Review

Evaluation of the efficiency of Boston brace on scoliotic curve control: A review of literature

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Context: Bracing is one of the most important treatment approaches that have been utilized in patients with scoliosis. Boston brace used to manage a scoliotic curve especially in lumbar and thoracolumbar areas.

Objective: The aim of this review was to evaluate the efficiency of Boston brace to control the progression of the curve based on the available literature.

Methods: A search was carried out using the following databases including Scopus, ISI Web of knowledge, PubMed, Ebsco, and Embasco. The key words used for the search were Boston brace, Boston orthosis which were used in combination with scoliosis. Articles identified were screened based on titles and abstracts. The quality of the studies was evaluated using Black and Down tool. Data were summarized based on PICO style.

Results: Based on the aforementioned key words, 18 papers were selected, in which 7 studies focused on efficiency of Boston brace, 3 papers focused on quality of life, 5 papers on finite element analysis and 3 papers on comparison of efficiency of Boston with other available braces. The quality of the selected studies varied between 14 and 21.

Conclusion: The results of most of the studies support the efficiency of this brace to control the progression of scoliotic curve, especially for the curve between T6 and L2. The efficiency of this brace may be due to its rigid structure and also location and direction of the straps.

Keywords: Scoliosis, Boston brace, Correction

Introduction

The origin of term scoliosis was derived from ancient Greek word which means curved. Scoliosis is when there is a lateral curve of the spine in the frontal plane, which is greater than 10 degrees, this is also associated with division in sagittal plane (mostly hypo-kypnosis) with rotation of vertebra.^{1,2} The incidence of scoliosis varies in different countries between 2% and 13.5%, mostly based on school screening programme.^{3,4} The cause of scoliosis is not been well understood. However, some reasons such as genetics, growth and hormonal dysfunction, bone mineral density change, abnormalities in body part tissues, skeletal muscle abnormality, and central nervous system abnormalities have been implicated.²

Various treatment approaches including surgery, use of brace, exercise, Yoga and functional electrical stimulation have been used to decrease its rate of progression and to influence on its natural history.^{2,5} Some braces such as Milwaukee, Rosenberger, TriaC, Cheneau, Gensingen, and derotational orthoses have been used for individuals with scoliosis, especially for those with curve between 20 and 40 degrees.⁶⁻⁹

Braces used for scoliosis can be categorized into low and high profiles. Some braces such as Boston, Rosenberger are classified as low profile braces (without neck part). Boston brace designed by Hall and Miler in 1972¹⁰⁻¹² is one of the most commonly used braces for individuals with scoliosis. However, Watts, Hall and Stanish reported its efficiency in 1977.¹² It is open in the back and corrects spinal scoliosis by pushing the spine with small pads. These pads are placed against the ribs to achieve partial rotational correction. The configurations of the pads inside the brace

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Figure 1 Boston brace.¹³

also increase the upright position of the spine. The efficiency of Boston brace to decrease scoliotic curve is enhanced through the use of both active and passive mechanisms.¹¹ Due to the length of this brace, which is between shoulder blade and inferior gluteal fold, this brace is not recommended to be used for very high curve (curve more than 40 degrees) (Figure 1).

Based on the results of various studies, this brace is mostly recommended for scoliotic curve ranging from 20 to 59 degrees, between levels T8 and L2.¹⁰ Based on the available literature, it is controversial whether this brace can control the curve progression and influence the natural history of scoliosis or not. Although the correction achieved follow the use of Boston brace reaches to 50% at the beginning of treatment, it decreases to about 15% by the time of brace discontinuance.¹⁰ Moreover, it is a source of question whether the efficiency of this brace (curve control) is more than other available braces or not. Therefore, the main aim of this review was to determine the efficiency of Boston brace based on the available literature.

Method

Actually the methodology of this review was based on PRISMA.¹⁴ A search was carried out in standard databases including Medline, PubMed, Cochrane Central Register of Controlled Trial (CCTR), Cochrane Data base of systematic reviews (CDSR), databases of abstracts of reviews of effects (DARE), Embase, Google scholar and ISI Web of Knowledge.

