

Adolescent idiopathic scoliosis: indications for bracing and conservative treatments

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Abstract: Adolescent idiopathic scoliosis (AIS) represents the most frequent tridimensional spinal deformity. Progression of curves is linked mainly to the rapid growth around puberty. The natural history can lead to large spinal and thoracic deformities, which could impose surgical treatments. In that specific adolescent period, it is possible with very accurate treatments to alt curves progression. We describe the different types of braces used worldwide their indications, technical applications, results and failures, as well our own experience. The literature agrees that with proper indications that means, still growing patients, and documented progressive curves between 20° and 45°, a well-designed and adapted brace providing a correction of 50% can stop the curve's progression in most of the cases.

Keywords: Adolescent idiopathic scoliosis (AIS); treatments; brace

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Introduction

The treatments of idiopathic adolescent scoliosis depend mainly on the size and localization of the deformity, and its progression's potential for due to the remaining growth. During the past decade, several studies have confirmed that the natural history of adolescent idiopathic scoliosis (AIS) can be positively affected by non-operative treatment, particularly bracing (1-6). The primary objective of nonoperative treatment is to successfully arrest progressive curves or to correct curves that cause or may likely cause disability. Orthotic device selection is based on the effectiveness of acute curves correction, on the type and level of curve and the anticipated tolerance of the patient. Avoidance of unnecessary surgery, cosmetic improvement, and an increase of vital capacity as well as pain control, are also of major importance (7-14).

In 1985, the Scoliosis Research Society (SRS) initiated a controlled clinical trial study to investigate the effectiveness of bracing as treatment for scoliosis. Patients of the same age, curve pattern and curve severity were divided into two groups, one treated with bracing and one untreated. Results published in 1993 demonstrated that brace treatment is effective compared to natural history (6). In another study (3), the records and radiographs of more than 1,000 scoliotic patients treated by bracing were reviewed and compared with unbraced patients (15). This retrospective study confirmed that bracing is an effective treatment to slow or arrest the progression of most spinal curvatures in skeletally immature patients compared with those untreated by this method. Furthermore, a meta-analysis of 20 studies showed that bracing 23 h per day was significantly more successful than any other non-operative treatment (1,6). Nevertheless, there are some patients for whom brace treatment is not effective (16).

Other forms of non-surgical treatment, such as chiropractic or osteopathic manipulation, acupuncture, exercise or other manual treatments, or diet and nutrition, have not yet been proven effective in controlling spinal deformities.

Global scoliosis screening programs targeted on prepubertal children are still debated in the literature (17). The debate addresses mainly the cost/benefit and not the effectiveness of mass screening programs. In order to

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detect early enough low-grade curves and to follow their possible progression, clinical back asymmetry assessments is mandatory. Thus, screening is already part of AIS conservative treatment.

Brace treatment: when to begin

Clinical checks are the appropriate strategy for small curves, curves at low risk of progression, and those with favorable natural history. Indications for brace treatment are patients with a curve of 25° to 40° still growing child or with curves less than 25° and a documented progression of 5° to 10° in six months (progression of more than 1° per month). Patients with scoliosis of 20° to 25° with pronounced skeletal immaturity (Risser 0, Tanner 1 or 2) should also be treated immediately. Braces are generally be worn full time, the treatment duration is two to four years, until skeletal maturation and the end of bone growth (18,19).

By contrast, contraindications for brace treatment are a child who is skeletally mature, or a growing child with a curve of over 45°, or under 25° without documented progression (1,3,4,20). Real thoracic lordosis is also a contraindication for orthotic treatment due to the flattening effect of braces on the thoracic spine. A patient without a good family support or who refuses to wear a brace should not be considered for brace treatment. Prevalence for AIS in girl is seven times higher than in boys but girl's response to brace treatment is more favorable in girls due to more spine flexibility, shorter growth pubertal spur and shorter length of treatment, compliance to brace treatment is also higher in girls and in boys. Body habitus has been found to be a predictive factor of poor outcome in the orthotic treatment of AIS. Overweight adolescent patients will have greater curve progression and be less successful with bracing. In addition, the ability of a brace to transmit corrective forces to the spine through the ribs and soft tissue may be compromised in these patients and this factor should be taken into account when making treatment decisions (21).

