Send Orders for Reprints to reprints@benthamscience.ae

 Current Pediatric Reviews, 2016, 12, 36-42

Bracing Scoliosis - State of the Art (Mini-Review)

Ng SY[*,1], Maksym Borysov[2], Marc Moramarco[3], Xiao F. Nan[4] and Hans-Rudolf Weiss [5]

[1]*Wanchai Chiropractic Clinic, Wanchai, Hong Kong;* [2]*Orttech-plus Rehabilitation Services, Kharkov, Ukraine;* [3]*Scoliosis 3DC, Woburn, MA, USA;* [4]*Nan Xiaofeng's Spinal Orthopedic Workshop, Xi 'an Shaanxi, P.R. China;* [5]*Orthopedic Rehabilitation Services, Gensingen, Germany*

Ng SY

Abstract: Spinal bracing is indicated in moderate to severe curves during growth. Brace effectiveness in halting progression of adolescent idiopathic scolisosis has been shown in a Cochrane review and in a randomized controlled trial (RCT). The outcome of brace treatment is dependent on the extent of in-brace correction and compliance. We have reviewed the literature on bracing to determine the types of brace that offer the best in-brace correction.

Materials and Methods: The literature has been searched for papers on bracing with documented in-brace corrections and long-term results.

Results: The in-brace percentage of correction of asymmetric braces is generally higher than that of the symmetric braces. According to the literature found in our search, long-term corrections are possible when starting treatment early, at an immature stage and with asymmetric braces of recent standards.

Conclusions: Bracing today is supported by high quality evidence (Level I). Asymmetric braces have led to better corrections than that described for symmetric braces. An improvement of the average corrective effect has been described due to the latest CAD / CAM development. Long-term corrections are possible when starting brace treatment early, at an immature stage and with asymmetric braces of recent standards.

Keywords: Brace treatment, CAD / CAM, conservative treatment, scoliosis.

INTRODUCTION

Scoliosis is a three dimensional deformity of the spine and trunk which may deteriorate quickly during phases of increased growth velocity [1-3]. Scoliosis curve-pattern-specific exercises have been shown to influence natural history in mild curves [4, 5]. For moderate to severe curves during growth, bracing is indicated as it has been clearly shown to be effective [6, 7], not only in halting progression of adolescent idiopathic scoliosis [7, 8], but also in improving the curvature [8-10].

A recent randomized controlled study has shown that bracing is more effective than observation in the treatment of adolescent idiopathic scoliosis [7]. This may be responsible for the shift in focus from addressing the effectiveness of bracing in AIS treatment to development of brace designs to improve in-brace corection and patient compliance [11].

There are at present many different braces on the market. There are symmetrical [8, 12-17] and asymmetrical braces [18-26], rigid and soft braces [27], full time braces and nighttime braces. These braces have different biomechanical corrective principles, with varying effectiveness in halting progression of curvatures.

*Address correspondence to this author at the Wanchai Chiropractic Centre, 11/fl China Hong Kong Tower, 8 Hennessy Road, Wanchai, Hong Kong; Tel: 852-39983208; Fax: 852-39983222; E-mail: ngshuyanhcc@gmail.com

At present, there is no internationally agreed-upon standard in bracing technology and clinical decision in brace treatment is empirical. We are not aware of any randomized controlled study that compare the effectiveness of different rigid underarm braces in the treatment of AIS. We thus undertake to review the literature and compare the in-brace correction and success rate of different braces in an attempt to identify braces that can effectively halt progression of curvatures and reduce surgical needs, so as to improve clinical outcome.

MATERIALS AND METHODS

PubMed was searched, using key words "brace" and "adolescent idiopathic scoliosis", and "CAD CAM". We excluded studies on nighttime spinal braces, juvenile idiopathic scoliosis and symptomatic scoliosis. Also, we excluded articles that do not have in-brace correction or success rate as outcome measures. We included studies on the effectiveness of all types of full time spinal braces, rigid or flexible, symmetrical or asymmetrical. Further, we reviewed studies on computer aided design/computer aided manufacturing (CAD/CAM) spinal orthoses, especially when compared to hand made braces. Research on brace compliance is also reviewed. Participant descriptive data, baseline Cobb angle, the type of braces used and outcome are extracted from these studies for comparison and review. As few articles contain in-brace apical vertebral rotation correction data, it is not included in the review and comparison.

1875-6336/16 $58.00+.00

RESULTS

The in-brace correction, success rate and failure rate of different braces were tabulated in Table **1**. As the compliance of many different braces is not available in the literature, it has not been included for review.

