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Bracing - Halting Progression or Improving Curves in Adolescent Idiopathic Scoliosis

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Abstract

The effectiveness of spinal bracing in the treatment of adolescent idiopathic scoliosis has been controversial. Some studies have shown that bracing is only as effective as observation, whilst others have shown that bracing is superior to observation, halting progression and effectively reducing progression to surgical threshold. Recently, some studies have even shown improvement of curves with bracing. Yet, many of these studies have been judged to be of low methodological quality. In 2005, the Scoliosis Research Society (SRS) attempted to standardize the inclusion criteria and outcome measurements for bracing studies, to enable comparison among studies. In the guidelines, progression of ≤ 5° is regarded as success. It is apparent that SRS did not regard improvement of curves probable. Improvement which is defined as a decrease of ≥ 6°was not proposed until 2009. This may reflect an improvement in outcome with bracing in the last one to two decades.

The present review attempts to determine if there is a trend of improvement in outcome with bracing in the last 3 decades. Manual literature search was made in the PubMed using the keywords of brace, conservative treatment and adolescent idiopathic scoliosis. Relevant English articles on the outcome of wearing rigid braces from 1990-2016 were retrieved and reviewed to determine if there is a trend towards improvement in outcome with bracing and if bracing halts progression and improves curves.

Results show that there has been an apparent improvement in the effectiveness of bracing in reducing surgical rate since 2005. Close inspection shows that the reduction in surgical rate is not due to an improvement over time, but is related to the types of brace. The effectiveness of Boston brace is not consistent over the years. The surgical rates vary and no consistent trend of improvement can be discerned in the last 2-3 decades. The surgical rate reported in 2007 for TLSO was as high at 79% and that in 2014 for Boston brace was 28%. The surgical rates with European braces (Progressive Action Short Brace (PASB), Cheneau derivatives and Lyon/Sforzesco braces), however, are consistently lower, at less than 8%. Similarly, the European braces have been found to be able to improve curves in over 50% of the at risk patients. Bracing does not therefore only halt progression of curves. Given a well-constructed brace, with good patient compliance, improvement of curves in over 50% of the patients is possible, particularly when used in conjunction with scoliosis specific exercises.

Introduction

Spinal bracing is at present a standard treatment in growing patients with adolescent idiopathic scoliosis with Cobb angle in excess of 20-25° [1, 2]. Yet, systematic reviews regarded that the evidence in support of bracing in the treatment of Adolescent Idiopathic Scoliosis (AIS) is low [3, 4]. As late as 2007, Dolan et al reported that there was a high degree of variability in opinion among clinicians concerning the effectiveness of bracing. Some clinicians embraced the treatment, whilst others utterly rejected using braces for treatment [5].

A critical review of 15 studies on bracing and 3 studies on observation showed virtually no difference in the effectiveness of Thoracolumbosacral Orthosis (TLSO) bracing versus observation [6]. The pooled bracing surgical rate from the 18 studies was 23% compared with 22% in the observation group, showing no clear advantage of either approach[6].This view was similarly held by Goldberg et al (2001), who found that the incidence of surgery in their centre (28.1%) did not differ significantly from another with aggressive orthotic policy (22.4%). They questioned if bracing has any meaningful advantage [7].

Yet, many studies have shown that there is a decreased risk of curve progression with bracing as compared to observation [8, 9, 10]. Emans et al (1986) followed up 295 patients one year after weaning of the Boston brace [8]. They found that 49% of the curves had no change (remained±5°of pre-brace angle). 7% of the patients worsened by ≥ 5° and 11% of the patients received surgery [8]. Similarly, a prospective, multicenter study showed that bracing was more effective than observation and electrical stimulation [9]. At four years the successful rate, defined as progression of ≤ 6°of bracing was 74%, whereas those of observation and electrical stimulation were 34% and 33% respectively [9]. Yet, the study was regarded as of low methodological quality, as it was not randomized, non-blinded and the baseline differences between the groups were not statistically adjusted for and the results did not include the surgical rates [3, 6]. Danielsson and colleagues (2007) followed a

