The Evolution of Scoliosis Treatment

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Abstract

The complications of scoliosis have been apparent to mankind for centuries, and as a result there have been numerous attempts to reduce and correct the spinal deformity associated with scoliosis. Scoliosis is a three dimensional deformity of the spine with 70% of the cases classified as idiopathic [2]. The most common presentation of idiopathic scoliosis is a rotatory scoliosis with a right thoracic convexity, which is more prevalent among the female population [1]. Traditional medical treatment of scoliosis has been observation from 10° to 20°, bracing from 20° to 40°, and surgical intervention when the curve progresses above 40° [11]. However, this treatment regiment appears to be unsatisfactory, and a new protocol that addresses curves at a lesser degree is warranted. Chiropractic has a strong representation through case studies proving its effectiveness in managing scoliosis. However, there are differing treatment protocols including full spine diversified and chiropractic biophysics, to mention only two, which are both evaluated in the context of this paper.

Key terms: Scoliosis, Chiropractic, Treatment, Biomechanics.

Introduction

Mankind has always recognized the detrimental effects of scoliosis to the human frame, and since the early times of Hippocrates there have been methods developed to correct abnormal curvatures of the spine. For Example, Paul of Aegina; in the seventh century, tried bandaging deformed torsos to splints, and in 1852, Ambroise Paré instructed armorers to forge cuirasses that were molded to fit the trunks of scoliosis patients[6]. Later in 1914 the first spinal fusion for scoliosis was performed by Russell

Hibbs, and in 1946 the Milwaukee brace was developed by Blount and Schmidt [6] in Milwaukee, thus giving rise to the name of the popular brace. Although the majority of early methods developed had little lasting effect, it is evident that great strides have been made in the diagnosis and treatment of scoliosis throughout the past centuries. However, even with these great advances in treating spinal deformities, the management of scoliosis continues to be a formidable challenge for any health care provider.

The term scoliosis can be traced back to Hippocrates and the Greek word *skolios*, which means twisted or crooked [1]. The medical literature has defined scoliosis as a complex three-dimensional deformity of the spine, with more than 70% of the cases diagnosed in the category of idiopathic scoliosis, which means the cause of this abnormality is unknown [2]. Further definition of idiopathic scoliosis classifies it as a lateral curvature of the spine with vertebral rotation in the absence of any congenital spinal anomaly or musculoskeletal condition [3]. An understanding of the three-dimensional nature of the scoliotic spine is essential in attempting to grasp the etiology of such a disorder. For instance due to the three-dimensional nature of the deformity, uniplanar measurements may be misleading. It has been demonstrated that the true anteroposterior magnitude is up to 41% greater than that measured from an A-P projection [3]. Therefore the three-dimensional nature of idiopathic scoliosis not only makes it difficult to diagnose and characterize, but also difficult to treat and correct.

Most experts agree that scoliosis is a lateral curvature of the spine with a rotational component; however, there continue to be very differing views on the etiology of this spinal deformity. Generally experts within the chiropractic field state that scoliosis is a result of structural and biomechanical insufficiencies. Coggins states that

the initiating factor in the rotatory scoliosis is an unequal support affecting the plane of the sacral base, which may be due to leg length deficiency or sacral subluxations [4]. Barge states that the lack of development of the secondary curves predisposes a child to scoliosis [5]. Furthermore, that the normal development of these secondary curves is hindered by activities of developing children from infancy through adolescence. According to Barge there are major causes of scoliosis which include the lack of development of the secondary curves particularly the lumbar curve, youth exercises that stress backbends found in gymnastics and ballet, vertebral subluxations, unilateral sacral inferiority, and a disturbance in the righting reflex or the proprioceptive spinal balance mechanisms which are commonly caused by cervical vertebral subluxations [5]. Others contest that scoliosis is more of a genetic disease. Reports show a 25% to 33% reoccurrence among relatives; and there are some reports of even 3 to 4 times that involving first degree relatives to children of unaffected parents [3]. Another study noted that the occurrence increased to 40% when both parents were affected [3]. This genetic predisposition may be one of a biomechanical factor that allows the mechanics of scoliosis progression to occur [3]. Another view point is that the primary cause of idiopathic scoliosis is due to a dysfunction of the brainstem, possibly a lesion to the posterior columns or the inner ear creating a neuromuscular imbalance [4]. There are still further studies that have found a possible link with low serum melatonin levels in adolescents and the progression of idiopathic scoliosis [7,8]. Regardless of the differing beliefs as to the initial contributing factors that cause idiopathic scoliosis, it can be agreed upon that the process is a result of a loss of the normal biomechanical stability of the

