ANNOTATED BIBLIOGRAPHY
BRACING FOR SPINAL DEFORMITIES

ADOLESCENT IDIOPATHIC SCOLIOSIS

Bracing and Idiopathic Scoliosis

Brace treatment during pubertal growth spurt in girls with idiopathic scoliosis (IS): a prospective trial comparing two different concepts. Weiss HR, Weiss GM. relevant. 2005 Jul-Sep;8(3):199-206. PMID: 16087554 [PubMed - indexed for MEDLINE]

12 patients during the pubertal growth spurt with idiopathic scoliosis were treated with the SpineCor brace and compared to 12 age-matched controls treated with the Cheneau brace. The SpineCor brace did not alter the natural progression of scoliosis as compared to the Cheneau brace when administered during the pubertal growth spurt.

Effects of short term cast wearing on respiratory and cardiac responses to submaximal and maximal exercise in adolescents with idiopathic scoliosis. Margonato V, Fronte F, Rainero G, Merati G, Veicsteinas A. Eura Medicophys. 2005 Jun;41(2):135-40. PMID: 16200029 [PubMed - indexed for MEDLINE]

16 patients with idiopathic scoliosis had respiratory function measured before and after brace application during exercise. FVC and FEV(1) were immediately reduced in the brace. The pulmonary function in female patients remained reduced at 12 weeks. This suggests that bracing limits the cardiopulmonary efficiency during maximal exercise. The authors recommend moderate exercise to counter-act these effects. This study has a very small sample size (totaled 16 subjects) and short follow-up (12 wks).

Visualisation of the brace effect on the spinal profile in idiopathic scoliosis. Schmitz A, Konig R, Kandyba J, Pennekamp P, Schmitt O, Jaeger UE. Eur Spine J. 2005 Mar;14(2):138-43. Epub 2004 Oct 5. PMID: 15480826 [PubMed - indexed for MEDLINE]

38 patients with thoracic curves were studied by MRI in the supine position while using the Chêneau brace. There was a statistically significant correction of the scoliosis deformities when compared to no bracing. The correction appeared to be primarily by translation. This article suggests a possible usefulness in using MR to evaluate the "brace effect".

Use of the Rosenberger brace in the treatment of progressive adolescent idiopathic scoliosis. Spoonamore MJ, Dolan LA, Weinstein SL. Spine. 2004 Jul 1;29(13):1458-64. Review. PMID: 15223939 [PubMed - indexed for MEDLINE]

71 patients with adolescent idiopathic scoliosis were treated with the Rosenberger brace. Patients were evaluated an average of 2.3 years following brace discontinuation. 30% of patients went on to arthrodesis and 56% progressed 5 degrees or more. Failure of this brace was correlated with Risser grade 0, an initial apical curve greater than 16 deg, and the location of the curve.

Personalized biomechanical simulations of orthotic treatment in idiopathic scoliosis. Perie D, Aubin CE, Petit Y, Labelle H, Dansereau J. Clin Biomech (Bristol, Avon). 2004 Feb;19(2):190-5. PMID: 14967583 [PubMed - indexed for MEDLINE]

This is a biomechanical study examining the different forces exerted by the Boston brace on 3 girls with idiopathic scoliosis. It suggests that each individual scoliosis patient should be analyzed with the presented modeling system for the most effective bracing.

The rib epiphysis and other growth centers as indicators of the end of spinal growth. Hoppenfeld S, Lonner B, Murthy V, Gu Y. Spine. 2004 Jan 1;29(1):47-50. PMID: 14699275 [PubMed - indexed for MEDLINE]

This study proposes a new marker for the end of skeletal growth: the rib epiphysis/ Risser 5/ and proximal humeral growth centers instead of the traditional apophyseal capping (Risser 4). No growth occurred after iliac apophysis fusion

(Risser 5) or closure of either the rib epiphysis or proximal humerus growth plates, whereas 75% of patients had some growth after Risser 4.

Early onset idiopathic scoliosis. Gillingham BL, Fan RA, Akbarnia BA. J Am Acad Orthop Surg. 2006 Feb;14(2):101-12.

In early onset scoliosis the Milwaukee brace is preferred over a thoracolumbar orthosis because of rib cage distortion and pulmonary function reduction reported with circumferentially fitting thoracolumbar orthoses. The immature rib cage often deforms before significant correction is transmitted to the spine.

Nonoperative treatment for adolescent idiopathic scoliosis: a 10- to 60-year follow-up with special reference to health-related quality of life. Haefeli M, Elfering A, Kilian R, Min K, Boos N. Spine. 2006 Feb 1;31(3):355-66.

Restrospective study of 135 patients treated nonoperatively with a minimum follow up of ten years. Treatment was bracing in 60, physical therapy in 59 and electrical stimulation in two. Patients responded to a questionnaire on pain, disability, psychological well being and health quality of life. All parameters were satisfactory when compared to controls except for pain. Curve size was found to be a significant parameter for pain.

Outcome at 10 years after treatment for adolescent idiopathic scoliosis. Andersen MO, Christensen SB, Thomsen K. Spine. 2006 Feb 1;31(3):350-4.

Quality of life health questionnaires including SF-36 were administered to patients with AIS treated with either bracing or surgery. 181 patients were included with a mean follow-up of 26 years. The patients had moderately reduced perceived health status and activities of daily living, and increased pain with the surgically treated patients generally at a better level than the brace treated patients.

The objective determination of compliance in treatment of adolescent idiopathic scoliosis with spinal orthoses. Helfenstein A, Lankes M, Ohlert K, Varoga D, Hahne HJ, Ulrich HW, Hassenpflug J. Spine. 2006 Feb 1;31(3):339-44.

9 patients with idiopathic scoliosis were fitted with a thoracolumbar orthosis that included a micro-electric device to measure skin brace temperature in order to measure compliance with brace wear. Patients were instructed to wear the brace 23 hours/day. Brace use ranged from 4.2 to 22.4 hours per day (average 15.4 hours).

Effectiveness of the Providence nighttime bracing in adolescent idiopathic scoliosis: a comparative study of 36 female patients. Yrjonen T, Ylikoski M, Schlenzka D, Kinnunen R, Poussa M. Eur Spine J. 2006 Jan 21;:1-5

36 consecutive patients with an average Cobb angle of 28 degrees and an apex below T 10 were followed prospectively utilizing the Providence night-time brace until 1.8 years after discontinuation. They were compared to 36 matched patients using the Boston brace. Similar progression after discontinuation of the brace occurred in both groups. Use of the Providence night time brace may be recommended in adolescent idiopathic scoliosis in curves less than 35 degrees in the thoracolumbar and lumbar spine.

Effect of bracing and other conservative interventions in the treatment of idiopathic scoliosis in adolescents: a systematic review of clinical trials. Lenssinck ML, Frijlink AC, Berger MY, Bierman-Zeinstra SM, Verkerk K, Verhagen AP. Phys Ther. 2005 Dec;85(12):1329-39.

The authors searched the literature and found thirteen randomized clinical trials or trials on the non operative management of scoliosis. Two reviewers independently concluded that the effectiveness of bracing and exercises is not yet established, but might be promising. They found no effectiveness of electrical stimulation.

Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS Committee on Bracing and Nonoperative Management. Richards BS, Bernstein RM, D'Amato CR, Thompson GH. Spine. 2005 Sep 15;30(18):2068-75.

This is a literature review. Criteria are established by the SRS Brace Committee to standardize future studies and reporting on the non operative management of adolescent idiopathic scoliosis. They recommend inclusion criteria for future

adolescent idiopathic scoliosis brace studies to include: age of 10 years or older when brace is prescribed, Risser 0-2, primary curve angles 25 degrees -40 degrees, no prior treatment, and, if female, either premenarchal or less than 1 year postmenarchal. Assessment of effectiveness should include the percentage of patients with 6 degrees or greater progression at maturity, the percentage of patiet5ns with curves that exceed 45 degrees at maturity and those that have surgery or surgery is recommended, and a 2 year follow-up after maturity.

Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence-based review. Dolan LA, Weinstein SL. Spine. 2007 Sep 1;32(19 Suppl):S91-S100. Review. PMID: 17728687 [PubMed - indexed for MEDLINE]

This paper is a literature analysis of papers describing bracing for Idiopathic scoliosis with surgical outcomes noted compared to patients undergoing observation only with documented surgical rates. Eighteen papers were identified, 15 describing bracing and 3 observation papers. Ultimately, the brace group and the observation cohort of patients both had similar rates of surgery. The authors conclude that there is no significant benefit from bracing reducing the incidence of spinal fusion surgery, and patients and families may be counseled accordingly.

A prospective study of brace treatment versus observation alone in adolescent idiopathic scoliosis: a follow-up mean of 16 years after maturity. Danielsson AJ, Hasserius R, Ohlin A, Nachemson AL. Spine. 2007 Sep 15;32(20):2198-207. PMID: 17873811 [PubMed - indexed for MEDLINE]

This paper follows the original patients in the well-known original 1995 study of the late Alf Nachemson which remains the only prospective study on bracing for idiopathic scoliosis.With an average follow-up of 16 years, and an average age of 32, 87% of the patients from the two Swedish centers in this multi-center study were re-evaluated. Of the patients from the center where bracing was instituted at the time of diagnosis, no patients progressed to surgery during this time period. Of those from the other center where observation was done primarily with some undergoing bracing for documented progression, 6 patients or 10% did undergo spinal fusion surgery, all during the adolescent years. No patients from either group had surgery during adulthood. The authors conclude that well performed bracing in scoliosis patients during adolescence prevents curve progression in patients with moderate curves. Similarly, initial observation spares bracing in 70%, and yields bracing in 20% and surgery in 10 % of patients.

A Comparison of the thoracolumbosacral Orthoses and Providence Orthosis in the Tretament of Adolescent Idiopathic Scoliosis: *Results Using the New SRS Inclusion and Assessment Criteria for Bracing Studies.* Janick, J; Poe-Kochert, C; Armstrong, D; and Thompson, G. J Pediatr Orthop 27(4) June 2007, pp 369-374.

Forty-eight patients who wore the TLSO were compared to 35 patients who wore a Providence brace for scoliosis treatment. The authors used the new SRS assessment criteria for the effectiveness of bracing. Overall, the Providence orthosis was more effective for avoiding surgery and preventing curve progression when the primary initial curve at bracing was 35 degrees or less. However, the overall success of orthotic management for AIS in both groups is inferior to previous studies. This raises the question of the effectiveness of orthotic management of AIS.

General:

Changes in curve pattern after brace treatment for idiopathic scoliosis. vanRhijn LW, Plasmans C, Veraart B. Acta Orthop Scand 73:277-281, 2002.

The authors studied 50 patients with progressive thoracic idiopathic scoliosis (King types 1, 2, and 3). All were treated with an anti-lordotic Boston brace. They found an increasing correlation between the thoracic and lumbar curve size before, during, and after treatment (statistically significant). Seven patients had a change of King type during treatment with a mean increase of 8° in the lumbar curves. All of these had an insufficient (<50%) initial brace correction of their lumbar curves. It is suggested that idiopathic scoliosis is a dynamic process and that insufficient correction of the lumbar curve can lead to progression.

A reliable and accurate method for measuring orthosis wearing time. Harvey R, Gavin T, Patwardhan A, Pawelczak S, Ibrahim K, Andersson GB, Lavender S. Spine 27:211-214, 2002.

A four-pressure switch and data logger embedded in a thoracolumbar spinal orthosis was shown to be reliable in documenting wear time of an orthosis in both patients with a test group.

Factors that influence outcomes in bracing large curves in patients with adolescent idiopathic scoliosis. Katz DE, Durrani AA. Spine 26:2354-2361, 2001.

A retrospective review of 51 patients with AIS with curves 36- 45° treated with a Boston brace. Patients were ≥10 yrs, Risser 0, 1 or 2 and no prior treatment. Of the 51 patients, 31 (61%) were felt to have a successful outcome. Twenty patients failed (≥5° progression) and 10 required surgery. Only patients with double curves were found to have radiographic values predictive of outcome. This article gives guideline for the orthotic management of large curves with AIS treated with the Boston brace.

Effectiveness of bracing in male patients with idiopathic scoliosis. Karol LA. Spine 26:2001-2005, 2001.

A clinical review of a series of male patients with AIS treated with bracing (Milwaukee, Boston, and Charleston braces). Of the 112 patients reviewed 98 had completed treatment (1.2 years mean follow-up bracing). At follow-up 74% progressed at least ≥6 degrees and 46% underwent surgery or had surgical treatment recommended to them. Compliance with the brace was poor, with only 38% reporting consistent use.

Childbearing, curve progression, and sexual function in women 22 years after treatment for adolescent idiopathic scoliosis: a case-control study. Danielsson AJ, Nachemson AL. Spine 26:1449-1456, 2001.

The authors surveyed 267 women with a diagnosis of AIS who either underwent Harrington rod instrumentation (145) or brace treatment (122) between 1968 and 1977 with the SRS questionnaire. In addition, 129 surgically treated and 105 brace treated women were radiographed at follow-up. These two groups were compared to a non-scoliotic control group. Marital status and number of children was similar to controls in both treatment groups. Scoliosis did not progress with childbearing. Some sexual dysfunction was noted secondary to physical limitation or cosmetic concerns. The rate of vacuum extraction delivery was higher in surgical group but the rates of cesarean section were not different. Back pain was similar between the groups.

Radiologic findings and curve progression 22 years after treatment for adolescent idiopathic scoliosis: comparison of brace and surgical treatment with matching control group of straight individuals. Danielsson AJ, Nachemson AL. Spine 26:516-525, 2001.

This is a minimum 20-year radiographic follow-up of AIS patients who either underwent spinal fusion utilizing Harrington rods (156) or brace treatment (127). These patients were compared to age matched controls (100). Surgically treated patients lost a mean of 3.5° of correction, while braced patients progressed a mean of 7.9°. Both treatment groups had more radiographic disc degeneration than the control group. There was no radiographic difference in the surgical group in terms of disc degeneration below the fused segments whether the fusion stopped at L3 or below.

Health-related quality of life in patients with adolescent idiopathic scoliosis: a matched follow-up at least 20 years after treatment with brace or surgery. Danielsson AJ, Wiklund I, Pehrsson K, Nachemson AL. Eur Spine J 10:278-288, 2001.

An excellent long-term outcomes study. The authors studied 127 patients with AIS who were braced between 1968 and 1977. All were followed at least 20 years after completion of treatment and 91% completed several health-related quality of life questionnaires. Their results were compared to a matched control group. The braced patients had slightly, but significantly, reduced physical function. No difference was seen in mental subscales. One-third of braced patients and 1/6 of the controls admitted limitation of social activities due to their back.

Adolescent idiopathic scoliosis. The effect of brace treatment on the incidence of surgery. Goldberg CJ, Moore DP, Fogarty EE, Dowling FE. Spine 26:42-47, 2001.

A review of the incidence of surgical intervention in 153 patients with AIS at a single center in which bracing was not used. Curves were initially evaluated by radiographs, and subsequently by Quantec evaluation. Surgical decisions were based upon Cobb angle, appearance, maturity, and probability of progression. Forty-three patients (28%) underwent surgical treatment. While not easily comparable to bracing studies utilizing radiographic parameters, this article offers an alternative view of the effectiveness of bracing in preventing surgery in this population.

Effects of thoracolumbosacral orthosis on spinal deformities, trunk asymmetry, and frontal lower rib cage in adolescent idiopathic scoliosis. Korovessis P; Kyrkos C; Piperos G; Soucacos PN. Spine 25(16): 2064-71, 2000.

