Bracing in adolescent idiopathic scoliosis

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Abstract The article reviews the present knowledge about brace treatment for adolescent idiopathic scoliosis (AIS). Indications, technique, problems, and results, are presented based on the literature. It is stressed by the authors that more scientific evidence is needed to reach a final conclusion whether brace treatment in AIS is effective or not.

Keywords Adolescent idiopathic scoliosis · Bracing · Conservative management · Indications · Compliance

Introduction

Brace treatment of adolescent idiopathic scoliosis (AIS) is controversial. The body of evidence for its efficacy is weak, despite the fact that it has been advocated in different forms for centuries. There are numerous retrospective case series reporting a favourable outcome. No randomized controlled trials have been published to date. In a recent systematic review of the English literature from 1970 to 2010, Davies et al. identified only eight cohort studies comparing results of bracing with observation of curves, five being prospective and three retrospective. They conclude: “Given the poor scientific evidence currently available, bracing should probably only be considered if patients are involved in a randomized controlled trial to confirm its efficacy” [1].

Prognosis of AIS

The natural history of adolescent idiopathic scoliosis is benign. The prognosis *quoad vitam* is not impaired. Nachemson published a 30-year follow-up study of untreated 117 scoliosis patients with mixed aetiology. At follow-up, 16 patients had died from cardiopulmonary disease. This was significantly more than the expected death rate for this age group. However, the fatalities were related to congenital and non-idiopathic deformities [2]. This result is supported by an almost 60-year follow-up showing an increased death rate only for patients with infantile and juvenile curves but not for AIS [3]. This has to be borne in mind when making any treatment decisions.

Indications for bracing

Generally accepted indications for brace treatment of adolescent idiopathic scoliosis are

- Curves between 25° and 30° with demonstrated $\geq 5^\circ$ progression
- Curves 30°–40°
- Immature patient (at least 1 year of growth left)
- Risser <3
- Motivated patient/parents

Technique

An absolute prerequisite for successful bracing is the availability of a dedicated team including specially trained nurses, physiotherapists, technicians, and an orthopaedic surgeon who is committed to the treatment. The patient and

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the caretakers must have a thorough understanding of the bracing philosophy and realistic expectations.

The majority of braces used are solid plastic constructs based on plaster cast or prefabricated modules fitted to the individual patient in order to correct the lateral curvature as well as the rotation and hold the spine during growth in the corrected position. Significant in-brace curve correction (ideally 50 % or more) is necessary to achieve a lasting effect. There is a correlation between in-brace correction and favourable outcome of treatment [4, 5]. The brace is recommended to be worn more than 22 h per day [5–7]. Treatment is carried on until the end of growth. Cessation of growth, Risser 5, and an interval of 2 years post-menarche are commonly used as criteria for making the decision to stop brace wearing. It is not clear whether step-wise weaning from the brace is necessary at the end of treatment. This traditional regimen subjects the teen-age patients to substantial restrictions. Compliance problems are common. There is also a fear that brace treatment could have a negative psychological impact on the patient [8]. To make bracing less uncomfortable for the patient and so improve its acceptance, night-bracing has been introduced [9, 10]. In this technique, the braces are shaped in a way that in-brace corrections of up to 100 % or even overcorrection can be achieved. Night-braces can be worn only in recumbent position. The system relies on the assumption that markedly superior in-brace curve correction compensates for wearing time.

The most recent development aiming at better comfort and cosmesis is a harness type of flexible orthosis consisting of a plastic pelvic base, tight straps, and elastic bands [11, 12].

Compliance

Compliance with the prescribed regimen is a critical issue. Traditionally, it has been estimated by a patient diary, by assessing the condition of the patient's skin and/or the presence of wearing signs at the brace. These methods are rather unreliable. More recently, electronic monitoring using temperature or pressure sensors inside the brace has been introduced. Average wearing times from 45 to 75 % of the recommended duration with a large range (4.2–95 %) have been reported [13–18]. The awareness of being monitored seems to increase wearing time [19]. The use of night-braces or flexible functional orthoses could not be shown to improve compliance in comparison to full-time bracing [16, 18].