spine creating a decrease in the saggital curves, which in turn causes an axial rotation of the spine resulting in a lateral deviation of the spine.

There are numerous ways that scoliosis may appear in the spine, and the prevalence and rate of progression has been linked with certain forms of idiopathic scoliosis. The most common form of scoliosis is adolescent idiopathic scoliosis and affects approximately 2-3% of the total population in the age range of 10 to 16 [9]. Within this category females are the highest percentage that is affected with a ratio of 9 to 1 over males [1]. It has always been assumed that the most critical time for progression is during periods of rapid growth; however, the question remains what creates such a great predominance among adolescent females when both sexes experience periods of rapid growth during this age range. One explanation incorporates biomechanical factors such as curve, severity, curve length, tissue properties, and general stability of the spine as key aspects of curve progression. A significant biomechanical factor that has been presented is that spinal curves in the median plane change during growth, and normally the thoracic kyphosis reduces in size from the age of 8 to 12 years, reaching a minimum at about the age of 12[3]. This reduction in the thoracic kyphosis happens at the same time in both boys and girls which demonstrates its independence from growth velocity. Boys on average mature 2 years later than girls in respect to when they experience there peak growth velocity which is typically around the age of 14[3]. Girls on the other hand, are going through peak adolescent growth velocity at the age when the thoracic kyphosis is at its minimum, which may help explain the greater progression potential in girls. Boys are experiencing the minimum thoracic kyphosis when their growth velocity is constant and

therefore more stable [3]. In general there are certain curves that are more prevalent and lead to greater rates of progression.

A relatively common finding among those with a developing scoliosis is a lateral wedge deformity of the vertebral body. This irregularity is a result of impaired growth at the disco vertebral junction on the concave side of the curvature because of excessive compressive forces which is known as the Heuter-Volkmann principle [1]. In general the most frequent curve pattern is the right convex thoracic type, with three other curves that present regularly which are right thoraco-lumbar, a left lumbar, and a combined form of left lumbar and right thoracic[1]. A study showed that thoracic curves are not only the most prevalent but that they also progress more than lumbar curves, and lumbar more than thoracolumbar, and thoracolumbar more than double major curves[10]. Furthermore in one study conducted in Greece, none of the left thoracic curves evaluated in the study showed any progression over a 3.2 year follow up period, while the incidence of progression of right thoracic curves was 22% [18]. In addition, both boys and girls with a right thoracic curve demonstrated a high incidence of progression 17.6% and 23.2% for boys and girls respectively [18]. On the other hand, while girls with right and to a lesser extent those with left thoracolumbar curves showed a higher incidence of progression than boys, boys with right lumbar curves demonstrated a higher incidence of progression 27% compared to just 10% by girls [18]. Therefore, it is obvious that there is a significant relationship between curve pattern and progression of idiopathic scoliosis.