subset of Swedish patients from this study for 16 years, comparing the effectiveness of bracing versus observation in two groups of patients with comparable curves and demographics [10]. Results showed that in the braced group, no patient progressed by more than ≥ 6°. In the observation group, however, 40% of the patients progressed by ≥ 6°; 20% required brace treatment; and 6 patients (9.2%) required surgery [10]. A multicenter study in 2013 which enrolled randomized cohort and preference cohort showed that TLSO effectively reduced the percentage of braced patients with curve progression to surgical threshold [11]. Indeed, the difference in outcome between bracing and not bracing was so significant that the trial was stopped early [11].

In view of the contradiction and the difficulties of comparing different studies, which used different inclusion and outcome criteria, Scoliosis Research Society (SRS) established a guideline for bracing studies to enable ease of comparison of effectiveness of braces in subsequent studies. Reviewing 32 bracing studies, Richards et al (2005) determined the inclusion criteria that would best identify patients most at risk of progression and the most appropriate definitions for bracing effectiveness [1]. It was determined that the patient braced should be 10 years or older, with curves between 25-40° and Risser sign of 0-2. If the patient is a female, she should be either premenarchal or less than one year postmenarchal. Assessment of brace effectiveness should include: the percentage of patients with ≤ 5° curve progression, the percentage of patients with progression ≥ 6° at skeletal maturity, the percentage of patients with curves exceeding the surgical threshold of 45° at maturity and the percentage of patients who require surgical intervention during the 2-year follow up beyond maturity [1]. It is of note that the success of the bracing was defined as progression of ≤ 5° [1]. Presumably, improvement of curves with bracing was deemed improbable and was not defined in the Scoliosis Research Society (SRS) guidelines [1].

Negrini et al (2009) defined improvement of curves as a reduction of ≥ 6° at skeletal maturity when compared to pre-brace angle [12]. This possibly stems from their findings that bracing can improve curves. Thus the successful rate as defined by SRS guidelines includes the improvement rate. To better define the terms, the present review regards change of curve ±5° as stabilization of curves. Successful rate is thus the sum of stabilization rate and improvement rate.

The SRS criteria did not take into consideration of the standards of bracing. The Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) convened in 2008 and established a consensus concerning the standard of management of adolescent idiopathic scoliosis with bracing, with the aim to increase the efficacy and compliance to treatment [2]. SOSORT recommends clinicians to follow the guidelines in clinical practice [2].

Since the establishment of SRS and SOSORT guidelines [1, 2], there have been a number of studies. With uniformity of inclusion criteria and outcome measures, comparison of the effectiveness of bracing should theoretically become easier. We review the studies in the past 2-3 decades to determine if the effectiveness of bracing has improved in terms of halting curves progression, reducing the percentage of patients requiring surgical intervention and improving curves, particularly after the adoption of the two guidelines.

Materials and Methods

Studies from 1990 were manually searched in PubMed, using the key words "brace", "conservative treatment", "adolescent idiopathic scoliosis". Articles on early onset idiopathic scoliosis, secondary scoliosis and adult scoliosis were excluded. Also, articles on soft braces, night time braces and surgery were excluded. Studies using outcome measures other than Cobb angles were excluded. Only articles that were English or having English abstract were included. Studies that determined the combined effects of bracing and scoliosis specific exercises were included, whereas those dedicated solely to scoliosis specific exercises were excluded.

The articles were screened by the lead author for relevance. Only those articles that included inclusion criteria and outcome measures similar to that stipulated by the SRS guidelines were included for comparison. Studies that reported bracing for curves in excess of 40° were not included. Data from studies published from 1990 onwards are reviewed to determine if the effectiveness of bracing has improved over the years, in terms of halting progression of curves, reducing surgical rates and improving curves in patients with AIS.