Results

In the SRS Brace Study, a comparative prospective cohort study published by Nachemson and Peterson, failure was

defined as at least 6° of progression on two consecutive radiographs. A 15 % failure rate for brace-treated patients compared favourably with 45 % in the observation group. Risser 0–1, apex above T12, and a balanced spine were identified as predictors for curve progression [6].

In a retrospective 22-year follow-up study, Danielson and Nachemson reported the radiographic outcome of 127 patients who completed treatment with a Milwaukee or a Boston brace. During treatment, the mean pre-bracing Cobb angle decreased from 33.2 (12–60)° to 29.7 (0–50)°. At final follow-up, it was 37.6 (5–71)°. The mean progression during 22 years after treatment was 7.9 (–7 to 24)°. In 36 % of the patients, progression of more than 10° was registered [20].

Emans et al. [21] published a retrospective series of 295 brace-treated patients after a mean follow-up time of 2.4 years. The rate of surgery was 11 % during brace treatment and an additional 1 % after weaning.

In their systematic review of comparative studies, Davies et al. [1] pooled the published results according to the outcome measures used. Three studies reported on surgery rates [22–24]. Overall, 120 patients underwent brace treatment, and 115 were observed. The surgery rates were 23 and 21 % respectively with a risk difference of 2 %. This result, however, is somewhat skewed towards observation due to the fact that one of the three pooled studies, published by Mannherz et al. [22], is dealing with early-onset scoliosis. This is inconsistent with the inclusion criteria of the systematic review listing only adolescent idiopathic scoliosis [1]. In the paper of Mannherz et al. [22], the curves of the braced group were more severe compared with the observation group (mean Cobb angle pre-treatment 22° vs. 11°). Braced patients had also a greater rib vertebra angle difference and more thoracic hypokyphosis. Four studies used quality-of-life outcomes at follow-up. Cheung et al. reported a statistically better outcome for the observation group based on the SRS-22 questionnaire (total mean score 4.24 vs. 4.47, $p < 0.005$) [25]. Parent et al. [26], using the same questionnaire, found slightly better results in the brace population, but the difference in the mean overall score was statistically not significant. Pham et al. used the quality of life profile for spine deformities (QLPSD). They demonstrated a significantly better outcome for the brace patients (48 vs. 32.25 points, $p < 0.001$) [27]. Ugwonalie et al. reported minimal differences in expectations favouring the brace group and in function/symptoms favouring the observation group. They used the Child Health Questionnaire (CHQ) and the Paediatric Outcomes Data Collection Instrument (PODCI) [28]. Four studies used Cobb-angle changes as outcome measures [22–24, 27]. From three of them p values could not be calculated because of incomplete data. Two studies reported a positive treatment effect [24, 27]. One study saw

a better radiographic outcome after observation [22]. The favourable results for bracing in the fourth study were not statistically significant [23].

Night bracing

The Charleston night-time bending brace was introduced by Price et al. [9] in 1990. They reported an in-brace mean curve correction of 73 %. Applying the Providence night brace, d'Amato et al. [10] achieved an average of 96 % primary correction. In thoracolumbar curves it was even as much as 111 %. These figures are substantially higher than what usually can be achieved using conventional full-time braces. One has, however, to bear in mind that the measurements are based on radiographs taken supine. This gives a more favorable picture if compared to in-brace radiographs of conventional braces which are usually taken in standing position. Price et al. reported progression of 5° or more in 34 patients, 17 % underwent surgery after using the Charleston bending brace. They concluded that night-time bracing is justified [9]. In the study of d'Amato et al. reporting the results of 102 consecutive patients treated with the Providence brace, 26 % of the patients progressed 6° or more. Looking at thoracolumbar or lumbar curves separately, the success rate was over 90 %. Patients with Risser Grade 0 or 1 had a better outcome than those with Risser 2 [10]. Yrjönen et al. retrospectively compared 36

consecutive patients (mean Cobb angle 28.4°, apex T10 or below) treated with the Providence brace with 36 matched controls treated with a Boston brace. The average in-brace correction was 92 % for the Providence group and 50 % in the Boston group. Failure of treatment (progression of more than 5°) occurred in 27 % of the Providence patients versus 22 % of the Boston patients. The difference was not statistically significant [29] (Figs. 1, 2).