It has been contested from a biomechanical viewpoint that scoliosis is caused by asymmetrical growth of the spine and affected by mechanical stress; suggesting that buckling and bone modeling may be responsible for inducing scoliosis and its

progression [2]. The fourth buckling mode has been shown to match the clinical characteristics associated with the thoracic type of idiopathic scoliosis which is the most prevalent and has the highest percentage of curve progression [2]. The fourth buckling mode occurs when the first, second, and third buckling modes are prevented; it is also the only one that can not be corrected by the body through postural changes [2]. Unlike the first three buckling modes, the fourth buckling mode, which is the second side bending mode, has its maximum displacement in the thoracic spine region, where there is no major muscle with the potential to control local curvature [2]. An analysis using a symmetric mathematical model for the laterality of the thoracic curve demonstrated an equal probability for curves to the right or to the left based upon the buckling phenomenon[2]. However the human body is an asymmetric structure with the heart located on the left side of the thorax causing a slight right shift in the thoracic spine, and this irregularity is believed to cause the predominance of the right scoliotic thoracic curve[2]. In fact, if a left convex thoracic curve is present it should always be evaluated further with the use of x-ray, as they are commonly associated with tumors such as osteoid osteoma, osteoblastoma, and aneurismal bone cyst [17]. There is no doubt that scoliosis is a serious condition that must be managed, and there are various approaches in dealing with the correction of idiopathic scoliosis including, bracing, surgery, and chiropractic adjustments all of which will be considered within this paper.

Discussion

The detection and categorization of idiopathic scoliosis is fairly universal within the arena of health care. The diagnosis of scoliosis is first suspected by the presence of

body asymmetries such as alteration in the patients shoulder height, scapular prominences, chest prominences, and decompensation by plumb line from C7 [17]. For instance, a patient with a typical right thoracic scoliotic curve, when viewed from the posterior, would present with a lower left shoulder, a right prominent scapula, and the thorax is shifted to the right with a decrease distance between the right arm and the thorax [17]. This shift in the thorax creates an alteration in the waistline which produces an apparent shift in the iliac crest causing the left crest to appear higher [17,18]. Rotational asymmetries are noted on the Adam's bend test, which is accomplished by having the patient bend forward at the waist standing with the feet together and knees straight. A patient with a typical right thoracic curve will produce a right thoracic prominence or rib hump revealing the rotational component of the scoliotic curve [17,18]. The final step to confirm a diagnosis of scoliosis is an x-ray of the spine.

To define a lateral deviation of the spine as a structural scoliosis, according to the Scoliosis Research Society criteria, there must be at least a 10° curve, as measured by the Cobb angle, present on an upright x-ray of the spine [18]. In order to not miss any curvatures and to be able to assess skeletal maturity, it is recommended to take a full spine radiograph that includes the entire spine as well as the iliac crests [17]. The Risser Sign is an indicator of spinal maturity used to assess the likelihood of curve progression in adolescent idiopathic scoliosis. Risser Sign looks at the gradual extension in excursion of the iliac crest epiphysis which is graded in quarters, 1+ (25%) through 4+ (100%) [1]. When the epiphysis fuses to the ilium it is graded a 5+ [1]. The pattern of formation and closure parallels the formation and progression of the scoliosis, with the greatest likelihood of curve progression prior to the appearance of iliac epiphysis [1]. A Risser 4

in females and a Risser 5 in males usually signals the end of curve progression [1]. Furthermore, supine lateral bending films into the convexity are taken to show flexibility, and the degree of flexibility is directly related to the likelihood of progression.

Some experts argue that only large curves associated with idiopathic scoliosis produce problematic symptoms; however, any degree of spinal deviation creates a cascade of events that ultimately creates biomechanical and physiological disturbances. Larger curves are associated with cardiopulmonary problems; as the degree of the lateral curvature increases, rotational coupling occurs resulting in narrowing of the thoracic cavity [11]. Restricted rib cage movement and lung volume ultimately produce pulmonary hypertension with subsequent right and left sided congestive heart failure [1]. Congestive heart failure is the single most common direct cause of death in the patient with scoliosis, and altered lung ventilation predisposes the patient to pulmonary infection and dyspnea[1]. Furthermore, as a patient ages the curve can continue to progress, and as the curve progresses the amount of pain associated with the abnormal curve will also progress [11]. In addition, the loss of disc height, osteophytes, and intersegmental instability frequently accompany adult scoliosis and occasionally adolescent scoliosis [1]. These degenerative changes are typically more pronounced on the concave side of the scoliosis and extend to involve other stressed articulations, including costotransverse, sacroiliac, and hip joints [1].