Prospective study to document immediate and late changes in shape and balance of the thoracic and lumbar spine and lower rib cage on the frontal plane induced by treatment with a thoracolumbosacral orthosis (TLSO). The effect of TLSO on lateral plane of spinal deformity, frontal lower rib cage, trunk balance, and natural history are poorly understood. Twenty-four female adolescents with major thoracic and/or lumbar scoliosis, averaging 30 degrees and 26 degrees, respectively, were treated with a full-time TLSO program. Scoliosis, kyphosis, convex, and concave rib-vertebral angles T7 to T12, frontal trunk balance, frontal vertebral inclination, rotation and translation from T7 to L4-vertebrae were measured during bracing and reevaluated at an average of 3.5 years after termination of bracing. Thoracolumbosacral orthosis program maintained the measured roentgenographic parameters at the prebrace levels in progressive adolescent idiopathic scoliosis, but it had no effect on the droop of the seven lower ribs. The TLSO treatment stopped progression of scoliosis and reduced the number of patients requiring surgery. Thus, it changed the natural history of scoliosis.

Measuring the compliance behavior of adolescents wearing orthopedic braces. Vandal S, Rivard C-H, Bradet R: Issues in Comprehensive Pediatric Nursing; 22:59-73, 1999.

In this study 40 female patients with adolescent idiopathic scoliosis were studied to measure brace wear compliance with a device measuring the strap tension on the orthosis. The Compli –O-meter was validated during various activities and exercises. The measured compliance with bracing was only 33% compared with a self-reported compliance of 88% by patient questionnaire. The paper includes a thorough discussion of medical compliance and warns against making important treatment decisions based on self- reported rates of compliance.

Spinal deformity – adolescent idiopathic scoliosis. Nonoperative treatment. Dickson, R.A. Spine, 24(24):2601-2606, 1999.

This is a review article discussing the current concepts and nonoperative management in adolescent idiopathic scoliosis. Four fundamental questions are addressed: (1) What is the deformity we are treating? (2) why are we treating it? (3) can we treat it successfully conservatively? and (4) do we treat it successfully conservatively? The article concludes that conservative management probably does not alter the natural history of adolescent idiopathic scoliosis.

Variability of strap tension in brace treatment for adolescent idiopathic scoliosis. Carl-Eric Aubin C-E, Labelle H, Ruszkowski A, Petit Y, Gignac D, Joncas J, Dansereau J. Spine 24(4) 349-354, 1999.

These authors found a high degree of variation in strap tension in patients wearing the Boston brace during activities of daily living. Using load cells, they studied nine different positions and found the greatest decreases when changing to the supine and lateral decubitus positions compared to the standing tensions prescribed. Since strap tensions affect pad pressure and brace efficacy, they recommend taking these facts into consideration when using recumbent bracing.

Bracing (and screening) – yes or no? Dickson, R.A.; and Weinstein, S.L. J. Bone Joint Surg. 81-B(2):193-198, 1999.

This is a review article analyzing the efficacy of conservative management for adolescent idiopathic scoliosis and the value of school screening for early deformity recognition. The authors concluded that there is a lack of data to support brace management of adolescent idiopathic scoliosis. They also felt that school screening was unethical, due to the uncertainty of the efficacy of treatment with a brace. Thus, early detection may not necessarily prevent curve progression and the need for surgical intervention. The authors provide an excellent reference section.

A comparative study of TLSO, Charleston, and Milwaukee braces for idiopathic scoliosis. Howard A; Wright JG; Hedden D. Spine 23(22): 2404-2411, 1998.

This study reviewed a single institution's experience using the three different braces. TLSO and Charleston braces were used on comparable curves whereas the Milwaukee brace was used on a subgroup in which the other brace designs were considered inappropriate. This point alone makes it difficult to compare the Milwaukee brace results with the others. The authors studied 170 patients who completed brace treatment for adolescent idiopathic scoliosis between 1988 and 1995: 45 patients used a TLSO, 95 a Charleston brace, and 35 a Milwaukee brace. Absolute increase in curve severity, the percentage of curves that progressed beyond 6 degree and 10 degree thresholds, and the percentage of patients who underwent surgery were assessed. Age and initiation of brace treatment, Risser stage, curve magnitude, and time braced and observed did not differ among the groups. The mean curve progression during bracing was 1.1 degrees with a TLSO, 6.5

degrees with a Charleston brace, and 6.3 degrees with a Milwaukee brace. More than 10 degrees of curve progression occurred in 14%, 20%, and 14% of the braces, respectively. The proportion of patients who underwent surgery was 18%, 31%, and 23%, respectively.The authors found that curve progression and the need for surgery was less with use of the TLSO when compared with the Charleston or Milwaukee brace.

Presentation of GTB orthoses for hyperlordotic treatment of idiopathic scoliosis- Griffet J., Thevenot J., Barral F.; Eur J Pediatr Surg (8): 163-167, 1998.

Presents method and concept of using braces molded into hyperlordosis to control idiopathic scoliosis. No results provided

A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. Rowe, DE; Bernstein, SM; Riddick, MF; Adler, F; Emans, JB; Gardner-Bonneau, D. JBJS 79-A(5): 664-74, 1997.

This comprehensive review of 37 peer-reviewed articles on scoliosis analyzed results of treatment in nearly 2,000 patients, about 1500 of whom were managed with bracing while over 300 patients had electrical stimulation and 129 were observed. Impact on outcome was assessed using three variables: type of treatment, level of maturity, and criterion for failure. Bracing for 23 hours per day was the most successful means of halting progression of scoliosis, with the Milwaukee brace found to have the highest rate of success. This review of the literature further substantiates the efficacy of full time bracing for managing idiopathic scoliosis as compared to electrical stimulation and the natural history in these patients.

Rib cage-spine coupling patterns involved in brace treatment of adolescent idiopathic scoliosis. Aubin, CE; Dansereau, J; deGuise JA; Labelle H. Spine 22(6): 629-35, 1997.

This study is a follow-up report to Labelle's 1996 article looking at the three-dimensional effect of the Boston brace on the thoracic spine and rib cage. In order to investigate the coupling movements between the spine and rib cage initiated by brace treatment, 36 adolescents with idiopathic scoliosis (treated with the Boston brace) were studied three-dimensionally. The Boston brace produced complex trunk motions that tended to shift the spine and rib cage anteriorly but had minimal derotation effect. The anterior displacement is undesirable, as it tends to increase hypokyphosis. In order to achieve better trunk correction, the authors proposed a brace concept that applies loads laterally on the convex side and on the anterior thorax opposite to the rib hump, yet constrains the posterior rib hump from moving backward.

New prognostic factors to predict the final outcome of brace treatment in AIS. Upadhyay, SS; Nelson IW; Ho, EK, HSU, LC; Loong, JC. Spine 20(5): 537-45, 1995.

Radiologic findings that correlated with successful outcome in 85 patients with AIS undergoing bracing included correction of both Cobb angle and vertebral rotation. Brace failure or surgery was significant in those patients with either no change or an increase in these measurements.

Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. Nachemson, AL; Peterson, L-E.; and members of Brace Study Group of the Scoliosis Research Society. JBJS 77-A (6): 815-22, 1995.

This landmark study describes results of a prospective multi-center analysis of AIS in 286 girls. Of the 111 girls braced with an underarm Boston orthosis for scoliosis of 25-35 degrees, only 17 patients had progression of 6 degrees or more. This study documents that bracing altered the natural history by preventing curve progression.

Effectiveness of TLSO bracing in the conservative treatment of AIS. Fernandez-Feliberti, R; Flynn, J; Ramirez, N; Trautmann, M; and Alegria, M. JPO 15(2): 176-81, 1995.