Some key words developed by National Library of Medicine were selected in this study. The key words

used were Boston brace, and Boston orthosis, which were used in combination with scoliosis. This search was done to cover the period between 1960 and 2018. Eligibility criteria to select the studies were based on population (the studies on degenerative scoliosis and neurological scoliosis were removed from the list) and linguistic range (only studies reported in English were selected). Due to limited number of the studies on this topic, the nature of studies and outcomes variables were not considered to select the studies.

Type of studies: Although, the emphasis of this study was to focus mostly on randomized control trial (RCTs), due to lack of these studies on this topic, we included other types of studies. However, low-level evidences such as abstracts, conference articles, editorials, comments, and expert opinions were excluded from the final list.

Type of participants: The patient population that was included are patients who were diagnosed with AIS between the ages of 10 and 15 years as well as had a Cobb angle between 20 and 60 degrees. Any papers on infant's scoliosis (early onset scoliosis), congenital scoliosis and scoliosis secondary to other conditions (such as vertebral fracture and degenerative scoliosis) were excluded.

Type of interventions: Only studies focusing on Boston brace were included in this study.

Type of outcome measures: The main outcome measures included in this study were Cobb angle and percentage of correction or change in scoliotic angle.

Secondary outcomes: Any adverse effects of bracing reported in the included studies were considered as secondary outcomes. Depending on the available studies, some others outcomes such as force of straps, quality of life, lung capacity and well-being were also selected.

Selection of the studies: Two researchers independently screened the articles based on the inclusion criteria to determine their suitability. This was done mostly based on the abstracts and titles. If there was any sense of disagreement, a third researcher was enrolled.

Data extraction and management: Data extraction in this review was based on population, intervention, comparison, and outcomes (PICO). Duration of follow up, outcomes assessed, and adverse side effects were also reported.

Quality assessment and determination of the risk of bias: The quality of the selected studies was evaluated based on Down and black scale, which is a reliable tool to assess the quality of the studies with high reliability score. It allowed the researchers to determine the trustworthiness, relevance, and results of published paper.

Results

One hundred papers were found based on the aforementioned key words. Finally 18 papers were selected for quality assessment and final analysis. Seven papers focused on the efficiency of Boston brace on scoliotic curve progression. There were three papers on the quality of life and mental health of scoliotic subjects treated with Boston brace. Five papers were on the design of Boston brace based on Finite Element analysis (FEA). The efficiency of Boston bracing compared to alternate bracing was examined in three papers.

Table 1 summarizes the results of quality assessment based on Down and Black tool. It should be emphasized that quality assessment was not done for the studies on FEA.

The results of the studies carried out on the evaluation of the efficiency of Boston brace on scoliosis progression curve highlighted the following points (Table 2):

- (1) Bracing outcome is more correlated with initial Cobb angle
- (2) Although the long-term results are satisfactory, the scoliotic curve may increase slightly after brace removal
- (3) Boston brace maximum curve correction is achieved for the curves with an apex at T9, T8, T7, and T6.
- (4) Boston brace must be used 18 h per day to be effective
- (5) The effect of Boston brace on natural history of scoliosis is questionable
- (6) It is recommended to use Boston brace for the scoliotic curve with an apex between T8 and L2.
- (7) For the subjects with neuromuscular scoliosis, it is recommended to use soft Boston brace.

Another group of studies examined the quality of life in patients with scoliosis who utilized a Boston brace. There were two studies on quality of life, which found that there is no difference between quality of life in patients with scoliosis who used a Boston Brace and patients without scoliosis.

FEA was the other approach used in some studies on Boston brace. FEA was utilized in five studies, and demonstrated the following (Table 3):

- (1) Boston brace provides significant curve correction in frontal plane but it does not influence on rib hump and frontal balance
- (2) The FEA is a feasible approach to determine the correction of scoliosis
- (3) The maximum efficiency of Boston brace can be achieved for lumbar and lower thoracic curves especially for the pad rotated posteriorly for 20 degrees.

There were three papers comparing the efficiency of the Boston brace compared to other types of bracing. One paper examined Boston bracing compared to Charleston bracing. Two studies compared Boston and Milwaukee braces. All three studies revealed that Boston bracing is superior to other types of bracing in the mid thoracic and lower lumbar curves.