Marked differences of in-brace correction of different types of brace can be seen in Table **1**. The in-brace correction of asymmetrical braces fared better than that of the symmetrical braces. The in-brace correction of ARTbrace ranked highest among the asymmetrical braces at 76% [26], followed by the Chêneau brace [25] and Gensingen brace (GBW) [9], which is a Chêneau derivative. In contrast, the in-brace correction of symmetrical braces was lower, ranging from from 28% [14] for the Boston brace to 63.4%% for the Lyon brace [13]. However, it has to be emphasized that the studies are not fully comparable. In the study by De Giorgi [25], only single curve patterns were included and the average curvature was 27°, which is significantly lower than that of other studies [9]. The patients with thoracic curves had

Table 1. The in-brace correction and success rate of different braces.

Brace Types		Author (yr)	N	Av Age	Cobb Angle $^{(o)}$			% Corr (I)	% Corr (W)	% Imp	% Stable	% Worse	% S. T	% Surg
	Name				**T0**	**T1**	**T2**							
Symmetrical Braces	Boston	Emans *et al.* 1985	295	13.2	29	14.6	25.6	-50	-11.7	44	49	7		11
	DDB	Grivas *et al.* 2003	28	13.2					-4.6	35	46	18		4.3
	Boston	Lou 2006	20	13.4	32.2	22.7	35	-28	+8.7		75	25		
	TLSO	Janicki *et al.* 2007	48	12.7	33.6		46.8		+39.3	0	15	85	56	
	TLSO	Gammon *et al.* 2010	35	13	33		37.5		+13.6	60%≦5°; 80% did not progress to 45°		46.9	20	
	Lyon	de Mauroy *et al.* 2011	1338	13.8	29.5	10.8 (-18.7)	21.3 (-8.2)	-63.4	-27.7	67.2	27.8	5		
	OMC	Kuroki *et al.* 2015	31	12	27.3	14.5	28.6	-46.9	+4.8	19.4	48.3	32.3	9.7	
Asymmetrical Braces	**RSC**	Rigo *et al.* 2003	106	12	34								14.1	
	Chêneau	Landauer *et al.* 2003	34		30.4		25.2		-17.1	78		22		
	Rosenberger	Spoonamore *et al.* 2004	71		29.5	21.5	30.7	-27.1	+4.1				56	30
	Chêneau Light	Weiss *et al.* 2007	64	12.9	35.6	19.2		-53.9						
	LA brace	Kessler 2008	40		30	14.9		-51		80		20		
	Chêneau	Zaborowska Sapeta *et al.* 2011	79		32.9					25.3	22.8	51.9	12.7	
	PASB	Aulisa *et al.* 2012	110		29.3	13.9		-52.5						
	Chêneau	Weiss and Werkmann 2012	34	12.1	31	13		-59						0
	Chêneau Gensingen	Borysov and Borysov 2013	92	12.4	29.2	12.8		-56						
	Chêneau Gensingen	Weiss *et al.* 2013	21	12.2	31.3	10.7		-66						
	Chêneau	de Giorgi 2013	48	11.3	27	7.6	11	-72	-59.3					
	ART	de Mauroy *et al.* 2014	72		30	7.6		-76						
	RSC	Maruyama *et al.* 2015	33	11.9	30.8	14.2		-53.8		24.2	51.5	24.2	12.1	3
Flexible	Spinecor	Coilliard *et al.* 2007	170							59.4		40.6	1.2	22.9
	Spinecor	Gammon *et al.* 2010	32	13.2	31		37.7		+21.6	53.1% ≦5°; 72% did not progress to 45°		57.1	28	

Abbreviation: N: number of patients; T0: Cobb angle at presentation; T1: Cobb angle in brace; T2: Cobb angle when brace weaned off or discontinued; % Corr (I): percentage of correction of Cobb angle when in brace (T0-T1)/T0 x 100%. Negative value denotes a reduction of curvature in brace and a positive value denotes an increase in curvature in brace; % Corr (W) refers to percentage of correction when the brace is weaned off or discontinued. % Imp: percentage of improvement by ≥5°; % stable: refers to curvature that remains within ±5° of the original curvature; % worse: refers to curvature that increases by ≥6°; S.T: refers to surgical threshold of 45° to 50°; % surg: percentage of patients who were surgically treated. DDB: dynamic derotation brace; TLSO: thoracolumbosacral orthoses; OMC: Osaka Medical College brace; LA brace: Los Angeles brace; PASB: progressive action short brace; RSC: Rigo System Chêneau scoliosis brace.

even smaller angles of curvature [25]. As a matter of fact, double curves correct less than single curve patterns and thoracic curves less than lumbar or thoracolumbar curves [9, 21]. Therefore, when looking at the in-brace correction of asymmetric braces the Gensingen brace can only be compared to the ATRbrace [26], which is much heavier and is about twice the size.