A comparison of a group of compliant female patients who wore a TLSO vs. a group of age matched patients with AIS who had no treatment found that compliance was an important factor in achieving a successful outcome. At an average follow-up of 3 years after skeletal maturity, the untreated control group patients older than 13 with a Cobb angle $\geq 30°$ were more than 3 times as likely as a similar braced group to require spine fusion surgery.

The pendulum has swung too far. bracing for adolescent scoliosis in the 1990's. Winter, RB. Orthop. Clinics of North America 25(2): 195-204, 1994.

A review of the history of bracing for AIS from 1960's - 1980's which examines the reasons for the enthusiasm of the 1960's and the recent pessimism of the 1980's and concludes with the rationale and justification for bracing in the 1990's.

A statistical comparison between natural history of AIS and brace treatment in skeletally immature adolescent girls. Goldberg, CJ; Dowling, FE; Hall, JE; Emans, JB. Spine 18(7): 902-8, 1993.

This study compared 2 similar groups of adolescent girls including an untreated control group in Ireland with 32 patients braced with the underarm orthosis. With no significant difference between the groups on any aspect of curve progression, the efficacy of bracing in AIS as a means to halt progression is questioned.

Part-time bracing of adolescent idiopathic scoliosis. Green, NE. JBJS 68-A: 738-742, 1986.

A prospective study of 44 patients with AIS with a minimum scoliosis of 25 degrees treated with either a Milwaukee or Boston Brace for 16 hours per day. At an average of 2 years following discontinuance of the brace, only 5 patients, 3 of whom were non-compliant, had worsening of their scoliosis. This study suggests that part-time bracing of 16 hours per day is effective in halting progression of AIS.

Classic Papers:

Current concepts review: scoliosis bracing. Clyde Nash, JBJS July 62-A: 848-52, 1980.

A comprehensive review paper in the JBJS tradition completely summarizing the state of the art for bracing of spinal deformity in 1980.

Treatment of idiopathic scoliosis in the Milwaukee brace. Long term results. Carr, WA; Moe, JH; Winter, RB; and Lonstein, JE. JBJS 62-A: 599-612, 1980.

One of the landmark papers on bracing for scoliosis from the Twin Cities Scoliosis Center, this paper reported on follow-up 10 years later on the same group of patients analyzed in the 1970 paper above. A gradual loss of correction originally achieved by the brace occurred over time, with an average of only 2° of correction and with 50% of the curves within 3° of their pre-brace value 10 years later.

The Boston brace system for the treatment of low thoracic and lumbar scoliosis by the use of a girdle without a superstructure. Watts, H; Hall, J; and Stanish, W. CORR 126: 87-92, 1977.

The paper introducing the underarm orthosis from Boston for management of AIS.

Milwaukee brace treatment of idiopathic scoliosis. Late results. Mellencamp, D.; Blount, W.; Anderson, A.; CORR 126: 47-57, 1977.

A long term follow-up by the originator of the Milwaukee brace of 47 patients at least 5 years following discontinuance of the brace. One third of patients lost less than 5 °, but the remaining patient had variable progression of their curves. A significant number of these patients were braced for scoliosis greater than 40°.

Idiopathic scoliosis: analysis of curve patterns and the preliminary results of Milwaukee brace treatment in 169 patients. Moe, JH and Kettleson, DA. JBJS 52-A: 1509-33, 1970.

This paper reviews the results of Milwaukee Brace treatment in 169 patients with idiopathic scoliosis, some of who were still weaning out of the brace at the time of evaluation. The median size of the thoracic curve was 38° and the median lumbar curve was 45° in this study. At follow-up, which was at a median of 18 months after discontinuance of the brace, the median correction was 23% for thoracic curves and 18% for lumbar curves.

The Milwaukee brace in the treatment of scoliosis. Blount, W and Schmidt, A. JBJS 37: 693, 1957.

The classic original paper on this subject.

Boston Brace:

Effectiveness of the Boston brace in treatment of large curves in AIS. Wiley JW, Thomson JD, Mitchell TM, Smith BG, Banta JV. Spine 25: 2326-32, 2000.

50 skeletally immature patients with curve magnitudes between 35^0 and 45^0 were treated with the Boston brace. The brace was successful in stopping progression over the long-term (avg f/u 9.7 years) but was dependent on the numbers of hours worn per day. Those who wore the brace ∃18 hours per day (full-time) were significantly less likely to experience progression of more than 5 degrees than were those who wore the brace 12-18 hours per day or 0-12 hours per day. The

authors concluded that although part-time bracing has been shown to be effective against smaller curves, full-time brace wear is necessary to prevent significant progression of larger curves

A comparison between the Boston brace and the Charleston bending brace in adolescent idiopathic scoliosis. Katz DE; Richards BS; Browne RH; Herring JA. Spine 22(12): 1302-1312, 1997.

In an effort to compare the Boston and Charleston brace, 319 patients with adolescent idiopathic scoliosis treated at the same institution were studied. At the time of prescription, all patients were skeletally immature (Risser 0, 1, or 2), older than ten years of age, had curves from 25 degrees to 45 degrees, and had no prior treatment. In nearly all curve patterns the Boston brace was more effective both in preventing curve progression and avoiding the need for surgery. This finding was most notable for the larger curves (36 - 45 degrees). In smaller (25-35 degrees) single thoracolumbar or single lumbar curves, both braces are equally effective.

Three-dimensional effect of the Boston brace on the thoracic spine and rib cage. Labelle H; Dansereau J; Bellefleur C; Poitra B. Spine 21(1): 59-64, 1996.

To determine the effect of the Boston brace on the shape of the thoracic spine or rib cage, three-dimensional reconstruction (using stereo radiography) was obtained on 40 adolescents with idiopathic scoliosis. The Boston brace was effective in reducing the Cobb angle on the frontal plane. It had no significant effect on rotation of the thoracic apical vertebra, on the rib hump, or on spinal balance. It had a negative impact on the sagittal plane as it significantly reduced thoracic kyphosis.

Boston brace in the treatment of I.S. Olafsson, Y; Saroste, H; Sodeolund, V; Hoffston, M. JPO 15(4): 524-7, 1995.

Initial correction of the scoliosis in the Boston Brace correlated with final results. Initial correction in the brace >50% resulted in a reduction of scoliosis. Both the 0° and 15° lumbar lordosis modules showed the same results in 2 groups of 60 patients.

Long-term results of Boston brace treatment on vertebral rotation in AIS. Willers, U; Normelli, H; Aaro, S; Svensson, O; and Hedlund, R. Spine 18(4): 432-5, 1993.

Computed Tomography was used to study the effects of the Boston Brace long-term in 25 patients with follow-up of 8.5 years. Vertebral rotation, apical vertebral translation, Cobb angle, and rib hump were not significantly changed. Bracing did not improve but prevented progression of vertebral rotation, translation, and rib hump in AIS by CT Scan analysis.

The Boston bracing system for idiopathic scoliosis. Follow-up results in 295 patients. Emans, JB; Kaelin; A; Bancel, P; Hall, JE; Miller, ME. Spine 11: 792-801, 1986.

An important paper from Boston discussing the effectiveness of the Boston Brace by its developers.

Charleston Brace:

Effectiveness of the Charleston bending brace in the treatment of single-curve idiopathic scoliosis. Gepstein R, Leitner Y, Zohar E, Angel I, Shabat S, Pekarsky I, Friesman T, Folman Y, Katz A, Fredman B. J Pediatr Orthop. 22:84-87, 2002.

This article from Israel compares 85 patients using a Charleston nighttime orthosis (8hrs/night) with 37 patients, using a TLSO (18-22 hrs/day) for idiopathic scoliosis. The patients had similar demographics and pretreatment criteria. The overall success rates were 80 and 81%, respectively. Surgery was performed in 12 and 14% of the patients in the Charleston and TLSO groups. This is another article documenting equal efficacy between nighttime bending orthosis and a full-time TLSO.S

Results of Charleston bracing in skeletally immature patients with idiopathic scoliosis. Trivedi JM, Thomson JD. J Pediatr Orthop 21:277-280, 2001.