Bracing in boys

The applicability of brace treatment to boys is questioned but the data in the literature is conflicting [30]. It is suggested that curves in boys are stiffer and have a higher risk of progression than in girls [31–33]. It has also been reported that the results of operative treatment are inferior in boys. Boys are seemingly also less compliant than girls. In a large series looking at patients treated with Boston brace and Charleston bending brace published by Katz et al. [34], the failure rate in 25 male patients was 80 % in comparison to 36 % in girls. Karol [30] found a 75 % failure rate (progression of more than 5°) in 112 male patients treated with a Milwaukee, Boston, or Charleston brace. A study by Yrjönen et al. comparing the radiographic results of 51 boys with a matched control group of 51 girls treated with a Boston brace, boys showed a significantly higher failure rate (31.4 vs. 21.6 %). Three of the

Fig. 1 Adequate indication for brace treatment: *flexible curve*, sufficient remaining growth. **a** 12-year-old girl, premenarcheal, skeletal age 12.5 years, Risser 0, **b** in-brace correction 64 %, **c** improvement after 1 year, **d** in new brace after 1 year, **e** start of weaning after 2 years, **f** 1 year after weaning, very satisfactory result. Patient's growth during bracing period 12 cm

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Fig. 2 Exceptional case **a** 14-year-old girl, 3 years post-menarche, Risser 2, **b** in-brace correction 66 %, **c** 1 year after weaning, **d** 2 years after weaning, very satisfactory result. Patient's growth during the bracing period 4.5 cm

boys but none of the girls had to be operated on. After excluding the non-compliant boys (14/51, 27.5 %), there was no difference in outcome if compared to girls. They conclude that although boys may have more compliance problems there is no reason to abandon bracing [35].

Discussion

Although brace treatment for adolescent idiopathic scoliosis has been used for a long time, there is still no final scientific proof for its efficacy. On the other hand, it has not been proven to date that bracing does not work. Due to that, the orthopaedic community is divided in believers and non-believers. Personal experience, orthopaedic training, and the cultural environment seem to play a role.

One important reason for the lack of solid and comparable data in the literature is the use of different criteria for outcome assessment. Most commonly, failure is defined by the need for surgery or by a certain amount of radiographic curve progression during treatment or follow-up. To overcome this drawback, the following standardized criteria for treatment failure have been proposed by Richards et al. [36]:

- curve over 45° at maturity
- progression of 6° or more at maturity
- surgery recommended or performed at maturity

- surgery performed 2 years after maturity

In addition, an intention-to-treat analysis should always be performed [36].

The criteria listed above are all curve size dependent, i.e., radiographic. They allow for judging the ability of the treatment method to stop or to slowdown curve development, i.e., to change the natural history. Patient-based outcomes, measuring pain and quality of life, are at least as important.

At the moment to the authors' knowledge, there are two prospective randomized trials in progress, one in the Netherlands [37] the other in North America [38]. We are looking forward to get new data which hopefully will ease our decision making pro or contra brace treatment for adolescent idiopathic scoliosis. If the efficacy of brace treatment can be proven, a reliable method for the assessment of the risk of curve progression in the individual patient would be extremely valuable. It would support patient selection and prevent patients from being braced unnecessarily. Genetic testing may help in this respect in the future.