Asymmetrical braces also maintained the correction of curvatures better than symmetrical braces when braces were discontinued. The loss of correction in asymmetrical braces was less than that of the symmetrical braces. After weaning of the thoracolumbosacral orthoses (TLSO) [15, 16] and Osaka Medical College Brace (OMC) [17], the Cobb angle increased to higher than that of the pre-brace level. The increase for TLSO amounted to 39.3% [15] and 13.6% [16] in the two studies. The percentage increase when OMC weaned off was only 4.8% [17]. The symmetrical brace that achieved the best final corrective effects was the Lyon brace [13]. When the brace was weaned off, there was a 27.7% reduction in curvature as compared to the pre-brace Cobb angle [13]. The final corrective effects of asymmetric braces, on the other hand, were better, ranging from 4.1% [20] to 59.3% [25].

The comparison of difference could be more reasonable when considering the actual compliance; but as stated, the compliance measurements of different studies were not available for comparisons.

Of particular interest is the success rate of the different braces. The majority of the studies used the SRS criteria to define success and failure of brace treatment. Successful bracing is defined as a Cobb angle reduction of more than 5^o after cessation of brace treatment or when the patient is skeletally mature. When the change is within $\pm 5^o$ of the initial Cobb angle, the curve is regarded as stable. When the curve increases by $\geq 6^o$, the treatment is regarded as a failure. Using the above criteria, the percentage of patients that failed with brace treatment and progressed to surgical threshold varied with braces, from 5% [28] to 56% [15]. The Gensingen brace (GBW) has the highest success rate, with the lowest percentage of patients falling into surgical threshold [28]. On the contrary, the TLSO brace and the Spinecor have the highest percentage of failure; 56% [15] and 28% [16] of the respective patients had their curves increase to surgical threshold.

DISCUSSION

Various studies have shown that in-brace correction and compliance negatively correlate with progression of curvatures [29-31]. A large in-brace correction and good compliance are associated with an improvement in final outcome [8, 29]. In-brace correction of at least 20% has been found to prevent progression of curvatures [30] and correction of 30% or more is required to achieve final improvement when skeletally mature [31]. A larger in-brace correction of 40% or more was found to accompany an improvement of 7^o Cobb at skeletal maturity [29]. All these suggest the need for a large in-brace correction to achieve final improvement in curvatures when skeletally mature.

Types of Braces

Reviewing Table **1**, the extent of in-brace correction and final correction in curvatures varies with braces. Asymmetrical braces in general fared better than symmetrical braces and flexible braces in correction of curvatures, with the Chêneau derivative [9] and the ARTbrace [26] providing more than 60% of the correction. The Lyon brace had the highest correction effect among the symmetrical braces. It corrected an average of 63.4% [13].

The final outcome of brace treatment depends on both in-brace correction and compliance and as the asymmetrical braces had a higher degree of correction when compared with symmetical braces, it is not surprising to find that the success rate of asymmetrical braces is higher than that of the symmetrical braces.

The success rate of the Chêneau derivates has been described in a few outcome studies. The Rigo System Chêneau brace (RSC) had a success rate of 76% [10] which is not much different from the success rate of 72% achieved by the Boston brace in an RCT [7]. In a prospective controlled trial with a very homogenous sample of patients at high risk for progression, the success rate with the hand made Chêneau brace was at 80% [32]. In a retrospective series [28], the success rate of the Gensingen brace was more than 95%; none of the patients was operated on. A similar outcome was reported in a preliminary prospective cohort study using the Gensingen brace (more than 90%) [33].

Bowman (2011) was of the opinion that symmetrical braces do not provide sufficient correction to prevent curve progression [34]. To achieve high in-brace correction, the interior shape of the brace has to be asymmetrical in configuration [34]. This view is shared by a number of other authors [9, 26, 35]. The large correction in curvatures may partly compensate for low compliance in wearing of the brace [35].

Though asymmetric braces may be more effective than symmetrical braces in the treatment of AIS, not all asymmetric braces perform equally well in different types of scoliosis. As the thoracic spine is more rigid, the percentage of correction achieved through bracing is less than that of the thoracolumbar and lumbar spine [10, 13] (Table **2**). Moderate curves correct less with bracing when compared with milder curves [8]. Also, the percentage of in-brace correction was less when the Cobb angle was at or above 30^o, rather than at 20-29° [8].