A single institution's experience with 42 female with idiopathic scoliosis who were $\geq$10 years of age, Risser 0-1, single curve 25-40°, no prior treatment, and followed for a mean of 3.3 years after brace discontinuation. Overall, the

Charleston brace was 60% effective in preventing curve progression. Only 3 patients (7%) required surgery. This is another study demonstrating the efficacy of a nighttime bending orthoses.

Nighttime bracing for adolescent idiopathic scoliosis with the Charleston bending brace: long-term follow-up. Price, C. T.; Scott, D. S.; Reed, F. R.; Sproul, J. T.; Riddick, M. F. JPO 17(6): 703-707, 1997.

98 immature patients (Risser 0,1, or 2) with adolescent idiopathic scoliosis were treated and followed until skeletal maturity. Scoliosis measured 25°-49° prior to bracing (average curve measured 31°). Progression was prevented in 66% of patients. Double curves had poorest response to treatment. Authors conclude that results of treatment are better than the natural history of untreated scoliosis.

Milwaukee Brace:

Use of the Milwaukee brace for progressive idiopathic scoliosis. Noonan, KJ; Weinstein, SL; Jacobson, WC; Dolan, LA. JBJS April 78-A (4): 557-671, 1996.

A review of over 100 patients treated with a Milwaukee Brace followed for an average of over 6 years post bracing. Nearly one half of the patients had curve progression of 5 degrees or more despite bracing and curves progressed an average of 5 degrees after bracing, findings which question the ability of the Milwaukee Brace to prevent progression of AIS.

The Milwaukee brace for the treatment of AIS. A review of one thousand twenty Patients. Lonstein, JE and Winter, RB. JBJS August 76-A (8): 1207-21, 1994.

Large study of patients managed by 2 physicians at one institution concluded that bracing does alter the natural history of AIS in the range of 20 to 39 degrees. A poorer prognosis for successful bracing was associated with younger age, larger curve size, and a Risser sign of 0-1.

Providence Brace:

Nighttime bracing with the Providence brace in adolescent girls with idiopathic scoliosis. d'Amato CR, Griggs S, McCoy B. Spine 26:2006-2012, 2001.

The authors report on 102 consecutive females with idiopathic scoliosis with Risser 0, 1, or 2 signs, and treated with CAD/CAM nighttime bending orthosis (8 hrs/night). All were followed for a minimum of 2 years following cessation of brace wear. The authors found 75 patients (74%) did not progress while 27 patients (26%) progressed $\geq$6° or required surgery. The results were better when the apex of the curve was at or below T9 (79%) compared to higher apical levels (61%). Risser 2 patients were more successful (83%) than Risser 0-1 patients (71%). This article supports nighttime bracing as being as effective as a TLSO worn 22-23 hours/day in preventing curve progression.

Spine Cor Brace

Effectiveness of the Spine Cor Brace Based on the New Standardized Criteria Proposed by the Scoliosis Research Society for Adolescent Idiopathic Scoliosis. Coillard, C; Vachon, V; Circo, A; Beauséjour, M; and Rivard, C. J Pediatr Orthop 27(4), June 2007, pp375-379.

Successful treatment was achieved in 59.4% of 170 patients from the time of the fitting of the Spine Cor to the point in which it was discontinued. This is an encouraging preliminary study from the inventors of the Spine Cor brace.

Wilmington Brace:

AIS: Treatment with the Wilmington Brace. A comparison of full-time and part-Time Use. Allington, NJ; and Bowen, JR. JBJS July 78-A(7): 1056-62, 1996.

The efficacy of part-time versus full-time brace wear for AIS in 188 patients was assessed. This study did not demonstrate significant differences in full or part-time bracing in restricting curve progression, although both part-time and full-time bracing were significantly more effective than electrical stimulation in preventing progression.

Curve progression after treatment with the Wilmington brace for idiopathic scoliosis. Piazza, MR and Bassett, GS. JPO 10(1): 39-43, 1990.

A review of 67 patients treated for AIS with the Wilmington Brace with minimum follow-up of 5 years showed curve progression of 5-16 degrees occurred in 21% (16). However 9 of these patients ended within 5-degrees of their pre-brace Cobb angle, indicating the effectiveness of this brace in preventing curve progression.

Computer Assisted Design:

Design of thoracolumbosacral orthosis (TLSO) braces using CT/MR. Eldeeb H, Boubekri N, Asfour S, Khalil T, Finnieston A. J Comput Assist Tomogr 25:963-970, 2001.

A well-developed orthotic study. It compared the TLSO volume and circumferential measurements between conventional casting methods and MRI reconstructed models. Accuracy of the MRI method was 97% demonstrating that this computer-aided design method can be a potential alternative to conventional anatomy-measuring techniques. A useful discussion of a technical topic.

Optimization method for 3D bracing correction of scoliosis using a finite element model. Gignac D, Aubin C-E, Dansereau J, Labelle H: Eur Spine J 9: 185-190, 2000.

In this study, finite element analysis was used to study the scoliotic deformity, in twenty patients. The model was personalized to the geometry of each subject's deformity. Two optimization studies were carried out, the first taking into account the thoracic deformity only and the second both the thoracic and lumbar deformity. The forces and vectors needed to correct the deformity toward the "optimal" spine values with respect to the normal spine axis and rib cage were calculated. These force vectors and magnitudes are illustrated for the subjects. This is an exciting study potentially offering a method of optimizing brace construction for correction of spinal curvatures using a three dimensional analysis of the deformity.

Surface Electrical Stimulation:

Surface electrode stimulation versus brace in treatment of idiopathic scoliosis. Durham, JW; Moskowitz, A; Whitney, J. Spine 15(9): 888-92, 1990.

Surface electrical stimulation utilizing the ScoliTron device in 40 patients with follow-up in 30 demonstrated failure in 50%. Fifteen failed patients required either surgery or a brace. Electrical stimulation seemed ineffective in preventing scoliosis progression in adolescent patients.

Electro-spinal stimulation in children with adolescent and juvenile scoliosis. Goldberg, C; Dowling, FE; Fogarty, EE; Regan, BF; and Blake, NS. Spine 13(5): 482-4, 1988.

A review of 41 patients with idiopathic scoliosis treated with electro-spinal stimulation found that nearly 50% of the patients (19) were removed from the study because of curve progression and 16 of these patients underwent spinal fusion. The 13 patients who reached maturity without significant increases in curve size were found to be in lower risk categories for progression. This form of treatment has been discontinued by the authors.

Further evaluation of ScoliTron treatment of AIS. Sullivan, JA; Davidson, R; Renshaw, TS; Emans, JB; Johnston, C; and Sussman, M. Spine 11(9): 903-6, 1986.

Of 142 patients with AIS undergoing treatment with the ScoliTron device of lateral surface electrical stimulation, 56% of patients failed based on a curve increase of 10°. Electrical stimulation was not recommended as an alternative to bracing for patients with AIS based on these findings.

SRS 22

Cheung KMC, Cheng EYL, Chan SCW, Yeung KWK, Luk, KDK. Outcome assessment of bracing in adolescent idiopathic scoliosis by the use of the SRS-22 questionnaire. International Orthopaedics (SICOT) 2007; 31:507-511

The SRS-22, completed on each visit, was complied retrospectively for 46 braced patients and 48 observational patients with similar curves who were classified as non-progressive and not treated. Overall, the observational group had a better quality of life. The most obvious differences were in patients with curves < 20 degrees – presumably these patients were annoyed that they had to wear a brace for reasons indiscernible to them. Both groups demonstrated a trend toward a reduction in the quality of life with time.