Results

The search revealed 596 papers. Basing on the above inclusion and exclusion criteria, 33 papers from 1990 – 2000, 53 papers from 2000 – 2010 and 42 papers from 2010 – 2016 were found. Papers that reported short term results of bracing and bracing designs were excluded. This leaves 53 studies for review.

The methodologies, inclusion criteria and outcome measurements of these studies differed significantly and quantitative comparison of the outcome measurements is impossible. Comparison is made qualitatively.

From 1990 to 2002, the reviewed English studies were braces designed in USA. Braces studied included the Milwaukee braces [9, 13, 14, 15], Wilmington braces [16, 17] and Boston or TLSO braces [18 – 23]. We were not aware of any English publication on the European braces during this time period. Since 2003, however, the number of publication on the effectiveness of European braces has increased dramatically [12, 24 – 31]. This may be a result of the establishment of SOSORT in 2005.

Progression to Surgical Threshold of 45°and Surgical Rates

From the data, it is evident (Figure 1) that the surgical rates reduce from the year 2005. Apart from the Janicki et al (2007) study which followed the SRS guidelines and reported 79% surgical rate [32], the surgical rates with bracing after 2005 hovered around 10%. Close inspection showed that the reduction in surgical rates is not related to the improvement in

effectiveness of a particular brace with time. The improvement is brace-dependent (Figure 2). Yet, brace with the same name can yield very dissimilar outcome. The percentage of patients requiring surgical intervention after wearing Wilmington brace varies from 13.4% [16] to 56% [17]. Also, the surgical rate of patients treated by Boston or TLSO brace varies from 0%[10, 20] to over 60% for patients under the age of 13 and with curve in excess of 30°[21].

Progression to surgical threshold was not reported in many studies. It similarly varies significantly from 3% [14] to 46% [20, 33].

Interestingly, European braces which include the Lyon braces [28, 34], the Cheneau derivatives [24, 26, 29, 35], the Sibilla braces [34, 36] and the PASB [27, 37] are associated with a significant lower rate of surgery. The highest surgical rate reported was 7.9% [38], with some studies reporting no surgery after bracing [12, 29, 31, 36, 37].

Successful Rate (Progression ≤ 5°)

The successful rate, or the percentage of patients progressing ≤ 5° is high for Wilmington brace [16, 17], Boston brace [10, 11, 19, 20, 39, 40] and Milwaukee brace [10, 14]. Danielsson et al (2007) and Weinstein et al (2013) reported that 100% and 72% of the braced patients did not progress more than 5° respectively [10, 11].

For the European braces, the successful rate is high as well. The highest reported was 100% [35 -37].

Improvement Rate (Curve Reduction ≥ 6°)

Review of the papers showed that between 1990-2002, only 4 papers showed an improvement of curves of ≥ 6°after bracing at skeletal maturity [16, 18, 19, 21].Piazza et al (1990) followed up 67 patients with AIS, wearing Wilmington brace [16]. For 42 patients with Cobb angles 20-29°, 24% of them improved and for 34 patients with Cobb angles 30-39°, 27% improved. The improvement was more marked in thoracic scoliosis (29%), than double major curve (21%) and thoracolumbar curve (16%). Willers et al (1993) reported an improvement of curve in 3 out of the 25 patients (12%) after weaning of Boston brace at skeletal maturity [18]. Similarly Goldberg et al (1995) reported an improvement of curve of more than 6° in 3 (9.4%) of the 32 patients, with mean age of 13.1 and Cobb angle of 22.2° at skeletal maturity after wearing Boston brace [19]. Of interest is that the Cobb angle of three of the five patients (60%) with lumbar curve improved. Fernandez-Feliberti et al (1995) followed up 75 female and 26 male AIS patients wearing TLSO until skeletal maturity [21]. They found a significant difference in the improvement rate in those with Cobb angle below and above 30° and aged below and above age of 13. For patients below the mean age of 13, those with Cobb angle less than 29° had a higher improvement rate of 54% as opposed to the 26% in patients with Cobb angle in excess of 30°. For patients with mean age above 13, however, those with Cobb angle less than 29° had a lower improvement rate of 58% as opposed to the 70% in patients with Cobb angle in excess of 30°[21].