A prospective, multicenter study conducted by Nachemson *et al.* in several countries showed that the success rate of bracing was significantly higher compared to observation and surface electrical stimulation (4). A meta-analysis of 20 studies further supported this finding and showed that the weighted mean proportion of success was low for lateral electrical surface stimulation and for observation, and progressively higher for bracing at 8, 16, or 23 h per day. The study concluded that bracing 23 h per day was significantly more successful than any other treatment (6). Furthermore, a recently published systematic review concluded that bracing AIS is effective in the long term (22). However, it remains controversial as to whether or not a brace treatment can decrease the risk of surgery (23,24). A review using the number of surgically treated patients as an indicator of failure of bracing and reported a broad spectrum ranging from 1% to 43% (25,26).

How to implement brace treatment

Brace construction must follow some rules in order to provide the best possible correction. The pelvis is first levelled so there is no side effect created by a pre-existing leg length discrepancy. The brace must fit the iliac crests, so the correction areas build-in will have the best sagittal and horizontal correction effects. When the patient is first fitted with a brace, an X-ray is performed, the correction must at least be 50% for the initial Cobb angle. The initial adjustment period is usually one to two weeks. Initially, the adolescent wears the brace for 2 to 4 h per day and the orthosis is left loose to allow the patient to gradually adjust to it. The orthosis is progressively tightened until the appropriate level of snugness is reached. If any areas of pain, discomfort or skin irritation develop, the brace is adjusted. X-rays should be performed approximately every four to six months without brace in order to follow the evolution of the curve. The brace is removed for a minimum of 18 h before the X-rays are taken so that the spine can settle back to its deformed position and imaging can accurately detect curve deterioration.

A curve evolution of 6 degrees or more during treatment is a bad result, progression to the need for surgical stabilization is considered a failure of brace treatment.

The articles written on the number of h per day of brace wearing show that the more h per day the brace is worn, the better the result. The orthosis is usually prescribed for 20 h out of 24 h wears the time out of brace is for shower, swimming, physical education and sport. The patient should be stimulated to be active in sports and continuing to wear the brace if possible. Contact sports are not allowed with the brace to protect other participants. These activities generally represent an average of 2 to 4 h a day to ensure brace-wearing of at least 20 h daily.

Brace's wear part-time or only at night has been described by some physicians and is widely advocated in some institutions. But there is a lack of long-term follow-up results to prove the effectiveness of this type of treatment in adolescents, and all series on effective orthotic treatment

are with full-time wear. Some series suggest that part-time wear can be effective but those series have a short follow-up after bracing and these reports do not compare their results to natural history or full-time bracing.

Wiley *et al.* analyzed the results of bracing according to the wearing regimen. Patients were divided into noncompliant (less than 12 h per day), part-time (between 12 and 18 h per day), and full-time brace wearing (between 18 and 23 h per day). The initial curves were similar in the three groups. Patients who wore the brace less than 12 h per day were associated with an average curve progression from 41.3° to 56.3°, and those who wore the brace parttime progressed from 37.6° to 41.2°. Significant curve improvement was noted in the full-time patient group and curves measured 35.7° at final follow-up compared to 39.3° at brace fitting. In addition, the surgical rate also depended on brace compliance with 73% in non-compliant patients compared to 9% in the fully compliant group (27).