These degenerative changes can be explained by a physical property known as piezoelectricity, which is known as pressure electricity, and alters the electrical charge of molecules due to stress [20]. The principles associated with piezoelectricity state that the side of tension (convex side) develops an electropositivity and the side of compression

(concave side) develops an electronegativity [20]. The reason for greater degeneration on the concave side of a scoliosis is that osteoblastic activity is stimulated by electronegative surfaces and osteoclastic activity is stimulated by electropositive surfaces [20]. Furthermore, it has been shown that the electrical fields produced by bone while under asymmetrical stress, such as that produced from scoliosis, are at a resonant frequency of the surrounding nerves [20]. These abnormal electrical fields produced by bones under stress, interfere with nerve transmission in two key areas, by affecting the spinal cord directly and by affecting the spinal nerve roots before and after they exit the intervertebral foramen [20]. Therefore not only does scoliosis produce biomechanical disturbances, but it also promotes bone deformation and nerve interference.

It is obvious that scoliosis is a real problem facing society today, and the public's changing attitude towards health risks associated with the disorder has lead to a reevaluation of current treatment protocols. The typical procedure in the medical community has been once a scoliotic curve is detected to monitor progression of the curve, and at 20° to 40° recommend bracing and at 40° to 60° recommend surgery[11]. However, it has been shown that for the majority of patients, this practice is simply not working. In one group of patients who were assigned to wear braces, 50% refused to wear them, and 50% of those who were recommended for surgery refused that procedure as well [12]. Further studies show that even those patients who agreed to wear the brace did not necessarily benefit. Evaluating the Milwaukee brace specifically it was concluded that a slight but statistically insignificant trend was found, suggesting that bracing idiopathic scoliosis curves with Cobb measurements from 15° to 30° reduces the probability of curve progression [11]. Furthermore, three fourths of the untreated curves

did not progress; suggesting, in retrospect, that a similar proportion of the braced curves did not need bracing [11,14]. In addition, Brace failure occurred in 5% of the braced patients who had a mean progression of 8° per year [11]. Therefore the results do not clearly support bracing as an effective treatment for curves in the range of 15° to 30°, since most of the curves of this magnitude do not progress anyway[11,14].

Therefore if one considers that the majority of those patients who are recommended to be braced would not benefit from it since they are unlikely to progress which is the intended purpose of bracing. Furthermore, those patients who do progress are unlikely to reduce the rate of progression by using the brace; the end result for patients with progressive curvature of the spine in the medical protocol is ultimately surgery. One study that evaluated the use of the OSI frame on operative scoliosis patients revealed that the OSI frame tends to decrease thoracic kyphosis and increase thoracolumbar lordosis, both of which destabilize the spine and lead to early degeneration and loss of function [13]. In another study the complications of spinal fusion for scoliosis were evaluated. It was determined that a loss of the lumbar curve as a complication following the surgical treatment of scoliosis leads to a debilitating condition known as "flat back syndrome", which is characterized by back pain, forward inclination of the trunk, and an inability to stand erect [15]. It has been shown that complications of surgery on an adult patient with scoliosis are relatively common, occurring from 30% to 53% of the time [16]. Patients with scoliosis who undergo surgery are at risk for epidural anesthesia, and also complications as serious as a subdural hematoma have been reported, which in one case resulted in paraplegia [16]. Therefore not only is surgery to correct

progressive scoliosis incredibly invasive and associated with numerous risks, but even when "successful" can lead to further complications later in the patient's life.