From 2003 onwards, we were able to identify 21 papers reporting an improvement of curves after weaning of braces at skeletal maturity [24, 25, 26, 29, 31, 38, 42, 43]. The improvement rate varies from 24.2% for the Rigo Cheneau brace [30] to 94% for the Progressive Action Short Brace (PASB) (Figure 3) [27].

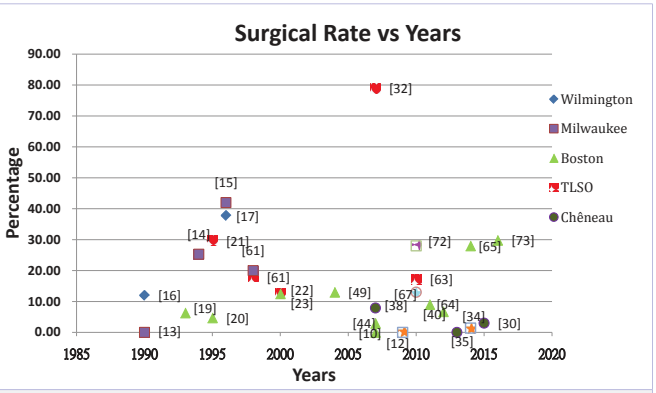

Figure 1: The surgical rates of bracing studies on AIS from 1990 to 2016.

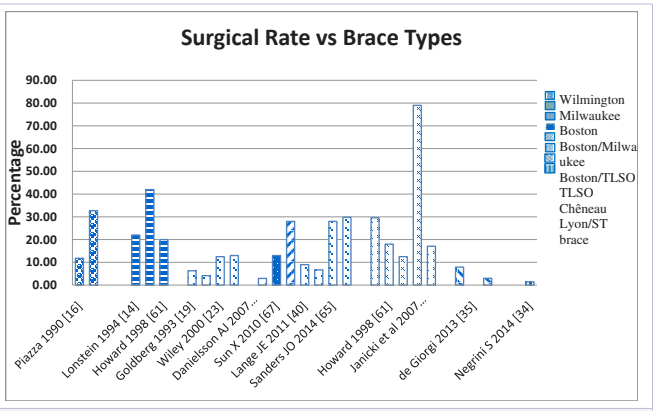

Figure 2: The surgical rates of different major braces in treating AIS reported from 1990 to 2016.

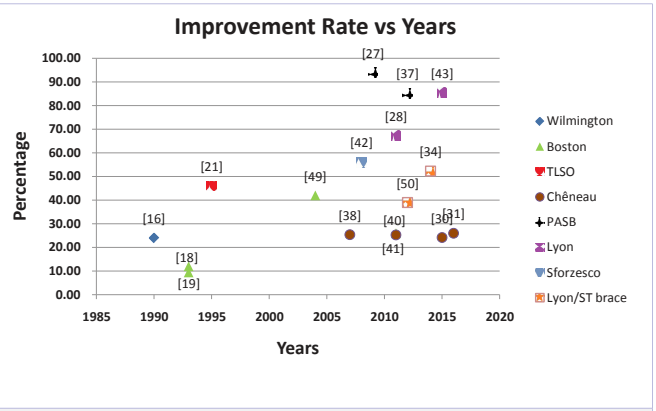

Figure 3: The improvement rates of bracing studies on AIS from 1990 to 2016.

It is to be noted, however, that PASB is specifically tailored for the treatment of thoracolumbar and lumbar curves, which are generally more responsive to bracing than thoracic scoliosis and double major curves.