Green (28) reported that 16 h per day of bracing was effective in slowing curve progression. He studied a heterogeneous group of patients with curves between 23° and 49° and found that only 9% curves progressed 5° or more. However, both Boston and Milwaukee braces were used for treatment and follow-up was limited. Similarly, Emans *et al.* (29) found part-time brace wear to be as effective as full-time wear for smaller curves. Allington and Bowen (30) reported no difference in the efficacy of fulltime versus part-time wear using the Wilmington brace for curves of 30–40°, but observed that 58% of patients progressed more than 5° degrees in the brace. Peltonen *et al.* (31) also noted that the results of 12 h per day of bracing were similar to the results of 23 h per day.

How to stop brace treatment

Brace weaning begins when the patient reaches skeletal maturity, determined as the finding of a Risser sign of 3 in girls and 4 in boys, i.e., at least 1 year after the menarche and a documented stop of growth in height for 6 months. The time of brace wear is decreased progressively over a period of two to six months, and X-rays are then performed the patient being without the brace. If the curves remain stable, brace weaning continues to night brace for some months then to stop. Roentgenograms without the brace are performed to check the stability of the curves. If stability is obtained, the patient is freed of the brace. On the contrary, if the at the end of the weaning process there is progression of the residual curve, this can be an indication for surgical

correction of the scoliosis. At full bone maturation and growth, there is no evidence to support that continuing bracing regime provides any treatment benefit.

Brace treatment and complications

Treatments of AIS by brace can lead to some drawback. Treatment with a brace can be psychologically difficult (32,33), young adolescents aged between 10 and 16 years, have to wear the brace for 18 to 23 h a day during several years, the brace is always too much visible for them, and it can be cumbersome and uncomfortable to wear (34,35). The noncompliance to wear a brace is very often an issue and it goes from refusal to wear the orthosis, to early discontinuation of the use of it, to less than full-time use of the brace. Poor compliance is related to the following factors: the unacceptable appearance of the brace to the body image-conscious teenager, the discomfort from chin and throat contact (especially Milwaukee brace) or from the pelvic or axillary portion of the brace [especially thoracolumbo-sacral orthosis (TLSO) braces]. A recent study showed that scoliosis patients are willing to undergo brace treatment only if it provides sizeable reduction of the risk of surgery (34). While some studies report little variation in compliance between Milwaukee brace when compared to TLSO braces, other show significant less compliance with the Milwaukee brace when compared to TLSO's (3,36).

Other problems encountered due to brace treatment include skin irritation, a temporary decrease in vital capacity, and mild chest wall and inferior rib deformation. Skin irritation is a common problem and more frequent in warm climates and during the summer months due to the increase in heat and sweat. To reduce the likelihood or occurrence of skin irritation, frequent changing of the cotton undergarment is recommended, but discontinuation of brace treatment due to skin irritation is uncommon. The vital capacity may be temporarily reduced in patients treated with TLSO and mild chest wall and inferior rib deformation can appear during treatment.

Chest wall and rib deformation commonly occurs if bracing is performed at ages where the chest is very plastic and easily deformed with drooping of the ribs on the convexity of the scoliosis, where corrective forces are applied. When brace use is discontinued, the mild rib cage deformity usually disappears. However, if full-time bracing starts at very young age at continues for a numbers of years, chest wall and rib deformation may become permanent and may not reverse (7-14).

Brace Types

Milwaukee brace—cervico-thoraco-lumbo-sacral orthosis (CTLSO)

The Milwaukee brace is an historical bracing system, also named CTLSO, is a full torso brace extending from the pelvis to the base of the skull. It was originally designed by Blount and Schmidt in 1946 for postoperative care when surgery required long periods of immobilization and it has subsequently been used for thoracic and double curves. Milwaukee braces are often custom-made from a mold of the patient's torso. One anterior and two posterior bars are attached to a pelvic girdle made of leather or plastic, as well as a neck ring. The ring has an anterior throat mold and two posterior occipital pads, which fit behind the patient's head. Lateral pads are strapped to the bars and adjustment of these straps holds the spine in alignment.