Discussion

Scoliosis is one of the spinal deformities with high incidence of occurrence. Various treatment approaches have been used for patients with scoliosis, especially braces. Boston brace is one of the new designs of braces recommended for the subjects with scoliosis deformity. The aim of this study was to collect all available evidence published on Boston brace to determine its efficiency to control scoliotic curve progression compared to other available braces. Moreover, it was aimed to determine the parameters which influence the efficiency of Boston brace (Tables 4 and 5).

There were 18 papers published on the efficiency of Boston brace, comparison with other braces, on quality of life and health status of scoliotic subjects (used Boston brace) and also on FEA. The quality of

Table 1 The results of quality assessment based on Down and Black tool.

References	Reporting (10)	External validity (3)	Internal validity(bias) (7)	Internal validity (selection bias) (6)	Power
Lange <i>et al.</i> ¹¹	5	2	3	3	1
Yrjonen <i>et al.</i> ¹⁵	5	2	5	4	1
Shi <i>et al.</i> ¹⁶	8	2	5	4	1
Emans <i>et al.</i> ¹⁰	6	1	5	3	1
Peltonen <i>et al.</i> ¹⁹	4	1	5	2	1
Pellios <i>et al.</i> ¹⁸	8	2	5	4	1
Goldberg <i>et al.</i> ²⁸	6	2	4	2	1
Howard <i>et al.</i> ²⁴	8	2	5	4	1
Ganjavian <i>et al.</i> ²⁵	8	2	5	5	1
Montgomery and Willner ²⁶	6	1	4	4	1
Yu <i>et al.</i> ²⁷	4	1	5	5	1
Simony <i>et al.</i> ²⁹	7	2	5	4	1
Laurnen <i>et al.</i> ¹⁷	6	1	5	3	1

Table 2 The results of the studies done on the efficiency of Boston brace on scoliosis curve correction.

References	Methods	Results
Shi <i>et al.</i> ¹⁶	Participants: The scoliotic subjects including none progressive group (group 1) and progressive group (group 2) Age at initial visit: Group 1: 12.4 ± 1, Group 2: 12 ± 1.1 Risser sign: Group 1: 0.7 ± 0.8, Group 2: 0.5 ± 0.8 Cobb angle at initial visit: Group 1: 27.6 ± 5.5, Group 2: 26.1 ± 4.1 Initial angle reduction velocity (IARV): Group 1: 12.8 ± 21.4, Group 2: 25.4 ± 15.2 Intervention: Boston brace Evaluated parameters: Curve correction	Cobb angle at follow up: Group 1: 24.1 ± 7.3, Group 2: 37.8 ± 6.5 There was no significant difference between Cobb angles at last visit. Moreover, there was no difference between (ARV) between the both groups. It seems that bracing outcomes is more correlated with initial Cobb angle reduction velocity than initial correlation rate. The reduction velocity of Cobb angle lower than 10 degrees/per year indicates higher risk of curve progression in scoliotic patients
Lange <i>et al.</i> ¹¹	Participants: 109 scoliotic Age: Risser sign: Cobb angle: 33.4 Intervention: Boston brace Evaluated parameters: Cobb angle, Global Back disability question, Oswestry disability index, general function score, VAS Follow up: 12 years	The magnitude of primary prebrace major curve was in average 33.4 degree but at wearing and at last follow up, the Cobb angle were 28.3 and 34.2, respectively. The mean angle at follow up was 35. Most of the subjects were at full-time job. Moreover, 88% of females delivery baby. Long-term results were satisfactory in most of the patients with scoliosis treated with Boston brace
Laurnen <i>et al.</i> ¹⁷	Participants: 300 scoliotic subjects (with an apex of T9 or higher) Age: Risser sign: Cobb angle: Intervention: Boston brace Evaluated parameters: Cobb angle	The results confirmed that the success of Boston brace depends on the placement of thoracic pads for both concave and convex sides. Use of Boston brace for thoracic curve had good results at T9, T8, and T7 and may be T6. It should be noted that higher thoracic curves are difficult to manage
Peltonen <i>et al.</i> ¹⁹	Participants: 162 scoliotic subjects (37% thoracic, 16% thoracolumbar, 17% lumbar and 30% double major curve) Age: 15 Risser sign: Cobb angle: 25–40 degrees Intervention: Boston brace Evaluated parameters: Cobb angle, Follow up: 1.5 years	The average correction was 2 degrees in thoracic and lumbar curves. Thoracic and lumbar curves remain unchanged and double major curves deteriorated by 1 degree. Progression of the curve more than 5 degree was noted in 24 of patients. Curves between 25 and 45 degrees are suitable for brace treatment. Primary correction correlated with final correction
Yrjonen <i>et al.</i> ¹⁵	Participants: 51 scoliotic subjects Age: Risser sign: Cobb angle: Intervention: Boston brace Evaluated parameters: Cobb angle, progression of the curve Follow up:	At final follow up, progression occurred in 31.4 of male and 21.6% of female. The association between the risk of progression and percentage of correction with brace was statistically significant. The final result of brace treatment for male was inferior compared to female. This study also supports this finding that bracing improved the natural history of scoliosis in both group of subjects