References

1. Davies E, Norvell D, Hermsmeyer J (2011) Efficacy of bracing versus observation in the treatment of idiopathic scoliosis. *Evid Based Spine Care J* 2(2):25–33

2. Nachemson A (1968) A long-term follow-up study of untreated scoliosis. *Acta Orthop Scand* 39:466–476
3. Pehrsson L, Karlsson J, Oden A, Nachmeson A (1992) Long-term follow-up of patients with untreated scoliosis. A study of mortality, causes of death, and symptoms. *Spine* 17:1091–1096
4. Peltonen J, Poussa M, Ylikoski M (1988) Three-year results of bracing in idiopathic scoliosis. *Acta Orthop Scand* 59:487–490
5. Olafsson Y, Saraste H, Söderlund V, Hoffsten M (1995) Boston brace in the treatment of idiopathic scoliosis. *J Pediatr Orthop* 15:524–527
6. Nachemson AL, Peterson LE (1995) Effectiveness of treatment with a brace in girls who have adolescent scoliosis. A prospective, controlled study based on data from the Brace Study of the Scoliosis Research Society. *J Bone Jt Surg [Am]* 77:815–822
7. Wiley J, Thomson J, Mitchell T, Smith B, Banta J (2000) Effectiveness of the Boston brace in treatment of large curves in adolescent idiopathic scoliosis. *Spine* 25:2326–2332
8. Matsunaga S, Hayashi K, Naruo T, Nozoe S, Komiya S (2005) Psychologic management of brace therapy for patients with idiopathic scoliosis. *Spine* 30:547–550
9. Price CT, Scott DS, Reed FE Jr, Sproul JT, Riddick MF (1997) Nighttime bracing for adolescent idiopathic scoliosis with the Charleston bending brace: long-term follow-up. *J Pediatr Orthop* 17:703–707
10. d'Amato CR, Griggs S, McCoy B (2001) Nighttime bracing with the Providence brace in adolescent girls with idiopathic scoliosis. *Spine* 26:2006–2012
11. Nijenbanning G (1988) Scoliosis redress. Design of a force controlled orthosis. Thesis, University of Twente, pp 1–122
12. Christine C, Alin C, Rivard CH (2008) Treatment of early adolescent idiopathic scoliosis using the SpineCor System. *Stud Health Technol Inform* 135:341–355
13. Houghton GR, McInerney A, Tew T (1986) Monitoring true brace compliance. Paper #50, 21st annual meeting of the Scoliosis Research Society combined with the British Scoliosis Society, Hamilton, Bermuda, 21–25 Sept
14. Lou E, Raso J, Hill D, Durdle N, Mahood J, Moreau M (2002) Brace monitoring system for the treatment of scoliosis. *Stud Health Technol Inform* 88:218–221
15. Nicholson GP, Ferguson-Pell MW, Smith K, Edgar M, Morley T (2003) The objective measurement of spinal orthosis use for the treatment of adolescent idiopathic scoliosis. *Spine* 28:2243–2250
16. Takemitsu M, Bowen JR, Rahman T, Glutting JJ, Scott CB (2004) Compliance monitoring of brace treatment for patients with idiopathic scoliosis. *Spine* 29:2070–2074
17. Helfenstein A, Lankes M, Ohlert K, Varoga D, Hahne HJ, Ulrich HW, Hassenpflug J (2006) The objective determination of compliance in treatment of adolescent idiopathic scoliosis with spinal orthoses. *Spine* 31:339–344
18. Hasler CC, Wietliesbach S, Büchler P (2010) Objective compliance of adolescent girls with idiopathic scoliosis in a dynamic SpineCor brace. *J Child Orthop* 4:211–218
19. Miller DJ, Franzone JM, Matsumoto H, Hyman JE, Royce DP Jr, Vitale MG (2011) Electronic monitoring improves brace compliance in patients with adolescent idiopathic scoliosis: a randomized clinical trial. *J Child Orthop* 5(Suppl 1):S41–S42
20. Danielsson AJ, Nachemson AL (2001) Radiologic findings and curve progression twenty two years after treatment for adolescent idiopathic scoliosis: comparison of brace and surgical treatment and with a matching control group of straight individuals. *Spine* 26:516–525