Curve patterns that should be treated in a Milwaukee brace are thoracic curves that have an apex at or above T8, double thoracic, and other double curves when the apex of the thoracic component is above T8, i.e., double thoracic and lumbar, or double thoracic and thoracolumbar patterns.

Success rate

Curves between 20° and 29° with a Risser sign between 0 and 1 progressed 28% less than untreated curves of similar magnitude (40% versus 68%, respectively). Treated curves of similar magnitude, but a Risser sign of 2 or more, progressed 10% less than untreated curves (10% versus 23%, respectively). Similarly, curves between 30° and 39° with a Risser sign between 0 and 1 progressed 14% less than untreated curves of similar magnitude (43% versus 57%, respectively). Treated curves of similar magnitude, but a Risser sign of 2 or more, progressed 21% less than untreated curves (22% versus 43%, respectively) (3,15).

Boston brace—TLSO

As Fayssoux *et al.* stated, JE Hall and ME Miller developed the Boston Brace System in 1972 (35) and Watts *et al.* first reported on its efficacy in 1977 (36). This rigid orthosis is open in its back and corrects the scoliosis deformities by small pads placed against the rib in alternate fashion, these pads are also used for partial rotational correction. These pads are usually placed in the back areas of the brace so that the body is pushed forward against the front of the brace. Areas of void are provided opposite the sites of pads corrective areas in order to allow the patient to escape pressure pads by active muscular effort (29). The brace is build-up with a 15° lumbar lordosis, which increases the pelvic grip and the correction in lumbar and thoracolumbar areas. The brace stabilizes the trunk from the pelvis to around shoulder blade height and the Boston Brace is not useful for the correction of high curves above T6 (5,26,27,29,36). The original brace design was modified in order to increase the lumbar lordosis to 15° to better derotate the spine (35).

Success rate

The Boston Brace is be particularly effective for scoliosis ranging from 20° to 49° between T6 and L4. The aim at the first X-ray in brace is a correction of at least 50%, so the permanent correction 2 years after brace discontinuance can be 15% in relationship to the initial angle. By the use of Boston Brace System treatment, 49% of the curves remain unchanged, (\pm 5°), 39% of the scoliosis have a permanent correction of 5° to 15°, 4% are stabilized with a correction of at least 15°, 4% lose between 5° to 15°, and 3% progress more than 15°. A study by Emans *et al.* describes that 11% of patients treated by Boston had a surgical indication during the period of bracing (29).

Lyon brace

The Lyon brace was invented by Stagnara *et al.* in 1947 and is also known as the Stagnara brace, this brace system is the first, which had prospective studies and consistent documented efficacy. It is composed of a pelvic section with axillary, thoracic and lumbar plates connected in units by two vertical aluminium rods, one anterior and one posterior. The pelvic section is composed of two lateral valves, one for each hemi-pelvis. The valves are connected by metal pieces to the vertical aluminium rods. Forces are applied at the two neutral vertebrae and a counterforce is applied at the apex of the curve. It is usually prescribed for progressive scoliosis with lumbar or low thoracolumbar curves between 30° to 50° (37).

Success rate

The overall efficacy of the Lyon brace is 95%. However, it drops to 87% for thoracic curves and to 80% in patients with Risser sign 0.

Chêneau brace

Jacques Chêneau designed the original Chêneau Brace in 1979. The brace is commonly used for the treatment of

scoliosis and thoracic hypokyphosis in many European countries, Israel and Russia. However, it is not commonly prescribed in North America and the United Kingdom. The Chêneau Brace utilizes large, sweeping pads to push the body against its curve and into blown out spaces and is usually coupled with the Schroth physical therapy method. The Schroth theory holds that the deformity can be corrected through retraining muscles and nerves to learn what a straight spine feels like, and by breathing deeply into areas crushed by the curvature to help gain flexibility and to expand (38,39). The brace helps patients to perform their exercises throughout the day. It is asymmetrical and used for patients of all degrees of severity and maturity, and often worn 20 to 23 h daily. The brace principally aims to allow lateral and longitudinal rotation and movement (40).