The majority of the full time scoliosis spinal braces are rigid plastic braces. Spinecor is the only flexible full time brace currently commonly in use [27]. Studies have been conducted, comparing the effectiveness of rigid TLSO braces with Spinecor in halting progression of AIS in growing adolescents [16, 36-38]. Gammon *et al.* (2010) compared the TLSO braces with the Spinecor and found no statistically significant differences in the final outcome [16]; using SRS outcome criteria, the success rate of the TLSO was 60% and that of the Spinecor was 53% [16]. Yet, prospective [37] and randomized controlled studies [38] have shown that the Spinecor was less effective than the rigid TLSO in reducing the progression of AIS. The percentage of patients that got worse with the Spinecor brace was between 28% [16] and

Table 2. The in-brace correction of different braces in scoliosis of different regions.

Braces	Author (yr)	Thoracic			Thoracolumbar			Lumbar			Double Curve						
		ICA	BCA	% Corr	ICA	BCA	% Corr	ICA	BCA	% Corr	ICA		BCA		% Corr		Remarks
											Th	LB	Th	LB	Th	LB	
Boston	Emans 2003	24	12.7	- 47	24	6.5	-73	24	9.1	-62	24		10.8		-55		Prebrace Cobb angle 20 - 29°
Boston	Emans 2003	35	17.8	- 49	34	16	-53	31	15.2	-51	35		19.9		-43		Prebrace Cobb angle ≥30°
DDB	Grivas 2003	25	19	-24	24	21.6	-10				23.2	21.2	20.8	22.1	-10.3	+4.2	
Chêneau	Landauer 2003	30.7	12.5	- 59.3													Hi corr gp
Chêneau	Landauer 2003	32.2	23.1	- 28.3													Low corr gp
LA Brace	Kessler 2008	31	12.4	- 60	31	13.6	-56	40	14	-65					-30		
Lyon	De Mauroy 2011	32.3	15.1	-53.3	28.5	9.4	-67	28	7.2	-74.3	31.5	28.8	15.8	11.7	-49.8	-59.4	
PASB	Aulisa 2012				29.3	13.9	-52.5	29.3	13.9	-52.5							
RSC	Maruyama 2015			-34.4			-73.8			-73.8					- 48.8		

Abbreviation: ICA: initial Cobb angle; BCA: braced Cobb angle; % corr: percentage of correction; LA brace: Los Angeles brace; PASB: progressive action short brace; RSC: Rigo System Chêneau scoliosis brace.

80% [36] and that which required surgery was 22.9% [27]. It is noteworthy also that patients whose curvatures progressed when wearing the Spinecor had the progression halted and curvatures improved by changing to the Boston [38] or the Chêneau brace [36].

From the data, it is apparent that asymmetrical braces are more effective than symmetrical braces in the treatment of AIS, with ARTbrace and Gensingen braces ranking high in correction. Also, rigid TLSO are more able to control progression of curvatures than the flexible Spinecor. Recently, a case report has been published showing that long-term corrections of about 20° are possible when starting treatment early, at an immature stage and with asymmetric braces of recent standards [39].

CAD/CAM Braces

The extent of in-brace correction depends on the design of the braces and the flexibility of the treated areas. Yet, not all braces with the same name correct to a similar extent. The in-brace correction of the Boston brace reported by Lou *et al.* (2006) was 28%, whereas that reported by Emans (1986) was 50%. The marked difference in outcome is believed not to relate to the demographics and pre-brace curvatures of the two groups of patients, as they were similar in the two studies. Whether it is related to the difference in flexibility of the spine in the two groups of patients, however, is difficult to determine. Difference in flexibility can significantly impact the percentage of correction by brace [29].

Landauer *et al*. [29] used the Chêneau brace to correct thoracic scoliosis [29]. They found some of the curvatures could be corrected significantly, while others could not. The difference in correction was as high as 100% [29]. Similar differences in outcome are also noted in the two studies that employed the Chêneau brace to treat AIS. The failure rate reported by Landauer *et al*. was 22% [29], whereas that by Zaborowska-Sapeta (2011) was 51.9%. It is possible that that the differences in in-brace correction might be related to the skills and experience of the orthotists.

In a study comparing the outcome of brace treatment with observation, Danielsson *et al*. suggested that the good outcome of the brace treatment was related to the skill of the orthotist [40]. Similarly, Rigo reported that with experience, the effectiveness of bracing improved [41]. Successful outcomes with bracing outside of the specialized centres vary considerably [34] and several studies showed worse in-brace corrections, suggesting that bracing is somewhat less effective [42, 43]. For instance, the ARTBrace and the Gensingen brace (GBW) ranked high in terms of in-brace correction. However, there is not much familiarity with these braces outside of Europe, where they originated. CAD/CAM technology can fill this void.