the papers based on the used scale is not high. In most of the studies neither participants, nor staff were blinded regarding the type of brace used. Moreover, in most of the studies follow period after removal of brace was short (in most of the studies, there was no information regarding the period of brace used). Lastly, some of the participants were removed from final consideration (due to not involvement in follow up to the end of the studies). The details of quality assessments of the studies are summarized in Table 1.

The first question addresses the effectiveness of Boston bracing in controlling progression of scoliotic curves. There were seven studies which evaluated the

efficiency of Boston brace. In the research which was done by Yrjonen *et al.*, on 51 boys and girls, treated with Boston brace, it was shown that bracing imposed the natural history of scoliosis curve.¹⁵ Moreover, there was no difference between the outputs of brace treatment between boys and girls. In another study done by Emans *et al.*, the mean best in brace correction was 50%.¹⁰ They also showed that the best correction was achieved for the curve between T8 and L2. Young subjects with a higher degree of scoliosis had less chance to control the scoliotic curve by use of the brace. Shi *et al.* also support the efficiency of Boston brace to control scoliotic curve progression.¹⁶ The

Table 3 The results of the studies regarding the time of brace use and also quality of life in the subjects with scoliosis with history of Boston brace usage.

References	Methods	Results
Emans <i>et al.</i> ¹⁰	Participants: 295 scoliotic subjects Age: 13.2 year Risser sign: Cobb angle: 20–59 degrees Intervention: Boston brace Evaluated parameters: Cobb angle, curve correction Follow up: 1.4 year after brace removal Treatment time: 2.9 years Follow up: 1.4 years	Means best in brace correction was 50% (23% at initial of wearing the brace and 15% after brace removal). For major curve: 49% were unchanged, 39% achieved correction between 5–15 and 4% achieved final correction of 15 degrees. It was defined that the best correction obtained for the curve between T8 and L2. Increase incidence of surgery was seen for young people and those with higher degree of scoliosis. Partial compliance with brace wear appears as effective as full time.
Pellios <i>et al.</i> ¹⁸	Participants: 77 scoliotic subjects (the patients were divided into two groups, those used the brace 23 h per day and those use brace for 18 h) Age: Risser sign: Cobb angle: Intervention: Boston brace Evaluated parameters: Quality of life, curve progression Follow up: 25 years	The subjects were followed up for 25 years after brace removal. The mean cohort scoliotic curve increased by 3.9 ± 6.9 degrees. There was no significant difference between both groups regarding the progression of the curve. Moreover, there was no difference between the mean values of quality of life between both groups. Scoliotic curve does not stop progression after brace removal. Bracing may be a good treatment approach for some groups of scoliotic subjects. It is not possible to have an idea regarding the time of brace usage
Goldberg <i>et al.</i> ²⁸	Participants: 64 scoliotic subjects (the subjects were divided into part-time and full-time users) Age: Risser sign: Cobb angle: Intervention: Boston brace Evaluated parameters: Cobb angle, progression of the curve Follow up:	There was no difference between both groups on any parameters of curve progression. This study raises a question regarding the efficiency of spinal orthosis in modifying the natural history of late onset of IPS
Simony <i>et al.</i> ²⁹	Participants: 159 scoliotic subjects Age: Risser sign: Cobb angle: Intervention: Boston brace and surgery Evaluated parameters: Quality of life Follow up: 25 years	There was no difference between the quality of life between normal and scoliotic subjects. There was also no difference between those treated with Boston brace and surgery, except in satisfaction domain where those got surgery had a better score
Yu <i>et al.</i> ²⁷	Participants: 51 scoliotic subjects Age: 14.4 years Risser sign: Cobb angle: Intervention: Boston brace, surgery Evaluated parameters: Cobb angle, mental health score Follow up:	The results showed no difference between scoliotic curves of both groups. No difference between mental health statuses of both groups. Use of brace did not influence on mental health score of the subjects