Night-time braces and Charleston brace

Full compliance to brace treatment with program that involves 18 to 23 h of daily wear through the end of growth and full bone maturity is difficult for these young patients. Partial time and night-time treatments were developed improving order to increase adolescents' compliance in reducing the total time in the brace and by-passing the psychological difficulties created by daytime wear.

Night-time braces are more effective in patients with single, correctible thoraco-lumbar and lumbar curves. They are also useful for noncompliant patients which received prescription for a full-time wear program, adolescents in whom other types of braces had failed, and patients close to bone maturity who may require partial time treatment (18,35).

The Charleston bending brace was developed with the concept that compliance would increase if the brace in prescribed only for night wearing. The first publication by Hooper and Reed in 1978 describes the early development of this new side-bending brace for nocturnal wear. The brace is asymmetrical and overcorrects the scoliotic deformity. The pelvic mold is similar to the Boston brace and it proximal extend is approximately the same height as the Boston, but it curves the patient's body to the side of the convexity of the curve and overcorrecting it. It is used for thoracolumbar curves in young patients, before structural maturity, who have reducible scoliosis from 25° to 35° (41-43).

Success rate

Adolescents with a curve over 25° and a Risser sign between

0 and 2 showed a rate of surgery between 12% and 17% (41-43). In a 2002 study, with short follow-up it has been shown to be as effective as the Boston brace (41).

In articles that compare nighttime orthosis to more traditional brace methods (18,42-45), Katz et al. retrospectively recommended the use of the Boston Brace System in curves between 36 to 45 degrees because it prevented curve progression of 6 degrees or more in 57% of patients, as compared with only 17% success in using the Charleston Orthosis. The Boston orthosis also controlled curves of 25 to 35 degrees more effectively than did the Charleston orthosis, preventing progression in 71% of patients versus 53% in using Charleston Orthosis (18). Howard et al. also found that the TLSO was superior at preventing curve progression when compared with the Charleston brace (41). Gepstein et al., however, found no statistical difference in the surgery rate of 13.5% using the TLSO and 11% using the Charleston Brace (46). Similarly, Janicki et al. found the Providence nighttime orthosis more effective in avoiding surgery and preventing curve progression than a TLSO in a comparable population of patients with AIS having initial curves of 25 to 40 degrees (47).

Providence brace

The Providence Brace System is developed by D'Amato, Griggs and McCoy in the 1990s. The orthosis applied a direct, lateral and rotational forces on the apex of the curve to move the spine toward the midline even beyond the midline (48). The brace doesn't bend the spine as with the Charleston bending brace, but the foreseen effect is to bring the apex of the scoliotic curve to the midline or beyond through the application of lateral forces. The mechanical effect is a three-point-pressure systems and the void areas that are located at opposite these pressures points. In comparison to natural history of scoliosis in adolescents and the prospective study data of Nachemson *et al.* (4), the Providence brace is effective for the control of curves progression for deformities less than 35° and apex lower T9 (47-49).

Success rate

Studies showed that the Providence night brace achieves about 90% correction of the primary curve and at long term the scoliosis progression of the curve of more than 5° degrees is expected in about 25% of cases. The providence night brace may be recommended for the care of AIS with very flexible curves less than 35° in lumbar and thoracolumbar area (47-49).

Soft brace and SpineCor brace

The SpineCor scoliosis correction system was developed by Coillard *et al.* in the mid-1990s (50). This system has a pelvic girdle made of soft plastic, and strong elastic bands are wrapped around the trunk, the thighs and the shoulders, pulling against the spine curvatures, rotations, and imbalances. The correction is more important in patients who have small, flexible and simple curvatures and patients that are young and compliant. The SpineCor system is an adjustable, flexible, and less rigid technique providing correction that continues as a child moves and grows. The system is usually applied 20 h a day and the patient cannot remove it for more than 2 h at time.