Thus a new protocol for management of scoliosis is desperately required not only to help prevent progression to the extent warranting surgery, but also to help reduce smaller curves which some contest to be unproblematic. Even though it has largely gone unrecognized within the medical literature on scoliosis treatment, chiropractic has long reported to offer significant changes on scoliotic spines. There are numerous case studies that illustrate the effectiveness of chiropractic treatment on diminishing the severity and musculoskeletal discomfort associated with idiopathic scoliosis.

In a single case, a 45 year old male patient presented with a right thoracic scoliosis extending from T5 to T11 with a Cobb angle of 22 degrees which was first discovered at the age of 20 [4]. A chiropractic treatment regimen, which consisted of high velocity, low amplitude, manipulative thrusts directed towards the hypomobile segments of the spine with special attention to the occipito-atlanto-axial complex, fourth cervical, seventh cervical, first thoracic, seventh and eighth thoracic, twelfth thoracic, third lumbar, and lumbosacral regions [4]. After following this treatment plan for three months, the patient's Cobb angle measured 16°, which demonstrated a 6° reduction in the right thoracic curvature [4]. Another case involved a 39 year old woman with a long term history of scoliosis with associated problems, who underwent spinal fusion of T9 through L4 due to debilitating pain from the curve deformity [16]. The patient's condition had continued to worsen following the surgery and 20 years later she again pursued active treatment. After a failed muscle strengthening program, the patient sought chiropractic care as an alternative to spinal fusion of the cervical and thoracic spine estimated to cost

$150,000.00 [16]. Initially the patient received chiropractic treatments 1 to 2 times per week for a 6 to 8 week period; however, due to her chronic habituation and facilitation the patient was referred to a Pilates instructor to help her isolate and balance problem muscle groups [16]. One year after starting her chiropractic treatment the patient was beginning to stabilize and increase her physical activity, and continued to improve with every visit [16]. There is an obvious rational for chiropractic treatment of idiopathic scoliosis due to the effectiveness shown in specific case studies; however, it is also important to understand the protocol of chiropractic treatment and why it is effective in managing scoliosis.

Traditional chiropractic management of idiopathic scoliosis focuses on returning normal motion to fixated joints, as well as bringing the sacral base into a level plane, in order to reduce and possibly correct spinal curves associated with scoliosis. According to Barge, the disc block subluxation is a primary contributor to scoliosis [5]. The disc block subluxation occurs when weight is shifted from the normal "tripod theory" of weight bearing, where the weight is distributed on the facets and posterior elements of the body, to the nucleus instead [5]. The inordinate pressure on the nucleus of the discs makes the discs prone to lateral and posterior bulge creating the disc block subluxation [5]. In addition to the normal A-P radiographs taken to evaluate scoliosis, there is another view used to evaluate scoliosis known as the hanging A-P x-ray which eliminates weight bearing on the spine [19]. The extent of change from the weight bearing A-P film versus the hanging A-P film illustrates the areas of disc block subluxation, and indicates the maximum degree of correction that can be obtained with proper chiropractic techniques [19]. Manipulation or chiropractic adjustments cause movement within the structure upon

which the force is applied [4]. The movement could possibly apply the stress needed to realign collagen tissues, disrupt fibrous tissue adhesions and joint constrictions, and move fibrotic synovial tabs in the facet joints [4]. The majority of chiropractors treating scoliosis use a form of full spine diversified technique with heel lifts and exercises as a possible adjunct. Barge recommends the use of a knee chest or hi-low table [5]. Furthermore, he states that chiropractors normally use heel lifts to reduce inferiorities that in turn cause or have caused adaptive change, such as scoliosis [5]. The majority of support for chiropractic care is derived from individual case studies; however, one clinical trial evaluated the effectiveness of chiropractic intervention in the management of adolescent idiopathic scoliosis.