efficiency of Boston brace on scoliotic curve after a long period of follow up was evaluated by Lange *et al.* They followed the scoliotic subjects for more than 12 years.¹¹ The results of this study showed that although the mean value of scoliotic curve decreased slightly while using Boston brace, it increased slightly after long period of time out of brace. Lange *et al.* also support this finding that long-term results were satisfactory in most of the patients with Boston brace.¹¹ Laureren *et al.* also showed that the outcome of treatment with Boston brace is considerable depending on the design of the brace.¹⁷ Boston brace has good results for the curve with an apex at T9, T8, T7 and may be T6.¹⁷ From the above-mentioned studies and also the results of the studies shown in Table 2, it can be concluded that Boston brace could control the progression of scoliotic curve.

Based on the results of studies presented in Table 2, it was determined that Boston brace could control the progression of scoliotic curve. However, the second question addresses the parameters which influence the efficiency of the Boston brace. Both time the brace was worn, location of the curve and magnitude of the curve impacted the efficiency of the brace. One of the main parameters was the time of brace use. In the study done by Pellios *et al.*, the progression of the scoliotic curve was evaluated for a long period of time (25 years after use of brace).¹⁸ The results of their study showed that there was no difference between the increases in scoliotic curve of those used their braces as full time (23 h per day) and those used their braces as part time (18 h per day). They concluded that full-time use of Boston brace may not control the curve

Table 4 The results of the studies done on the use of FEA and Boston brace.

References	Method	Results
Chung <i>et al.</i> ²⁰	The correction forces were applied on a 3D model of spine with Boston brace. This model was used to investigate the effects of strap-related brace alternations	Optimal brace stiffness was achieved with three straps (no change with adding another strap). The results of this study showed that the brace applied an inward and upward force to the spine
Liao <i>et al.</i> ²²	The aim of this study was to decrease the weight of Boston brace based on the FEA approach. Three scoliotic subjects were also included (age = 14–17, riser sign = 3–4, scoliotic angle = 29–30). A 3D model of spine was developed based on CT scan of the subjects	The force of the middle strap of the brace was negligible but for the other straps were as follows: Subject 1: 66.2–102, subject 2: 47–65, and subject 3: 42.1–67.6 N. No difference between Cobb angle correction between new and traditional designs of the orthosis. By this approach, Boston brace was lighter by about 12.4%
Cobetto <i>et al.</i> ²³	The aim of this study was to compare the efficiency of Boston brace designed based on CAD/CAM and CAD/CAM and FEA. 40 scoliotic subjects participated in this study with riser sign 0–2, Cobb angle 20–45. They were divided into two groups	The results showed that brace designed with CAD/CAM and FEA are more efficient at correcting the thoracic curve with advantage of being light weight and require less surface coverage
Chen-Sheng <i>et al.</i> ³⁰	The aim of this study was to check the effect of Boston brace strap location on the correction achieved with Boston brace. One scoliotic girl (13 years old, 37.4 right thoracic and 34.3 left lumbar) was recruited in this study. The model was modified based on the 3D model developed in the previous study. The force of strap used in this model were 57, 88 and 93 N	For thoracic spine curve, FEA showed that the pad 20 degrees posterior yield the best corrective force. For lumbar spine, rotating the pad 10–20 posterior with displacement of 30 mm yield the best results. The best results may be obtained if both pads rotate 20 degrees posteriorly. The thoracic curve without brace, with traditional brace and with the new design were 37, 31.4 and 24.3 degrees, respectively. The FEA showed that a pad located at the rib of the apex vertebra and rotate 20 degrees posterior provided best corrective results
Perie <i>et al.</i> ³¹	FEA was done on 12 adolescent idiopathic scoliosis. The personalized FEA of the trunk was developed. Two set of Boston brace force were defined. 1 High thoracic force 31–113 N, Lumbar force less than 47 N. 2 Low thoracic force less than 20, lumbar force up to 70 degrees	The results showed that high thoracic pads reduced more efficiently both thoracic and lumbar scoliotic curves than lumbar pads only

