children with IS was performed recently [89]. The study consisted of a follow-up of the outcome of two prospective studies using the outcome parameter incidence of progression ($\geq 5^\circ$) in treated and untreated patient groups matched by age, sex and degree of curvature at diagnosis. A 6-week SIR programme offering patient-specific physiotherapy including intensive therapist-assisted exercise in diagnosis-matched groups was

the method of treatment. The incidence of progression in groups of untreated patients ranged from 1.5-fold (71.2% vs 46.7%) to 2.9-fold (55.8% vs 19.2%) higher than in groups of patients treated with SIR, even when SIR-treated groups included patients with more severe curvatures. Statistically, the differences were highly significant. The results of this study indicate that a supervised programme of exercise-based therapies can reduce incidence of progression in children with IS.

BRACING

The results of certain bracing concepts support the hypothesis that braces can be effective [66, 68, 70, 75, 90]. The Boston brace has proven effective in preventing progression [66, 75], but in the international literature

there is no evidence that Boston brace treatment can lead to improvements of Cobb angle and cosmesis. The effectiveness of brace treatment depends on the treatment time/day. Nighttime bracing has not been proven effective in a meta-analysis [34] nor in controlled trials [91]. However, aggressive marketing is performed for nighttime braces with studies on an uncontrolled basis [5, 92–94].

Goldberg *et al.* [29] reported that incidence of surgery is not significantly reduced by American strategies of bracing. Neither Milwaukee braces nor the American TLSO underarm braces had a significant impact on the incidence of surgery when compared with an untreated control group from Ireland.

In central Europe, however, the excellence of brace construction seems much better. In a review of the literature, it has been shown that the initial correction in braces applying European standards is much greater than the initial corrections in American braces [68].

As early as 1985, Hopf and Heine [90] showed that an improvement of the Cobb angle can be achieved with the Chêneau brace correcting > 40% initially. Landauer [70] demonstrated that a correction effect of more than 40% in the Chêneau brace leads to an improvement of the Cobb angle of on average 7° in the compliant patient in the long term (2 years after weaning).

A retrospective analysis of the incidence of surgery was undertaken for patients with scoliosis treated conservatively (SIR and Chêneau braces), compared with incidence in an untreated control group [89]. For that study, scoliosis patients who had conservative treatment at our centre between 1993 and 1996 were chosen from our database. The incidence of surgery of our group was compared with that reported by a centre in Ireland.

All patients, like those of the control group, were at least 15 years of age at the time they were evaluated for the last time. Of 343 female scoliosis patients with a curve angle of 33.4° (SD = 18.9) and different aetiologies, 41 (11.95%) had surgery. The incidence of surgery of our collective was significantly lower than the incidence of surgery of the comparison group (patients with AIS only), which reported an incidence of 28%. The AIS matched group of patients ($n = 179$) had an incidence of surgery of slightly more than 7%. When compared with a matched group of untreated patients, incidence of surgery was significantly reduced by SIR combined with bracing when the Chêneau principles are applied.

Discussion

Efforts to establish conservative scoliosis treatments have lingered in uncertainty for more than a millennium [1]. Reported successes in clinical studies of treatments like bracing have been controversial because of a lack of standardization of protocols and data analysis and reliable information about the natural history of untreated scoliosis [28]. But, for judging effectiveness of exercise-based therapies, the primary problem is that no systematic, long-term clinical tests have ever been carried out [1, 32, 34, 35].

The Schroth Clinic has used an exercise-based approach to treat spinal deformity for decades, with a continuous history of positive subjective feedback from patients who now number 3000 patients per year. Though the use of postural exercises for scoliosis therapy is grounded in scientific principles that relate directly to known aetiologies and symptoms of spinal deformity, its effectiveness has remained in question. During the past decade a systematic analysis has been undertaken with the long-term goal of examining scientifically the efficacy of this conservative approach to treating IS. Research to date has examined predictions of the hypothesis that physiotherapy can alleviate the signs and symptoms of IS in a multi-layered experimental approach that has included case report series, clinical studies and population-based comparisons [60, 62, 63, 68, 84, 95]. The results are consistent with the hypothesis that physiotherapy can significantly alleviate the primary symptoms of spinal deformity: pulmonary deficiency, pain and psychosocial issues.