Since the advent of CAD/CAM technology 30 years ago, there is an increasing trend to use it to make spinal braces as it takes less time and permits standardization of brace production [44]. Various studies [45-48] have compared the in-brace correction of hand-made spinal orthoses with the correction of those made by CAD/CAM. No significant difference was found between their correction effectiveness, suggesting that CAD/CAM-made braces had at least equivalent if not superior correction of the Cobb angle compared to the standard plaster molded TLSOs [45-48] made by skilled orthotists. Thus CAD/CAM technology permits export of skills of the orthotists. This improves the care of AIS patients in areas where there are a lack of skilled orthotists in making highly corrective braces.

Recently, the last author has introduced a CAD/CAM solution, providing Chêneau-derived braces to address scoliosis specific curvature patterns, based on the augmented Lehnert-Schroth (ALS) classification (Figs. **1-3**). Brace formula is selected from the library of braces to match the curvatures of an individual patient [9]. The CAD/CAM technology permits easy modification, without the need to resort to a baseline standard as in manual methods when modification is required. Patients have reported that the braces made by

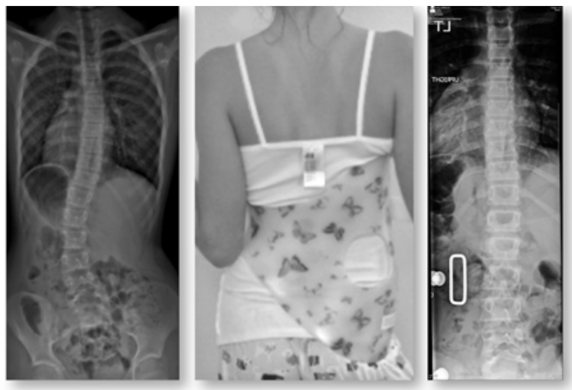

Fig. (1). Full correction in a short brace (CAD / CAM Gensingen brace) for a curve pattern 4CL (primary lumbar curvature) made in the US.

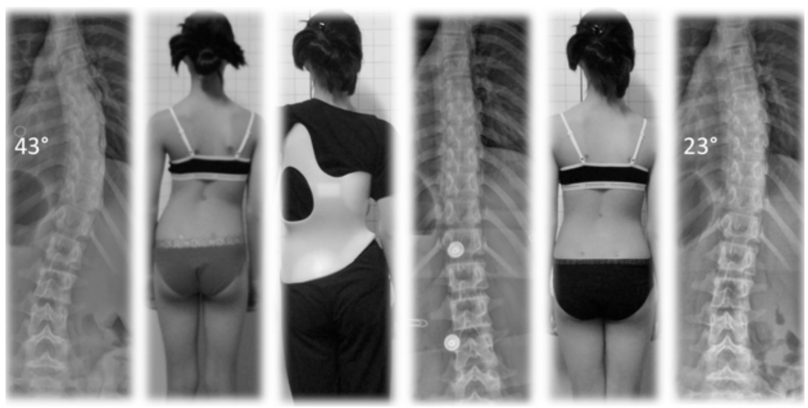

Fig. (2). Full correction in a CAD / CAM Gensingen brace (GBW) for a thoracic curve pattern (left). After 6 months of treatment the patient had outgrown her first brace and showed significant improvement of radiological and clinical correction (15).

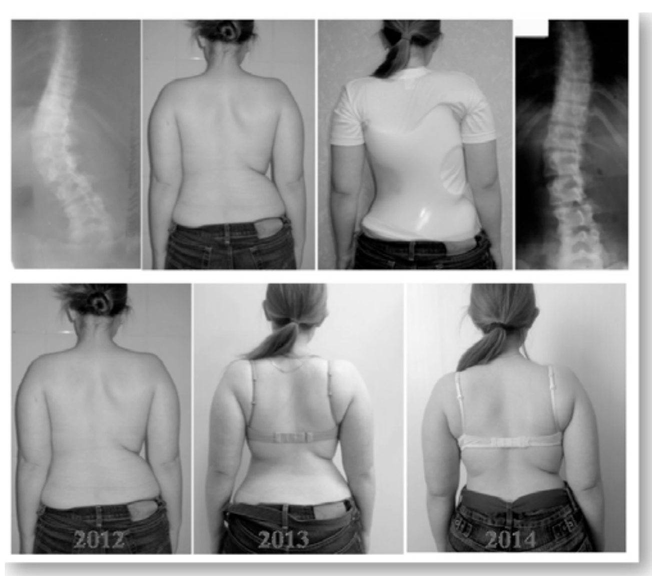

Fig. (3). Clinical and radiological improvement in a more mature girl treated with a Best Practice Chêneau style brace in the Ukraine.