more than part-time use. In contrast, Wiley *et al.* found a significant difference between the outcome of treatment of those used the brace full time (18 h per day or more) and part time (less than 12 h). From the above-mentioned studies, it cannot be concluded that part-time brace use had the same effects on scoliosis progression curve control as full-time wear. However, it is recommended that the brace should be used as full time.

Another parameter that has influence on scoliotic curve control is the location of the curve. Emans *et al.* showed that maximum curve correction achieved with Boston brace was for scoliotic curve with an apex between T8 and L2.¹⁰ Laurenen *et al.* also showed that the best correction with Boston brace was achieved for the curve between T9 and T6.¹⁷ Peltonen *et al.* also confirmed that the average correction achieved with Boston was greater in thoracic, thoracolumbar and finally in lumbar areas.¹⁹ Due to acceptable quality of the aforementioned studies, it can be concluded that the best correction of scoliosis with Boston brace can be achieved for the curve located between T6 and L2. However, it is recommended to use this brace for scoliosis curve with an apex located in lower thoracic area.

Another important parameter which determines the efficiency of Boston brace is the magnitude of scoliotic curve and initial correction velocity. Based on the results of the study done by Shi *et al.*, bracing outcomes is more correlated with initial Cobb angle reduction velocity than initial correction rate.¹⁶ The reduction velocity of Cobb angle lower than 10 degree per year indicates higher risk of curve progression in AIS patients.

The second group of studies focuses on the use of FEA to design and to improve the design of Boston brace. The quality of the studies on this topic is not high due to limited number of the subjects involved and also due to the type of studies. In the study done by Chung *et al.*, it was shown that the optimum stiffness required for Boston brace can be achieved by three straps and there is no need to add another strap to secure the brace.²⁰ The results showed that the brace applied inward and upward forces to spine. Labelle *et al.* also showed that Boston brace produces maximum curve correction in frontal plane, however, it does not have any influence on rib hump or on frontal balance.²¹ In another study done by Liao *et al.*, it was defined that FEA had a good feasibility

Table 5 The results of the studies on comparison between the efficiency of Boston brace with other available braces.

References	Methods	Results
Ganjavian <i>et al.</i> ²⁵	Participants: 215 scoliotic subjects, 182 female and 33 male (51% were double major curve, 19.5% single main thoracic and 14.4% single major thoracolumbar) Age: 13.2 ± 1.8 years Risser sign: Cobb angle: 24–50 degrees Intervention: Boston brace, Milwaukee brace (MB) Evaluated parameters: Cobb angle, curve progression Follow up:	The scoliotic curve improved in 21.3% of the subjects, 42.2% was the same, and 36.5% showed increase in excess of 5 degrees. 23.2% of the subjects underwent surgery during the period of brace using. The results showed that the correction of lumbar and main thoracic curves was better by the use of Boston brace compared to MB. However, bracing did not alter the natural history of scoliosis in early Risser stages with large magnitude of initial curve
Howard <i>et al.</i> ²⁴	Participants: 170 scoliotic subjects Age: Risser sign: Cobb angle: Intervention: TLSO (45), Charleston bending brace (95), MB (35) Evaluated parameters: Cobb angle, curve progression, number of the subjects got surgery Follow up:	Mean progression of the curve include: TLSO = 1.1%, Charleston = 6.5%, MB = 6.3%. Percentage of the subjects with curve progression more than 10 includes: TLSO = 14%, Charleston = 28%, MB = 43%. Percentage of the surgery includes: TLSO = 18%, Charleston = 31%, MB = 23%. It seems that curve progression control with TLSO is more than other available orthoses
Montgomery and Willner ²⁶	Participants: 244 scoliotic subjects Age: Risser sign: Cobb angle: Intervention: Boston, MB Evaluated parameters: Cobb angle, curve progression, failure percentage Follow up: 2 years	There were more than 300 times greater risk of failure of brace treatment for the curve more than 45 compared to the curve between 25 and 35 degrees. For this group of subjects, the failure rate not depends on curve pattern, skeletal age, monarchical status and brace type used. MB had failure rate of five times more than Boston brace. The main parameter to predict the failure of brace is initial curve magnitude and then the type of brace. Maturity may correlate with the incidence of curve progression but not with failure rate