Stabilization Rate (Change of Curve ±5°)

When the successful rate (progression ≤ 5°) is further divided into stabilization rate (change of curve ±5°) and improvement rate (curve reduction ≥ 6°), it is easier to observe the effectiveness of bracing. Lange et al (2011)found that the successful rate of Boston brace was 88.5% [40], while de Mauroy et al (2011) reported the successful rate of Lyon brace at 95% [28]. These two figures give an impression that both brace types are similar in effectiveness. Comparison of their improvement rates and the stabilization rates, however, show difference of effectiveness. The improvement and stabilization rates of Lyon brace study by de Mauroy (2011) was 67.2% and 27.80%respectively [28], whereas the improvement and stabilization rates of Boston brace reported by Lange et al (2011) was 26% and 62.5% respectively [40]. The figures infer that the Lyon brace is more effective than the Boston brace in improving curves in treatment of AIS.

Discussion

Bracing has been used in the treatment of AIS since the early 50s, with the primary objective of halting progression. Bracing is not regarded as being able to improve curves. It is possibly on this background that SRS regarded a progression of ≤ 5° as a success [1]. Interestingly, however, after Negrini et al (2009) defined improvement of curves as a reduction of ≥6°, many studies have since reported improvement of curves with bracing [12].

When comparing the percentage of patients progressing to surgical threshold, the surgical rates and the improvement rate in the past 26 years, we find that there is a trend towards reduction in surgical rate and an increase in improvement rate. Yet, close inspection showed that the change is more related to the type of brace used, rather than an improvement in the effectiveness of a particular type of brace over time.

Progression to Surgical Threshold of 45°and Surgical Rate

Comparing the data in the last 3 decades, we find there is an apparent trend towards reduction in surgical rate (Figure 1). However, close inspection showed that the data points refer to different braces. The reduction in surgical rates is found to be related to the types of brace, rather than an improvement of a particular brace over time. Also we find that the percentage of patients progressing to surgical threshold and the surgical rate differ significantly among different braces. The surgical rates of patients treated by Boston braces and TLSO over the time vary considerably, from 0% [10] to 79% [32]. The surgical rates of patients treated with European braces (PASB, Lyon and Sforzesco braces) are consistently lower.

The surgical rates reported for the Boston braces varied from less than 10% [19, 20, 44] to above 30% [15, 17, 21]. Some of the more recent reports had surgical rates as high as 60 – 70% [32, 45]. The reasons for the high failure rate were not explained. It is possible that the high failure rate in the Spoonamore et al (2004) [45] study was related to the use of Rosenberger brace, which was still in the developmental stage[45] and the Janicki et al (2007)study, which was the first study that followed the SRS guidelines, involved patients at risk of progression [32]. Yet, not all the TLSO had as high a failure rate. Kessler et al (2008) reported a much lower percentage of patients progressing to surgical threshold, using the Los Angeles brace. The surgical rate reported was only 5% [46].

The authors are unable to identify any English publication before 2003 using the European braces for comparison. Most of the publications in English on European braces were after 2003. Rigo et al (2003) reported the effectiveness of Rigo Cheneau brace in the treatment of AIS [26]. In the worst case analysis, assuming that patients who were lost to follow up progressed to surgical threshold, the percentage of patients progressing to surgical threshold was 14.1%, which was far below that reported for Boston braces[47] and other TLSO[21]. For the Cheneau derivatives, the surgical rates reported ranged from 0 [29, 31, 35] to less than 10% [30, 38]. Zaborowska et al reported a surgical rate of 12.7% [41]. The percentage of patients progressing to surgical threshold was similar in the study by Maruyama et al (2015)and Rigo et al (2003) at 12.1% and 14.1% respectively [26, 30].

The PASB brace which was fabricated specifically to treat thoracolumbar and lumbar curves had the best results, with surgical rates and percentage of patients progressing to surgical threshold of 45° reported to be 0 [27, 37].