21. Emans JB, Kaelin A, Bancel P, Hall JE, Miller ME (1986) The Boston bracing system for idiopathic scoliosis. Follow-up results of 295 patients. *Spine* 11:792–801
22. Mannherz RE, Betz RR, Clancy M, Steel HH (1988) Juvenile idiopathic scoliosis followed to skeletal maturity. *Spine* 13:1087–1090
23. Fernandez-Feliberti R, Flynn J, Ramirez N, Trautmann M, Alegria M (1995) Effectiveness of TLSO bracing in the conservative treatment of idiopathic scoliosis. *J Pediatr Orthop* 15:176–181
24. Danielsson AJ, Hassserius R, Ohlin A, Nachemson AL (2007) A prospective study of brace treatment versus observation alone in adolescent idiopathic scoliosis: a follow-up mean of 16 years after skeletal maturity. *Spine* 32:2198–2207
25. Cheung KMC, Cheng EYL, Chan SCW, Yeung KWK, Luk KDK (2007) Outcome assessment of bracing in adolescent idiopathic scoliosis by the use of the SRS-22 questionnaire. *Int Orthop* 31:507–511
26. Parent EC, Hill D, Mahood J, Moreau M, Raso J, Lou M (2009) Discriminative and predictive validity of the Scoliosis Research Society-22 questionnaire in management and curve severity subgroups of adolescents with idiopathic scoliosis. *Spine* 34:2450–2457
27. Pham VM, Houlliez A, Carpentier A, Herbaux B, Schill A, Thevenon A (2008) Determination of the influence of the Chêneau brace on quality of life for adolescent with idiopathic scoliosis. *Ann Readapt Med Phys* 51:3–8
28. Ugwonalu OF, Lomas G, Choe JC, Hyman JE, Lee FY, Vitale MG, Royce DP Jr (2004) Effect of bracing on the quality of life of adolescents with idiopathic scoliosis. *Spine J* 4:254–260
29. Yrjönen T, Ylikoski M, Schlenzka D, Kinnunen R, Poussa M (2006) Effectiveness of the Providence nighttime bracing in adolescent idiopathic scoliosis: a comparative study of 36 female patients. *Eur Spine J* 15:1139–1143
30. Karol LA (2001) Effectiveness of bracing in male patients with idiopathic scoliosis. *Spine* 26:2001–2005
31. Carr WA, Moe JH, Winter RB, Lonstein JE (1980) Treatment of idiopathic scoliosis in the Milwaukee brace. *J Bone Jt Surg [Am]* 62:599–612
32. Karol LA, Johnston CE, Browne RH, Madison M (1993) Progression of the curve in boys who have idiopathic scoliosis. *J Bone Jt Surg [Am]* 75:1804–1810
33. Helenius I, Remes V, Yrjönen T, Ylikoski M, Schlenzka D, Helenius M, Poussa M (2005) Does gender affect outcome of surgery in adolescent idiopathic scoliosis. *Spine* 30:462–467
34. Katz DE, Richards BS, Browne RH, Herring JA (1997) A comparison between the Boston brace and the Charleston bending brace in adolescent idiopathic scoliosis. *Spine* 22:1302–1312
35. Yrjönen T, Ylikoski M, Schlenzka D, Poussa M (2007) Results of brace treatment of adolescent idiopathic scoliosis in boys compared with girls: a retrospective study of 102 patients treated with the Boston brace. *Eur Spine J* 16:393–397
36. Richard BS, Bernstein RM, d'Amato CR, Thompson GH (2005) Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS Committee on Bracing and Nonoperative Management. *Spine* 30:2068–2075
37. Bunge EM, de Koning HJ; the brace trial group (2008) Bracing patients with idiopathic scoliosis: design of the Dutch randomized controlled treatment trial. *BMC Musculoskelet Disord* 9:57 [<http://www.biomedcentral.com/1471-2474/9/57/>]
38. Dolan LA, Weinstein SL (2009) BRAIST: planning and current status of bracing in adolescent idiopathic scoliosis trial. *Scoliosis* (Suppl 2): O42 [<http://www.scoliosisjournal.com/content/4/S2/O42>]