to be used to design Boston brace, as there was no difference between the angles of correction achieved by traditional approach and the brace designed based on FEA.²² Moreover, the results of their study showed that the force of middle strap of Boston brace is negligible and the force of the straps varied between 42.1 and 102 N. The brace designed based on FEA being light weight and requires less surface coverage.²³ From the above-mentioned studies, it can be concluded that FEA is a feasible approach in designing Boston brace for scoliotic subjects. The efficiency of the brace could be improved if the strap force is applied upward and slightly located posteriorly.

The efficiency of Boston brace was also compared with other available braces in some studies. Actually there were three studies on this topic with quality varied between 16 and 21. Howard *et al.* studied 319 patients with Adolescent Idiopathic Scoliosis. They compared the efficiency of the Boston and Charleston braces.²⁴ 83% of the subjects with curve 36 and 45 (treated with Charleston brace) had curve progression more than 5 degrees, compared with 43% with Boston brace. The results confirmed that the Boston brace is recommended to the Charleston brace. Another study compared the Boston brace and the Milwaukee brace. It was indicated that bracing did not influence the

natural progression of scoliosis.²⁵ However, Howard *et al.* study demonstrated that the Boston brace controlled mean correction more so that than Milwaukee and Charleston braces.²⁴ Montgomery and Willner's study demonstrates that the Milwaukee brace failed five times more than the Boston Brace.²⁶ Therefore, it can be concluded that Boston brace is more effective than other available braces to control the progression of scoliotic curve.

The other group of studies on Boston brace focused on the quality of life and mental health status of subjects with scoliosis following the use of Boston brace. Pellios *et al.* evaluated the quality of life of 77 patients treated with Boston brace.¹⁸ The results confirmed that there was no difference between the quality of life between patient with scoliosis and subjects without scoliosis. Yun *et al.* also evaluated the effects of using Boston brace on mental health status of scoliotic subjects received correction surgery. They confirmed that the use of Boston brace did not influence mental health status of scoliotic subjects.²⁷ From the above-mentioned studies, it can be concluded that the use of Boston brace did not influence mental health of subjects with scoliosis.

The results of studies evaluated in this review showed that the effect of Boston brace on scoliotic curve correction is more than other commonly used braces. This may

be due to the structure of the brace (close fitting) and also the force of its strap. The straps of this brace apply forces in upward and also a transverse load which seems to be more effective than Milwaukee brace. However, it should be emphasized that the best correction achieved with Boston brace is in lower thoracic and upper lumbar area. Therefore, although this brace is more efficient to control scoliotic curve, it can be used only for the curves between T6 and L2. It is recommended that the force configuration used in this brace will be put in high profile braces to increase the efficiency of scoliotic brace also for the subjects with a curve in upper thoracic area.

Conclusion

The results of most of these studies support the efficiency of Boston brace to control the progression of scoliotic curve, especially for the curve between T6 and L2. The efficiency of this brace may be due to its rigid structure and also the location and direction of its straps. The brace should be used 18 h per day to be effective.

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Conflicts of interest Authors have no conflicts of interest to declare.

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