Physiologic Effects of Bracing:

The immediate effect of a Boston brace on lung volumes and pulmonary compliance in mild adolescent idiopathic scoliosis. Katsaris G, Loukos A, Valavanis J, Vassiliou M, Behrakis PK: Spine J 8:2-7, 1999.

In this study 15 patients with adolescent idiopathic scoliosis had pulmonary functions measured with and without a Boston brace using spirometry and plethysmography. They found that the brace had an immediate, significant reduction in lung volumes. Static lung compliance was reduced, but specific lung compliance was unaffected. These findings were due to external restriction of the thoracic cage without any effect on the elastic properties of the lung.

Back pain during orthotic treatment of idiopathic scoliosis. Ramirez, N; Johnston, C. E.; Browne, R. H.; Vasquez, S. JPO 19(2): 198-201, 1999.

303 patients treated with an orthosis were asymptomatic prior to treatment. 34 patients (11%) developed back pain during treatment. 50% of those with pain showed progression >10° compared to only 25% progression for patients without pain (p = 0.002).

Long-term alterations of respiratory function in adolescents wearing a brace for idiopathic scoliosis. Korovessis P; Filos KS; Georgopoulos D. Spine 21(17): 1979-1984, 1996.

30 adolescents treated with the Boston brace underwent pulmonary function studies at the beginning of brace treatment and 12 and 24 months after the initiation of treatment. PFT's were taken both in and out of the brace and were found to be significantly lower when measured in the brace. Nearly continuous wearing of the Boston brace produced a significant but reversible impairment of vital capacity, FVC, FRC, and residual volume. The authors concluded that brace wearing for mild adolescent idiopathic scoliosis does not harm lung function over a two-year period.

Does bracing affect bone density in AIS? Snyder, BD; Zaltz, I; Brentenbach, MA; Kidd, TH; Myers, ER; Emans, JB. Spine 20(14): 1554-60, 1995.

In this analysis of bone density, braced patients and unbraced patients followed for scoliosis were found to have no differences, suggesting that AIS patients treated with a brace should not have any adverse effect on their bone mass.

Pulmonary function and gas exchange at rest and exercise in adolescent girls with mild idiopathic scoliosis during treatment with the Boston thoracic brace. Refsum, HE; Maess-Andresen, CF; Lange, JE. Spine 15(5): 420-3, 1990.

Pulmonary function studies were accomplished in 49 girls with AIS prior to, during and after bracing. A decrease in lung volumes and function was identified likely due to increased dead space and the O2 cost of breathing. These affects on pulmonary function resolved completely after bracing.

Kotwicki t, Kinel E, Stryly W, Szulc A. Discrepancy in clinical versus radiological parameters describing deformity due to brace treatment for moderate idiopathic scoliosis. Scoliosis 2007 2:18, available from http://www.scoliosisjournal.com/content/2/1/18

An interesting comparison of morphology of the trunk in 24 braced and 26 unbraced girls with similar curves(Cobb angles 34.9 vs 32.7 respectively) and age. Trunk asymmetry was much less in the braced group, with a more pleasing clinical appearance despite little change in Cobb angle.

Psychological Effects of Bracing:

Early weaning might reduce the psychologic strain of Boston bracing: a study of 136 patients with adolescent idiopathic scoliosis at 3.5 years after termination of brace treatment. Andersen MO, Andersen GR, Thomsen K, Christensen SB. J Pediatr Orthop B 11:96-99, 2002.

A questionnaire was sent to 136 patients with idiopathic scoliosis treated with a Boston brace between 1983 and 1990. Of these ,93% responded. The patients were a mean of 3.5 years following brace termination. The authors found that daily activities and social contacts were affected both during treatment and at this follow-up. They felt that brace weaning should begin as soon as safely possible, and no later than 3 years after menarche in females.

Impact of the type of brace on the quality of life of adolescents with spine deformities. Climent JM, Sanchez J. Spine 24: 1903-8, 1999.

102 adolescents with spine deformities (75% with AIS) were treated with various orthoses, including Milwaukee brace, Boston brace (or other TLSO), and Charleston bending orthosis. To determine brace effects on self-perceived health status, patients completed the Quality of Life Profile for Spine Deformities (QLPSD). The Milwaukee brace showed a significantly greater impairment in the quality of life of patients managed with this method, compared with the Boston brace and TLSO and, especially with the Charleston bending orthosis, which was the type of brace with the lowest impact.

Cognitive strategies and self-esteem as predictors of brace-wear noncompliance in patients with idiopathic scoliosis and kyphosis. Lindeman, M.; and Behm, K. J. Pediatr. Orthop 19(4):493-499, 1999.

Psychological determinants of brace-wear compliance were analyzed among 113 patients with either adolescent idiopathic scoliosis (92%), kyphosis (5%), or both (3%) in Finland. Noncompliant females did not expect to succeed with brace management and were anxious about the possibility of failure. They also had low self-esteem and did not seek social support from others. Noncompliant boys had high self-esteem and high achievement success expectations. Patients with short brace use and low compliance was best predicted by low amount of reflective thinking and a good body-image. In contrast among patients who had used the brace for greater than six months, low compliance was best predicted by a high amount of reflective thinking, poor body-image, low social success expectation, and low master orientation in social behavior. Only sleeping problems predicted compliance across gender and the time of brace use. The more the patient experienced sleeping problems, the less they used their orthosis.

Long-term psychosocial characteristics of patients treated for idiopathic scoliosis. Noonan KJ; Dolan LA; Jacobson WC; Weinstein SL. JPO 17: 712-717, 1997.

Psychosocial characteristics were examined between 95 female patients who were treated with the Milwaukee brace (30 also requiring surgery) and 49 age-matched female controls. At the time of treatment, the scoliosis patients felt discriminated against and had a lower satisfaction level regarding their overall appearance. At follow-up, the operative patients continued to have a more negative body image than those who were braced and the control group.

Stress and coping with scoliosis: psychological effects on adolescents and their families. MacLean, WE; Green, NE; Pierree, CB; and Ray, DC. JPO 9(2): 257-61, 1989.

The psychological, functional and family effects of part-time brace treatment for AIS in 31 girls was assessed. The initial period of bracing was described as stressful by 84% of the families. Although overt psychopathology was not identified, lower self-esteem of the patients was found in the initial period of bracing. Contact with peers undergoing similar treatment and the availability of supportive counseling were cited by families as means to help cope with stress.

The psychosocial sequelae of the Milwaukee brace in adolescent girls. Apter, A; Morein, G; Munitz, H; Tyano, S; Maoz, B; and Wijsenbeek, H. CORR 131: 156-9, 1978.

The psychosocial status of 38 patients under going treatment with the Milwaukee Brace 23 hours per day was evaluated using standard psychiatric interview techniques and the Offer Self Image questionnaire. After the 2-6 week period of initial adjustment, all patients except one were found to be coping well, and no patients would admit to any psychosocial difficulties. The study concluded that a competent orthopaedic surgeon could manage all the psychosocial aspects of brace treatment for scoliosis, given the resilience and coping skills of normal teenagers.

Determination of the influence of the Cheneau brace on quality of life for adolescent with idiopathic scoliosis. Pham VM, Houlliez A, Carpentier A, Herbaux B, Schill A, Theyenon A.Ann Readapt Med Phys. 2008 Jan: 51(1)::3-8, 9-15. Epub 2008 Dec 3. PMID: 18093579

The authors studied 108 patients with scoliosis and found that wearing the Cheneau brace significantly affected the quality of life (QoL). The QoL is the worst in the full-time brace wearing group when compared to part-time and no brace group.