CAD/CAM are more comfortable [9]. This is supported by the study by Sankar *et al*. [46].

At least for the GBW it has been shown that in-brace correction has been improved using CAD/CAM when compared to hand-made Chêneau braces [9].

Limitation and Future Development

The present review is a comparison of outcome of different braces. The comparison inherently has a number of biases. Though many of the studies follow the SRS inclusion criteria for bracing, there are a number of factors that confound the correction of the curvatures. These include the flexibility of the spine, the accuracy of the spinal orthoses prescribed and fabricated and the skill of the orthotists. Comparing the response of a heterogenous group of patients also may not be valid. For instance, the study by De Giorgi [25], using the Chêneau brace, only included patients with single curve patterns and with smaller angles of curvatures.

Of the three asymmetrical braces that had high correction, only the ARTbrace measured the in-brace correction in three planes. The apical vertebral rotation correction and the lordosis of the thoracolumbar spine were not measured in the Chêneau [25] and Gensingen brace [9] studies. This makes comparison of derotation impossible. Additionally, it has been found that measures of transverse plane deformity correlate strongly with progression of curvatures [49, 50]. Future studies of the in-brace correction should include correction in three planes, as EOS 3D radiography [26] is available.

Finally, many studies have shown that compliance is important in producing final correction in curvatures [7, 8, 14]. Yet, only a few brace studies included the compliance of brace wear, making it difficult to compare the compliance among different braces. Future studies should include compliance of brace wear, as poor compliance can nullify the benefits of high in-brace correction.

Thus, to improve the standard of brace care, randomized controlled studies should be conducted to compare the 3D in-brace correction between common effective asymmetrical and symmetrical braces and between different asymmetical braces. Also, smaller, comfortable and more inconspicuous braces need to be developed to improve the acceptance and thus the compliance of the patients.

CONCLUSION

- Bracing today is supported by high quality evidence (Level I).
- Long-term corrections are possible when starting brace treatment early, at an immature stage and with asymmetric braces of recent standards.
- Asymmetric braces have led to better corrections than described for symmetric braces in single curve patterns.
- An improvement of the average corrective effect has been described due to the lastest CAD / CAM developments.
- The cited studies are with heterogeneous inclusion criteria and intervention methods. Therefore the studies are not fully comparable. An RCT study is suggested to compare the most effective orthotic designs.

COMPETING INTERESTS

HR Weiss is receiving financial support for attending symposia and receives royalties from Koob GmbH & Co KG. The company is held by the spouse of HR Weiss.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

HRW provided the first draft. SYN has made the full literature research and wrote the second draft, All authors developed the final manuscript in a 3-step Delphi procedure. All authors have read and approved the final manuscript.

REFERENCES

[1] Asher M, Burton D. Adolescent idiopathic scoliosis: natural history and long term treatment effects. Scoliosis 1(1): 2.

[2] Goldberg C, Moore D, Fogarty E, Dowling F. Adolescent idiopathic scoliosis: natural history and prognosis. Studies in health technology and informatics 2002; 91: 59-63.

[3] Weiss HR, Moramarco M. Scoliosis - treatment indications according to current evidence. OA Musculoskelet Med 2013; 1(1): 1.

[4] Romano M, Minozzi S, Bettany-Saltikov J, *et al*. Exercises for adolescent idiopathic scoliosis. Cochrane Database Syst Rev 2012; 8.

[5] Monticone M, Ambrosini E, Cazzaniga D, Rocca B, Ferrante S. Active self-correction and task-oriented exercises reduce spinal deformity and improve quality of life in subjects with mild adolescent idiopathic scoliosis. Results of a randomised controlled trial. Eur Spine J 2014; 23(6): 1204-14.

[6] Negrini S, Minozzi S, Bettany-Saltikov J, *et al*. Braces for idiopathic scoliosis in adolescents. Cochrane Database Syst Rev 2010(1): CD006850.

[7] Weinstein SL, Dolan LA, Wright JG, Dobbs MB. Effects of bracing in adolescents with idiopathic scoliosis. The New Engl J Med 2013; 369(16): 1512-21.

[8] Emans JB, Kaelin A, Bancel P *et al.* The Boston bracing system for idiopathic scoliosis. Follow up results in 295 patients. Spine 1986; 11(8): 792-801.

[9] Weiss HR, Seibel S, Moramarco M, Kleban A. Bracing scoliosis: The evolution to CAD/CAM for improved in-brace corrections. Hard Tissue 2013; 2(5): 43.