The Italian Isico group employed different braces, which included the Sibilla brace, Lyon brace, Sforzesco brace and ART brace basing on individual patient needs also achieved good results [34, 36]. Only 1.4% of the patients progressed to surgical threshold in one study [34]. In another study, the percentage was 0 [36]. It has, however, to be noted that in the studies, scoliosis specific exercises were used in conjunction with bracing. Courvoiser et al (2013) using a combination of Cheneau brace, Lyon brace, Milwaukee and Charleston braces also reported zero percentage of patients progressing to surgical threshold [48].

Improvement in Curves (≥ 6°)

Successful treatment was defined as progression of ≤ 5° [1], indirectly suggesting that bracing would not improve curves. The number of studies reporting improvement rate was few before Negrini et al (2009) defined the improvement rate [12]. After 2009, the number of studies reporting improvement of curves increase dramatically (Figure 3).

For Boston brace, Piazza et al (1990) reported an improvement rate of 21% [16]. Goldberg reported an improvement of 60% in the three lumbar patients. Fernandez-Feliberti et al (1995) reported 70% improvement rate in patients over the age 13 and with Cobb angle in excess 30°[21]. Lange et al (2011) and Vijverman et al (2004) reported an improvement rate of 26% and 42% respectively [40, 49].

Similar improvement rates were reported for Cheneau derivatives. The reported improvement rates ranged from around 25% [30, 38, 41] to 30% [24, 31].Landauer et al (2003) reported a successful rate of 78%, using Cheneau brace. However, they did not report the improvement rate [24].

The improvement rate of Progressive Action Short Brace (PASB) is more significant. The reported improvement rate was above 85% [37] and was as high as 94% [27]. The improvement rate of Lyon brace was also significant at 85.5% [43]. The improvement rate in using a combination of braces basing on individual needs was also good [34, 50, 51], ranging from 39% [50] to 65.7% [51].

Halting Progression or Improving Curves

From the data, it is apparent that the effectiveness of bracing hinges on the type, quality and fitting of braces (Figure 4). The compliance of the patients and incorporation of the scoliosis specific exercises may improve the outcome of bracing.

The lower percentage of patients reaching surgical threshold and the surgical rates in patients wearing European braces as compared to those wearing Boston braces may be related to the brace design and the treatment approach adopted by physicians using the braces.

Boston braces are generally employed by orthopedic surgeons. The objective of the brace is to halt progression of curves to below surgical threshold. In case the brace fails to achieve the objective, the patient can be treated surgically. On the contrary, the European braces are predominantly used by physicians who treat patients conservatively. Failure of the brace would require them to refer the patients for surgical treatment. They are motivated to improve the outcome of the brace treatment.

Boston brace was designed to have zero lumbar lordosis [20], as the effectiveness partially relies on the reduction of lumbar lordosis [20]. Yet, van Loon et al (2008) have shown that forced thoracolumbar lordosis would reduce coronal curves in patients with double major scoliosis [52]. Also, Boston braces encourage thoracic flat back, which has been shown to be detrimental to the correction of curves [53].

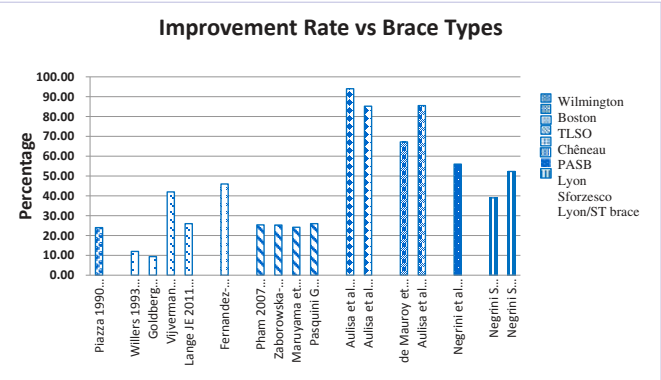

Figure 4: The improvement rates of different major braces in treating AIS reported from 1990 to 2016.