The latest controlled studies cited above support the hypothesis that curvature progression can be reduced by physiotherapy alone [89] and effective methods of bracing (figures 5 and 6) lead to a reduced rate of patients for whom surgery would otherwise be necessary [96]. Conservative management of scoliosis has to be regarded as effective. There are differences in the quality of conservative management worldwide, and in the quality of physiotherapy and braces.

The poor outcome of low quality non-operative treatments should not be allowed to detract from high-quality non-operative management any more than low-quality surgery should be allowed to detract from high-quality surgery when surgery is indicated.

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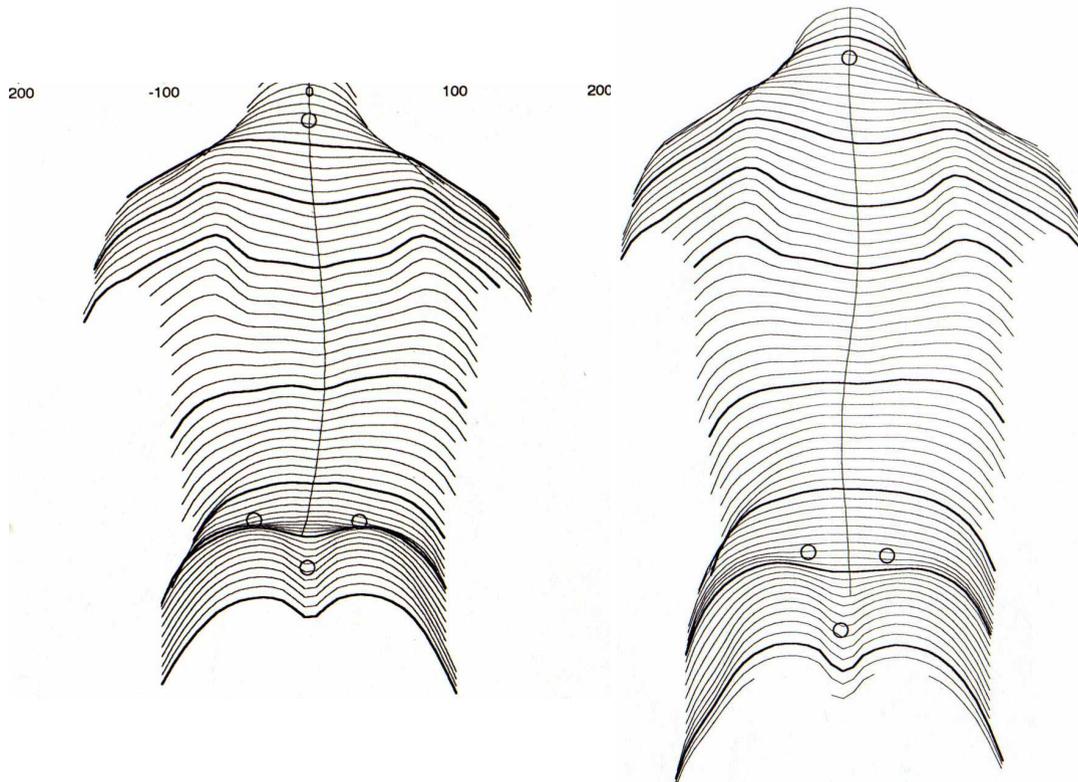


Figure 6 Surface topography of a girl with adolescent idiopathic scoliosis at the age of 10 years with right thoracic curvature entering brace treatment (left) and at the age of 12 years still pre-menarchial at the time of early brace weaning. The curve is still stable at the age of 14.6 years.

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