[10] Maruyama T, Kobayashi Y, Miura M, Nakao Y. Effectiveness of brace treatment for adolescent idiopathic scoliosis. Scoliosis 2015; 10(2): S12.

[11] Stokes OM, Luk KDK. Instructional Review: Spine. The current status of bracing for patients with adolescent idiopathic scoliosis. Bone Joint J 2013; 95-B:1308–16.

[12] Grivas TB, Vasiliadis E, Chatziargiropoulos T, *et al*. The effect of a modified Boston brace with anti-rotatory blades on the progression of curves in idiopathic scoliosis: aetiologic implications. Pediatric Rehabil 2003; 6(3-4): 237-42.

[13] De Mauroy JC, Lecante C, Barral F: The Lyon approach to the conservative treatment of scoliosis. Scoliosis 2011; 6: 4.

[14] Lou E, Hill D, Raso J, Mahood J, Moreau M. Prediction of brace treatment outcomes by monitoring brace usage. Stud Health Technol Inform 2006; 123: 239-44.

[15] Janicki JA, Poe-Cohert C, Armstrong DG, Thompson GH. A comparison of the thoracolumbosacral orthoses and providence orthosis in the treatment of adolescent idiopathic scoliosis. J Pediatr Orthop 2007; 27(4): 369-74.

[16] Gammon SR, Mehlman CT, Chan W, Heifetz J, Durrett G, Wall EJ. A comparison of thoracolumbosacral orthoses and SpineCor treatment of adolescent idiopathic scoliosis patients using the Scoliosis Research Society standardized criteria. J Pediatr Orthop 2010; 30(6): 531-8.

[17] Kuroki H, Inomata N, Hamanaka H, Higa K, Chosa E, Tajima N. Efficacy of the Osaka Medical College (OMC) brace in the treatment of adolescent idiopathic scoliosis following Scoliosis Research Society brace studies criteria. Scoliosis 2015; 10:12.

[18] Aulisa AG, Mastantuoni G, Laineri M, *et al*. Brace technology thematic series: the progressive action short brace (PASB). Scoliosis 2012; 7: 6.

[19] Rigo MD, Reiter CH, Weiss HR. Effect of conservative management on the prevalence of surgery in patients with adolescent idiopathic scoliosis. Pediatric Rehabil 2003; 6(3-4): 209–14.

[20] Spoonamore MJ, Dolan LA, Weinstein SL. Use of the Rosenberger brace in the treatment of progressive adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2004 Jul 1; 29(13):1458-64.

[21] Weiss HR, Werkmann M, Stephan C. Correction effects of the ScoliOlogiC® "Chêneau light" brace in patients with scoliosis. Scoliosis 2007; 2: 1.

[22] Kessler J. Efficacy of a new computer-aided design/computer aided manufacture orthoses in the treatment of adolescent idiopathic scoliosis. J Pediatr Orthopaed 2008; B17: 207–11.

[23] Zaborowska-Sapeta K, Kowalski IM, Kotwicki T, Protasiewicz-Fałdowska H, Kiebzak W. Effectiveness of Chêneau brace treatment for idiopathic scoliosis: prospective study in 79 patients followed to skeletal maturity. Scoliosis 2011; 6: 2.

[24] Borysov M, Borysov A, Kleban A, Weiss HR. Bracing according to' best practice' standards - are the results repeatable? OA Musculoskelet Med 2013; 1(1): 6.

[25] De Giorgi S, Piazzolla A, Tafuri S, Borracci C, Martucci A, De Giorgi G. Chêneau brace for adolescent idiopathic scoliosis: long-term results. Can it prevent surgery? Eur Spine J 2013; 22 (6): S815–22.

[26] de Mauroy. Prospective study and new concepts based on scoliosis detorsion of the first 225 early in-brace radiological results with the new Lyon brace: ART brace. Scoliosis 2014; 9: 19.

[27] Colliard C, Vachon V, Circo AB, Beausejour M, Rivard CH. Effectiveness of the SpineCor brace based on the new standardized criteria proposed by the Scoliosis Research Society for adolescent idiopathic scoliosis. J Pediatr Orthop 2007; 27(4): 375-9.

[28] Weiss HR, Werkmann M. Rate of Surgey in a Sample of Patients fulfilling the SRS Inclusion Criteria treated with a Chêneau Brace of actual Standard. St Heal T 2012; 176: 407-10.

[29] Landauer F, Wimmer C, Behensky H. Estimating the final outcome of brace treatment for idiopathic thoracic scoliosis at 6-month follow-up. Pediatr Rehabil 2003; 6(3-4): 201-7.