Success rate

A 2003 study reported that after 2 years, the SpineCor system is able to correct adolescents and children scoliosis by 5° degrees in 55% of patients. 45% are stabilized or worsened by more than 5° (7%). Studies done by the non-developing team show a different trend reported a success rate lower than the more rigid type of braces (50-52). According to Wong *et al.* (52), in patients with curves between 20° and 30° before skeletal maturity, a rigid brace showed better results than the SpineCor at 45 months follow-up: 31.8% in the SpineCor group had 5 or more degrees of curve progression versus 4.7% in rigid brace.

Other conservative treatments

The efficacy of conservative approaches to scoliosis treatment is still an open debate. Alternative forms of non-surgical treatment and braces, such as chiropractic or osteopathy, acupuncture, exercises or other manipulative treatments, or diet, have not yet been proven to be effective in changing the natural history of spinal deformities.

Although a subject of debate, most experts agree that physiotherapy alone will not affect the progression of a structural scoliosis. However, there is agreement that a selective physical therapy program in conjunction with brace treatment is beneficial. The triad of out-patient physiotherapy, intensive in-patient rehabilitation, and bracing has proven effective in conservative scoliosis treatment in central Europe (38,39).

Acupuncture it is commonly used for pain control throughout the world, to date, only one study has been published and the effects of acupuncture in the treatment of patients with scoliosis require further investigation (53).

Electrotherapy aims to stimulate muscle contraction by implanted or skin electrodes, this technique failed to alter the natural history of idiopathic scoliosis. Longitudinal spinal muscles in the convexity of the scoliosis are stimulated electrically are supposed to actively correct the curves. No benefit was observed in more than half of the patients treated by night-time electrotherapy and that the difference in progression between natural history and electrical stimulation was not significantly different (54).

Our preferred technique for brace treatment in AIS

Screening programs allows early detection, and to individualize adolescents with curves progression. Brace indications are: curve documented progression over 20° (*Figure 1A*: X-ray at diagnosis; *Figure 1B*: X-ray at brace indication), curves diagnosed between 25° and 45°, gross trunk imbalance in patients still in active growth (*Figure 2A*: X-ray at brace indication). The apex of structural curves must be D6 or caudal, in apex D5 and above braces have no real effect. The candidate for bracing and his family must understand the purpose of the treatment its length, goal and limits.

On a full spine X-ray in standing position (classic or EOS), we assess the pelvic position, and we draw the area where we plan to apply pressure forces for correction. The forces are applied in pair in order to perform also derotation forces (*Figure 2B*).

Our choice of brace's construct is based on the Boston system, with anterior opening, and pressure area and expansion windows after Cheneau principles.

In the orthotic workshop, the patient is scanned by a laser measurement system and the data are collected in the software: VORUMTM. We define the final shape of the brace on a screen with a 3D model (55), alterations to increase the curve correction, are made in constant trunk volume, the program manages also voids opposite to correction area (*Figure 2C*: computerized correction on the screen).

Digital data are sent to a milling unit, where a



Figure 1 Patient 1. (A) X-ray at diagnosis, immature girl, at 10 years 4 months old. Right thoracic curve: 14°: open triradiate cartilage, Risser 0, no menstruation. As it is the first X-ray without documented progression surveillance by clinical examination and X-rays program is set-up; (B) X-ray at 13 years old, in the last 3 months sudden curve's progression to 28°, Risser 0, menstruation 3 months ago. A clear indication for brace treatment.

polyurethane block is shaped to a positive mold.

A 2.5 mm polypropylene sheet, is soften by heat, it is applied on the mold, and then cut to the patient longitudinal size. Foam pads increase correction effect. (*Figure 2D*: adjusted brace with Velcro straps at first fitting)

Insertion of metallic landmarks allows seeing the correction's pads zones. After proper fitting on the patient, an initial X-ray demonstrate a correction of at least 50% of the original curve, if not pads are modified in position and thickness and if necessary, a new brace is built-up; 50% correction of initial Cobb angle is the best indicator for a successful treatment. (*Figure 2E*).