In 2001 Lantz published a study that evaluated the effectiveness of chiropractic in managing scoliosis in curves under 20 degrees. The study consisted of 42 subjects in the age range of 6 to 12 years, and curves ranging from 6° to 20° [12]. Full spine diversified and Gonstead adjustments for one year was the primary form of treatment, with heel lifts and postural counseling used as well [12]. Lantz concluded from his study that full spine chiropractic adjustments with heel lifts and postural and lifestyle counseling are not effective in reducing the severity of scoliotic curves [12]. The study was limited in that it only evaluated a single chiropractic treatment protocol; there are other methods of chiropractic treatment that are utilized in the management of idiopathic scoliosis.

Chiropractic Biophysics developed by Don Harrison incorporates the three dimensional aspect of idiopathic scoliosis in order to reverse and correct the spinal deformity. The principle of this approach is based on a basic theorem in physics that the movement of any object can be decomposed into a translational movement, a rotational

movement, and a deformation [20]. Consider that the discs, ligaments, central nervous system, and muscles to be deforming while the vertebrae are rigid bodies, then main motions and coupled motions of vertebrae can be described as rotations and or translations in three dimensions [20]. Another property that is crucial to understanding the mechanics of scoliosis is the non-communative property of finite rotation angles. All patients with true structural curves have a thoracic lordosis hidden in a three dimensional curve configuration [21]. Therefore the initial step is to force the spine towards a more normal kyphotic configuration by the main motion of posterior thoracic translation [21]. Taking out the other components will be experimental until the proper order of the coupling pattern is determined. First with an uncompensated scoliosis, that is a right or left thoracic translation; reverse the presenting posture [21]. If there is a lateral flexion of the thoracic cage, then reverse this posture [21]. Due to the principle of non-communative property of finite rotation angles, the patient's posture alone is not going to give a clear representation as to the order of coupling patterns that produced the existing scoliosis. Therefore, if one component at time is reversed and imaged through an x-ray, beginning with posterior translation, the proper order can be established [21]. If the Cobb angle reduces then that is the order for reversing the posture of the scoliosis; however, if the Cobb angle remains or worsens the order must be changed [21]. Once the proper order is established, that is the order in which to take out the posture for mirror image adjustments, exercises, and traction [21]. By finding the proper order of the finite rotation angles that create the scoliosis, and reversing the posture through mirror image protocol the degree of the scoliosis can be reduced if not corrected.

Conclusion

There is no question that scoliosis is a serious deformity that affects a significant number of the population and causes harmful and debilitating effects. The treatment and management of scoliosis is continuing to evolve, and greater emphasis must be taken to reverse and correct smaller curves before they deteriorate into a state that requires surgery. It has been shown that as the curve increases in the degree of lateral curvature, there is a natural tendency for the curve to progress due to the principle of the buckling phenomenon.

The problem with early treatment is that there seems to be a discrepancy among health care providers as to the most effective management of lesser degree scoliotic curves. Bracing has been proven to be at best only holding and is never corrective, but still fails to prevent curve progression [3]. Chiropractic has numerous case studies that show successful reduction in scoliosis and increased mobility and quality of life; however there are too few clinical trial studies conducted to prove chiropractic is the best method to reduce and correct scoliosis. The one study presented only shows a limited treatment protocol and does not accurately represent chiropractic as a whole. Additional clinical trials need to be conducted to substantiate the role of chiropractic in the treatment and management of scoliosis.

Ultimately scoliosis is a biomechanical problem deserving a biomechanical treatment, and should be advanced by biomechanical specialists such as chiropractors. The protocol of Chiropractic Biophysics addresses the biomechanical nature of scoliosis; however, clinical trials must be performed in order to validate the procedure as a treatment for idiopathic scoliosis. One thing that appears to be clear is that the future of scoliosis treatment is in the hands of biomechanical specialists such as chiropractors.