[30] Castro FP Jr. Adolescent idiopathic scoliosis, bracing, and the Hueter-Volkmann principle. Spine J 2003; 3(3):180–5.

[31] Appelgren G, Willner S. End Vertebra Angle - A Roentgenographic Method to Describe a Scoliosis. A Follow-up Study of Idiopathic Scoliosis Treated with the Boston Brace. Spine 1990; 15: 71-4.

[32] Weiss HR. History of soft brace treatment in patients with scoliosis: a critical appraisal. Hard Tissue 2013; 2(4): 35.

[33] Weiss HR, Seibel S. Preliminary results of a prospective AIS cohort treated with a recent CAD Chêneau development. ISPO World Congress 2015; Lyon France June 22-25.

[34] Bowman G. The L.A. Brace—Description and discussion. Physiotherapy Theory and Practice 2011; 27(1): 68–73.

[35] Chalmers E, Westover L, Jacob J, *et al*. Predicting success or failure of brace treatment for adolescents with idiopathic scoliosis. Med Biol Eng Comput DOI 10.1007/s11517-015-1306-7.

[36] Weiss HR, Weiss G. Brace treatment during pubertal growth spurt in Girls with Idiopathic scoliosis (IS) - A prospective trial comparing two different concepts. Pediatr Rehabil 2005; 8: 199-206.

[37] Wong M, Cheng J, Lam T, *et al*. The effect of rigid versus flexible spinal orthosis on the clinical efficacy and acceptance of the patients with adolescent idiopathic scoliosis. Spine 2008; 33(12): 1360–5.

[38] Guo J, Lam TP, Wong MS, *et al*. A prospective randomized controlled study on the treatment outcome of SpineCor brace versus rigid brace for adolescent idiopathic scoliosis with follow-up according to the SRS standardized criteria. Eur Spine J 2014; 23: 2650–7.

[39] Weiss HR. Bracing can lead to a persistent correction in the treatment of Adolescent Idiopathic Scoliosis: A case report. Hard Tissue 2014; 3(1): 8.

[40] Danielsson AJ, Hasserius R, Ohlin A, Nachemson AL. A Prospective Study of Brace Treatment Versus Observation Alone in Adolescent Idiopathic Scoliosis. A Follow-up Mean of 16 Years After Maturity. Spine 2007; 32(20): 2198–207.

[41] Noonan KJ, Weinstein SL, Jacobson WC, Dolan LA. Use of the Milwaukee brace for progressive idiopathic scoliosis. J Bone Joint Surg [Am] 1996; 78-A: 557–67.

[42] Rigo M. A series of patients with adolescent idiopathic scoliosis treated with a Rigo System Chêneau (RSC) brace. Primary correction in brace improved by technical evolution. Scoliosis 2007; 2 (1): S11.

[43] Dolan L, Weinstein S. Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence-based review. Spine 2007; 32(19): S91-S100.

[44] Weiss HR. Standardising the treatment with Cheneau braces via CAD: Prospects and risks. OA Musculoskelet Med 2014; 2: 10.

[45] Wong MS, Cheng JC, Lo KH. A comparison of treatment effectiveness between the CAD/CAM method and the manual method for managing adolescent idiopathic scoliosis. Prosthet Orthot Int 2005; 29: 105111.

[46] Sankar WN, Albrektson J, Lerman L, Tolo VT, Skaggs DL. Scoliosis in-brace curve correction and patient preference of CAD/CAM versus plaster molded TLSOs. J Child Orthop 2007; 1(6): 345–9.

[47] Rigo MD, Gallo D, Dallmayer R. In-brace correction of the Cobb angle with RSC-CAD CAM compared with 'hand made' from the original author. Scoliosis 2010; 5(1): O68.

[48] Cottalorda J, Kohler R, Garin C, *et al*. Orthoses for mild scoliosis: a prospective study comparing traditional plaster mold manufacturing with fast, noncontact, 3-dimensional acquisition. Spine (Phila Pa 1976) 2005; 30: 399-405.

[49] Courvoisier A, Vialle R, Skalli W. EOS 3D Imaging: assessing the impact of brace treatment in adolescent idiopathic scoliosis. Expert Rev Med Devices 2014; 11(1): 1-3.

[50] Nault ML, Mac-Thiong JM, Roy-Beaudry M, *et al*. Three-dimensional spinal morphology can differentiate between progressive and non progressive patients with adolescent idiopathic scoliosis at the initial presentation: a prospective study. Spine 2014; 39(10): E601-6.

Received: February 25, 2015 Revised: July 22, 2015 Accepted: July 24, 2015