Korovessis P, Zacharatos S, Koureas G, Mega P. Comparative multifactorial analysis of the effects of idiopathic scoliosis and Scheuermann kyphosis on the self-perceived health status of adolescents treated with brace. Eur Spine J 2007, 16: 537-46

79 adolescents undergoing brace treatment and 62 adolescents without spinal deformity were asked to complete the Quality of Life profile for Spine Deformities Instrument. Braced patients reported more difficulties with flexibility (which seemed self evident), losing friends, spending less time with friends, feeling nervous in a swimsuit, more ashamed of his/her body, and worry about the future effect of scoliosis. Girls were more dissatisfied than boys, and had more back pain. A paradoxical finding was that the emotional distress associated with the initial bracing declined over time, which did not seem to sensibly correlate with their other findings.

Chiropracty and Scoliosis:

Effects of chiropractic intervention on small scoliotic curves in younger subjects: a time-series cohort design. Lantz CA, Chen J. J Manipulative Physiol Ther 24:385-393, 2001.

These chiropractic authors report their negative results. These authors studied 42 patients age 6 to 12 years with curvatures between 6 and 25°. Each patients underwent a series of chiropractic full spine adjustment over a mean of 14.5 months. In addition, they also were given heel lifts, as well as postural lifestyle counseling and exercises, such as stretching on a chinning bar. No improvement in the curves was observed with this treatment. The authors concluded that chiropractic treatment does not improve scoliotic curves. An important study to quote when asked about the role of chiropractic intervention.

An inquiry into chiropractors' intention to treat adolescent scoliosis: a telephone survey. Feise, RJ. J Manipulative Physiol Ther 24:177-182, 2001.

The author is Research Director, American Chiropractic Research Foundation. The findings exemplify the state of current chiropractic management of scoliosis. In this study 90% (114/216) of an eligible sample of chiropractors responded to a telephone survey to determine the clinical management approach to a hypothetical 12 year old, Risser 1, female patient with a 25° curvature of the spine. It was found that the typical chiropractor would provide 6 months of intensive adjustive treatment and 4 years of follow-up care, 73% would use heel lifts, 87% exercise, and 39% physical therapy or electrical stimulation (30%). Ninety-five percent stated that they used clinical experience as a means of establishing a treatment regimen. Only 20% knew the difference between retrospective and prospective research design.

ADULT SCOLIOSIS

A systematic literature review of nonsurgical treatment in adult scoliosis. Everett CR, Patel RK. Spine. 2007 Sep 1;32(19 Suppl):S130-4. Review. PMID: 17728680 [PubMed - indexed for MEDLINE]

This article reviews the multiple forms of conservative management of adult degenerative scoliosis (PT, Chiropractic, injections, etc.) to determine which is most efficacious. Only level III/IV evidence could be found, and no treatment option within conservative care has support as a preferred solution.

INFANTILE SCOLIOSIS

Casting and traction treatment methods for scoliosis. D'Astous JL, Sanders JO. Orthop Clin North Am. 2007 Oct;38(4):477-84, v. Review. PMID: 17945127 [PubMed - indexed for MEDLINE]

The article provides an excellent overview with technical tips and practical advice on casting for infantile scoliosis according to the Mehta protocol emphasizing the importance of traction and rotational correction. Various techniques of halo traction are also described.

NEUROMUSCULAR SCOLIOSIS

General:

Soft Boston orthosis in management of neuromuscular scoliosis: a preliminary report. Letts, M; Brathborne, D; Yamashita, T; Nichol, B; Keeler, A. JPO 12(4): 470-4, 1992.

The use of a "soft" spinal orthosis in 55 children with neuromuscular scoliosis provided enhanced patient tolerance, facilitated postural positioning and sitting stability in a significant majority of the patients, offering an alternative to more rigid designs in this challenging population.

Effects of posture and spinal bracing on respiratory function in neuromuscular disease. Noble-Jamieson, CM; Heckmatt, JZ; Dubowitz, V; Silverman, M. Archives of Disease in Childhood. 61(2): 178-81, 1986.

The effect of posture and spinal bracing on lung function in 40 children with neuro-muscular disease were studied. Twenty of the children were non-ambulatory with scoliosis. Bracing with a rigid spinal jacket caused a significant (22%) decrease in mean vital capacity, and the reduction was proportional to the severity of the scoliosis and the amount of correction achieved by the brace. The significant respiratory impairment caused by bracing in patients with established severe scoliosis suggests that early prophylactic bracing may be more easily tolerated by patients.

Cerebral Palsy:

Treatment of scoliosis with spinal bracing in quadriplegic cerebral palsy- Terjessen T., Lange J., Steen H.; Devel Med Child Neuro. (42): 448-454, 2000.

This retrospective study evaluates the effectiveness of bracing (TLSO) in patients with total body involved spastic, quadriparetic CP. Mean follow-up was 6.3 years (2-14 years) and initial Cobb angle was 68° and mean correction was only 38%. Results show braces did not control progression relative to other natural history studies (Saito etal 1998) but sitting balance subjectively improved in the brace. Age was the factor most to progression with patients <15 years progressing less. Recommend use of brace for sitting balance. The question of brace effectiveness in less severe curves (20-30°) was not address.

Brace treatment in neuromuscular spine deformity- Olafsson Y., Saraste H., Al-Dabbagh Z: J Pediatric Orthop (19): 376-379, 1999

This is a retrospective survey of brace treatment in heterogeneous group of 83 patients including spastic and hypotonic subjects, ambulatory and non-ambulatory. The results show that despite average in-brace correction of 60%, curves progressed after cessation of bracing. Forty-one (50%) patients discontinued bracing prematurely. The study was poorly designed and did not meet its aim to determine factors influencing outcome.

Impact of orthoses in the rate of scoliosis progression in children with cerebral palsy. Miller, A; Temple, T; Miller, F. JPO 16(3): 332-335, 1996.

A review of 26 patients with neuromuscular scoliosis treated 23-hours per day with a Wilmington orthosis for an average of 67 months found that the orthosis had no effect on scoliosis progression in patients with quadriplegic cerebral palsy.

Friedreich's ataxia:

Friedreich's ataxia and scoliosis: the experience at two institutions. Milbrandt TA, Kunes JR, Karol LA. J Pediatr Orthop. 2008 Mar; 28(2):224-8. PMID: 18388721

77 patients with Friedreich's ataxia were studies. Scoliosis prevalence was 63% (49 patients) with mean age at diagnosis of 12.8 years in this group. Average progression of curve with brace treatment was 15 degrees. The authors observed variable curve patterns. During the surgical correction, the authors recommended a wake-up test as SSEP monitoring was ineffective.

Myelomeningocele:

Brace treatment of scoliosis in children with myelomeningocele. Muller, EB; Nordwall, A. Spine 19(2):151-5, 1994.

Twenty-one children with myelomeningocele were braced with a Boston type orthosis for progressive scoliosis. Six children underwent spine fusion surgery, but the brace seemed to decrease the rate of progression in the others.

The influence of scoliosis brace treatment on function in children with myelomeningocele. Muller, EB; Nordwall, A; von Wendt L. Acta Paediatrica 81(11): 925-8, 1992.

Twenty children between the ages of 5-19 with myelomeningocele and scoliosis treated with the Boston brace were assessed for functional and motor ability before, during and after brace treatment that lasted for an average of 2.7 years. Although ambulatory ability decreased slightly while in the brace, motor activity and ADL function were maintained during bracing. Since the effect of the brace on the scoliosis was "favorable", brace treatment for scoliosis in children with myelomeningocele was recommended.

Spinal Muscular Atrophy:

Scoliosis in spinal muscular atrophy: review of 63 cases. Rodillo, E; Marini, ML; Heckmatt, JZ; Dubowitz, V. Journal of Child Neurology 4(2): 118-23, 1989.

Scoliosis in 37 patients with intermediate type and 26 with mild type spinal muscular atrophy was reviewed for its incidence, progression and severity. In the more involved intermediate type patients, scoliosis appeared early and progressed rapidly before puberty despite the routine use of a spinal orthosis, and virtually all patients required spinal fusion. Scoliosis had a more variable course in the mild type patients, with maintenance of ambulation seeming to slow progression of the deformity.