References

1. Yochum T, Rowe L. Essentials of Skeletal Radiology: Volume One, second edition. Baltimore, MD: Williams & Wilkins; 1996.
2. Goto M, Kawakami N, Azegami H, Matsuyama Y, Takeuchi K, Sasaoka R. Buckling and Bone Modeling As Factors in the Development of Idiopathic Scoliosis. Spine 2003; 28:364-371.
3. Danbert R. Scoliosis: Biomechanics and Rationale for Manipulative Treatment. JMPT 1989; 12:38-44.
4. Sallahian C. Reduction of Scoliosis in an Adult Male Utilizing Specific Chiropractic Spinal Manipulation: A Case Report. Chiropractic: The J of Chiropractic Research and Clinical Investigation 1991; 7:42-45.
5. Barge FH. "Idiopathic" Scoliosis, Cause Prevention Control Reduction Correction & Analysis through Chiropractic Methods: Volume 3, second edition. La Crosse, WI: Barge Chiropractic Publishing, Inc; 1996.
6. Keim H, Hensinger R. Spinal Deformities, Scoliosis and Kyphosis. Clinical Symposia 1989; 41; No4.
7. Machida M, Dubousset J, Imamura Y, Miyashita Y, Yamada T, Kimura J. Melatonin, a Possible Role in Pathogenesis of Adolescent Idiopathic Scoliosis. Spine 1996; 21:1147-1152.
8. Bagnall K, Raso J, Hiil D, Moreau M, Mahood J, Jiang H, Russel G, Bering M, Buzzel G. Melatonin Levels in Idiopathic Scoliosis, Diurnal and Nocturnal Serum Melatonin Levels in Girls With Adolescent Idiopathic Scoliosis. Spine 1996; 21:1974-1978.
9. Tarola G. Manipulation for the Control of Back Pain and Curve Progression in Patients with Skeletally Mature Idiopathic Scoliosis: Two Cases. JMPT 1994; 17:253-257.
10. Ascani E, Bartolozzi P, Logroscino A, Marchetti G, Ponte A, Savini R, Travaglini F, Binazzi R, Di Silvestre M. Natural History of Untreated Idiopathic Scoliosis After Skeletal Maturity. Spine 1986; 11:784-789.
11. Cox J. Scoliosis. Michigan State Chiropractic J 1985; Nov/Dec:4-10.
12. Lantz C, Chen J. Effect of Chiropractic Intervention on Small Scoliotic Curves in Younger Subjects: A Time-Series Cohort Design. JMPT 2001; 24:385-392.
13. Marsicano J, Lenke L, Bridwell K, Chapman M, Gupta P, Weston J. The Lordotic Effect of the OSI Frame on Operative Adolescent Idiopathic Scoliosis Patients. Spine 1998; 23:1341-1348.
14. Miller JAA, Nachemson AL, Schultz AB. Effectiveness of Braces in Mild Idiopathic Scoliosis. Spine 1984; 9:632-635.
15. La Grone M. Loss of Lumbar Lordosis, A Complication of Spinal Fusion for Scoliosis. Orthopedic Clinics of North America 1988; 19:No2.

16. Blum C. Chiropractic and Pilates Therapy for the Treatment of Adult Scoliosis. JMPT 2002; 25:No4.
17. http://www.vh.org/Providers/Textbooks/AIS
18. Soucacos PN, Zacharis K, Gelalis J, Soultanis K, Kalos N, Beris A, Xenakis T, Johnson EO. Assessment of Curve Progression in Idiopathic Scoliosis. Eur Spine J 1998; 7:270-277.
19. Mawhiney RB. Scoliosis Manual. Oconomowoc, WI: Roberts Publishing Company; 1982.
20. Harrison D. Spinal Biomechanics: A Chiropractic Perspective. Donald D. Harrison & Sanghak O. Harrison; 1998.
21. Harrison D. Lumbar Spinal Rehab, Seminar. Evanston, WY: Harrison CBP Seminars