The effectiveness of a brace also depends on how it is made. The quality of the brace cannot be judged by its name [54]. Braces with the same name can produce markedly different results [54]. Danielsson et al (2007) pointed out the importance of the skill and dedication of the orthotist in the effectiveness of a brace [10]. They regarded the well dedicated orthotist as a bias or weakness of their brace study [10]. The orthotist was very committed to the bracing of scoliosis patients and by following the rules for performing brace treatment meticulously, he was able to obtain extraordinary good results [10]. Similar view is held by other authors [54, 55]. Rigo et al (2010) pointed out the importance of quality of the brace in the management of AIS [54]. With experience, the correction of the brace improved [25].

Apart from the design of the braces, the amount of in-brace correction and comfort are also important in the outcome. Large in-brace correction in excess of 50% would be accompanied by improvement at skeletal maturity [24, 56] and hours of brace wear are positively associated with the rate of treatment success [11, 17, 21, 23, 24, 57]. Well design braces that are comfortable to wear may improve compliance, which is important in improvement of the outcome. Wearing a brace full time (≥ 18 hours) is associated with a much lower surgical rate than wearing the brace part time (≤ 12 hours) [23].

From the review, it is noteworthy that the PASB produces remarkable improvement in thoracolumbar and lumbar curves [27, 37]. No patient progressed ≥6° and all the curves were either stabilized or improved [27, 37].

Also, bracing should not be employed alone in the management of AIS. Scoliosis specific exercises should be incorporated. The exercises improve the muscle strength of the trunk and the postural awareness of the patients. More importantly perhaps, they improved the curves [58, 59], reducing the loss of correction which frequently accompanied the weaning of brace [14, 15, 18, 19]. A recent prospective study based on SRS and SOSORT criteria showed that with a combination of brace and scoliosis specific exercises, 52.3% of the 73 patients improved [34].

Recently, it was reported that bracing can help reduce curves in excess of 45° [60]. It is thus timely to discuss if the objective of the brace remains to halt progression of curves, or to improve the curves and if the indications for bracing should be broadened to include patients with curves around the surgical threshold.

Limitation and Future Directions

The main weakness of the present study is that it is a qualitative review, comparing studies with different patient demographics, curve patterns, severity of curves, braces, bracing strategies and outcome measures. Many studies used TLSO, without defining the type of braces fabricated. Also, some studies used a combination of braces, making comparison among braces very difficult. PASB is a rigid brace specifically made to correct thoracolumbar and lumbar curves, which are easier to correct than thoracic and double major curves. Direct comparison of its effectiveness with that of other braces may not be appropriate.

Another limitation of the present review is that the surgical rates instead of the percentage of patients progressing to surgical threshold are compared. Some patients may progress to surgical threshold and yet refuse to receive surgery, especially when they are taken care of by physicians who opt for conservative treatment. Thus comparing the surgical rates may be somewhat misleading. No comparison of the percentage of patients progressing to surgical threshold was made, as only a few papers contain such data. Also many studies reported successful rate, but did not differentiate between improvement rate and stabilization rate.

To enable better comparison, future bracing studies should adopt the SRS and SOSORT guidelines. Patient population should preferably be more homogeneous, grouping by curve types as well. The in-brace correction should be reported as an assurance of the quality of brace. The compliance of the brace wearing should also be recorded. The dosage and frequency of scoliosis specific exercises, if employed should be reported. Study should also record the improvement rate, the stabilization rate, progression rate and the percentage of patients progressing to surgical threshold.

Conclusion

Bracing does not only halt progression of curves. Given a well-constructed brace, with good patient compliance, improvement of curves in some patients can be expected. The improvement rate can possibly be increased by the simultaneous incorporation of scoliosis specific exercises.

Conflict of Interest

All the authors declare no conflict of interest.

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