Charcot Marie Tooth Disease:

Spinal deformities in patients with Charcot-Marie-Tooth disease. Daher, YH; Lonstein, JE; Winter, RB; Bradford, DS. CORR 202: 219-22. 1986.

This is a review paper of 12 patients with Charcot-Marie-Tooth disease and scoliosis followed over 4 years. Three patients were treated with bracing for scoliosis, and two were successfully controlled. Four patients underwent posterior spine fusion surgery with Harrington instrumentation.

Scoliosis in Patients with Charcot-Marie-Tooth Disease. Karol, L and Elerson E. JBJS Am. 2007;89:1504-10.

Forty-five patients with scoliosis associated with Charcot-Marie-Tooth disease were evaluated. One-third of the curves were left thoracic and 49% were associated with increased thoracic kyphosis. Brace treatment was successful in only 3 of 16 patients. Bracing was usually unsuccessful. Surgical fusion was not associated with a high rate of complication. The authors found it often possible to perform intraoperative neurologic monitoring.

Duchenne Muscular Dystrophy:

Steroid treatment and the development of scoliosis in males with Duchenne muscular dystrophy. Alman, BA; Raza, SN; Biggar, WD. Journal of Bone & Joint Surgery – American Volume 2004; 86-A(3):519-524.

This prospective non-randomized comparative study involved 54 patients with Duchenne muscular dystrophy who were matched for age and pulmonary function. All were able to walk prior to the study. 30 were treated with Diflazacort and 24 acted as controls. The patients were followed for 5 years. 17% (5 pts) of the treatment group developed scoliosis, whereas 67% (16 pts) of the control group developed scoliosis.

Deflazacort in Duchenne muscular dystrophy: a comparison of two different protocols. Biggar, WD; Politano, L; Vajsar, J; Alman, B; Palladino, A; Comi, LI; Nigro, G. Neuromuscul Disord. 2004 Sep; 14(8-9):476-82.

This article retrospectively compares 2 protocols of deflazacort in the treatment of Duchenne muscular dystrophy. One group (N) was treated with 0.6 mg/kg/day for the 1st 20 days of the month. The second group (T) was treated with 0.9 mg/kg/day of deflazacort. Follow-up was 4 years or greater. Scoliosis >20 degrees developed in 30% of the boys on protocol N, in 16% of those on protocol T, and in 90% of controls.

Prednisolone therapy in Duchenne muscular dystrophy prolongs ambulation and prevents scoliosis. Yilmaz, O; Karaduman, A; Topaloglu, H. Eur J Neurol. 2004 Aug;11(8):541-4.

66 patients with Duchenne muscular dystrophy who were currently ambulatory were given oral prednisolone 0.75mg/kg every other day and Vitamin D. 22 age matched patients acted as controls. Patients were assessed for muscle strength, walking, and onset of scoliosis. Patients were followed from 1.5-5 years. No patient in the treatment group developed scoliosis, whereas 7/22 in the control group developed scoliosis.

Scoliosis management in Duchenne Muscular Dystrophy: A prospective study of modified Jewett hyperextension brace. Colbert, AP; Craig, C. Archives of Physical Medicine & Rehabilitation 68(5): 302-4, 1987.

This paper describes a prospective study comparing 22 patients with Duchenne muscular dystrophy, 7 of whom were treated with a modified Jewett hyperextension brace while 15 patients served as a control group. Over a period of two to seven years, there was found to be no statistically significant difference in the rate of curve progression between the two groups. The authors concluded that while the use of a brace may minimally slow the rate of progression, bracing does not ultimately prevent significant curves.

Scoliosis associated with Duchenne Muscular Dystrophy. Drennan, JC; Cambridge, W. JPO 7(4): 436-40, 1987.

A review of the pathoanatomy and natural history of scoliosis in 105 patients with Duchenne type Muscular Dystrophy found that orthotic management failed to halt curve progression. Thirty of 32 patients (92%) had curve progression despite bracing, 14 of whom underwent spine fusion surgery.

Other Syndrome Related Scoliosis:

Results of brace treatment of scoliosis in Marfan syndrome. Sponseller, P.D.; Bhiman, I.M.; Solacoff, D.; and Dormans J.P. Spine, 25(18):2350-2354, 2000.

This study reports the results of 22 patients with Marfan's syndrome with curves of 45 degrees or less, Risser sign 0-2, recommended brace of 18 hours or more per day, and follow-up until maturity or surgery (minimum 2 years). The mean age of inception or bracing was 8.7 years (range, 4-12 years). Although initial correction of the curve in the brace was good (45 %), only four of the patients had success. In 20 of 24 patients treatment was considered a failure. The mean progression was 6 degrees (+ 8 degrees per year) for a final curve measurement of 49 degrees. Sixteen of the patients had or were advised to have surgical correction. The difference in age and degree of curvature was not statistically significant between the success and non-success groups. The authors concluded that physicians should expect that most patients with Marfan syndrome with curves of 25 degrees or more and a Risser sign 2 or less will reach the surgical range even with brace treatment.

Orthopaedic manifestations of familial dysautonomia- Bar-On E., Flowman Y., Sagiv S., Katz K., Pollak R., Maayan C.; J. Bone Joint Surg. 82A:1563-1570, 2000.

This useful article outline the orthopaedic problems associated with this rare condition. It confirms the high prevalence (86%) of scoliosis and kyphosis, the high progression rate and the poor compliance with bracing that leads to failure. Instrumentation did poorly in correcting kyphosis. Furthermore, post-op curve progression and operative complications were common.

Spinal deformity in familial dysautonomia- Hayek S., LaPlaza J., Axelrod F., Burke S.; J Bone Joint Surg. (82A): 1558-1562, 2000.

Retrospectively reports on a rare syndrome, Riley-Day or familial Dysautonomia to determine prevalence of scoliosis and effectiveness of bracing. The results show 83% of 123 patients reaching twenty years of age developed scoliosis (25% also had kyphosis). Furthermore, of 65 patients that were braced, 89% progressed 4-5 degrees per year. Bracing was with Milwaukee in all but 9 who had TLSO. Authors still recommend bracing for progression above 20 degrees.

SCHEUERMANN'S KYPHOSIS

Orthotic results in adolescent kyphosis. Gutkowski, WT and Renshaw, TS; Spine 13: 485-89, 1988.

This study reviewed the results of treatment with either a modified Milwaukee brace or a Boston lumbar orthosis in 52 adolescent patients with kyphosis, 41 having Scheuermann's kyphosis and 11 with juvenile roundback deformity. At an average follow-up of 2 years out of the brace, both groups had about a 30% correction of their pre-brace deformity. Compliance was significantly greater in those patients managed with the Boston orthosis, although there was no significant difference in those patients wearing the brace 23 vs. 16 hours per day.

Scheuermann's kyphosis. Follow-up of Milwaukee brace treatment. Sachs, B; Bradford, D; Winter, R; Lonstein, J; Moe, J; and Willson, S. JBJS Jan 69-A: 50-57, 1987.

A review with long term follow-up of 120 patients treated with a Milwaukee brace for Scheuermann's Kyphosis. Patients wore the brace for an average of over 2 years, and the majority (69%) had correction of their deformity at an average of at least five years out of the brace.

Classic Paper:

Scheuermann's kyphosis and roundback deformity: results of Milwaukee brace treatment. Bradford, DS; Moe, JH; Montalvo, FJ; and Winter, RB. JBJS 56-A(4): 740-58, 1974.

This is a review of 233 patients with kyphosis, of whom 168 had Scheuermann's kyphosis and 75 completed treatment with a Milwaukee brace. After an average of 34 months in the brace, these patients showed an average improvement of 41% in their kyphosis and 36% in their lordosis.