Once the best correction achieved, patient wear his orthosis progressively from 2 h periods daily to a program of 20/24 h in around 2 weeks. Physical therapy exercises keep flexibility and good muscle tonus.

After 6 to 8 weeks a clinical assessment checks the skin, the patient morphology and the compliance, during the length of the treatment clinical and X-rays out of brace for 24 h are organized at least every six months, usually the brace is changed if growth exceed 8 cm or weight exceed 8 kg.

Weaning begins at Risser 3 in girls usually 18 months after first menstruation, and Risser 4 in boys, and when growth stops; all conditions must be fulfilled.

Weaning is performed in a period of 6 months.

We perform clinical examination and X-rays 1 and 2 years after brace's stop (*Figure 2F*,G).

From 2009 to 2011 a prospective study included 43 patients treated with this brace concept. 37 girls and 6 boys, mean age at bracing: 12 years and 6 months. 20 were single curves and 23 multiple curves. The best correction's percentage is in thoraco-lumbar area (81%), then in lumbar area (62%) and thoracic area (61%). The mean angle at bracing is 28.3°, the initial angle in brace: 11.1° with a correction of 17.2 and the mean angle at 2 years follow-up is 26°. Patients grow 9cm and gain 11kg during the brace treatment.

This series has two cases (4.3%) of failure leading to surgery, one because of an imbalanced thoraco-lumbar of 37° with important permanent imbalance, the other for progression due to lack of compliance. The results at 2 years follow-up after brace's stop are collected in the table 1 and demonstrate a mean long-term follow-up curves correction of 2° from 28° to 26°.

Conclusions

Treatment by brace is nowadays the only method that has been proven to alter with consistence the natural history of idiopathic scoliosis. Different orthoses and many bracing systems and regimens exist. Observation or exercises programs are appropriate for small curves, indication for bracing is for documented progressive curves or for curves over 25° in a skeletally immature child. In order to select patients early enough, clinical screening programs are very useful. Brace construction, adjustment, and followup must be done by dedicated and well trained teams who belief that brace treatment is worthwhile. Braces must be generally worn for at least 20 h a day and the results of brace treatment correlates to treatment compliance and the competence and dedication of the treating team. Complications and problems triggered by brace treatments are limited and overweighed by their benefits.

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Figure 2 Patient 2. (A) First visit, for a girl of 13 years old, Risser 0, no menstruation, the X-ray shows a thoraco-lumbar curve of 29° , immediate indication for bracing; (B) X-ray with the design of correction's pads for the orthopedic technician; (C) computerized image of the trunk with the corrective pads placement. The data are sent to a milling machine, which trims a polyurethane mold. A polypropylene heated foil is applied on the mold, and then cut at the patient's size, the pads are fixed inside the brace; (D) brace fitted on the patient; (E) X-ray done immediately after the first brace fitting in order to check the correction. The index of brace's treatment success is the correction index (Cobb pre-brace, Cobb in-brace/Cobb pre-brace*100); the correction must be at least 50%. For this patient the thoraco-lumbar curve decreases from 29° to 0°. The metallic dots are the landmarks for the corrective pads, this allows easy correction of the pad if needed. Rotational correction is also obtained; (F) X-ray at 15 years old, at the end of brace treatment, Risser 4, one year after first menstruation, the growth as stopped. Without brace for a month, the thoraco-lumbar curve is 17° (improvement of 12°), there is a compensatory thoracic curve of 14°; (G) at 2 year's follow-up after brace discontinuation, the patient is 17 years old, the thoraco-lumbar curve is 21° and the thoracic one is 16°. Full bone maturity. Brace treatment has stopped the progression and the correction is 8° on the long term.

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None.

Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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