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Conservative and surgical approaches in the treatment of congenital and degenerative scoliosis

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Abstract

Scoliosis is a diagnosis that affects all ages and all body types. It is becoming increasingly more common among patients due to the advancements in medicine, longer life-span of individuals, and the large stresses placed on the spine. Patients want answers as to what can be done to treat their condition, no matter what the reason for their scoliosis. Many studies explore the conservative and more invasive surgical approaches for prevention, correction, and maintenance of abnormal spinal curvatures. Bracing and surgical approaches are more commonly studied than alternative exercise-based methods; but there is no clear-cut, definitive solution that would be appropriate for every scoliosis patient. This literature review will discuss the most commonly used treatments for individuals with scoliosis with varying etiologies and curve angles.

Scoliosis is characterized by an irregular lateral curve of the spine with rotation of the vertebrae. The spinous processes rotate towards the side of concavity, while the ribs rotate in a posterior direction on the side of convexity1. Scoliosis is defined by a 10 degree lateral curvature (according to the Cobb method) with vertebral rotation on a radiograph of the spine with the patient standing in an upright position[2]. Two to three percent of the population is diagnosed with some type of scoliosis. Scoliosis is classified into two types: structural and nonstructural. Nonstructural scoliosis is easier to resolve than structural scoliosis due to purely lateral curvature; there is no rotational component within the curve. Nonstructural scoliosis includes postural, psychogenic, sciatic, inflammatory, and compensatory scoliosis. Structural scoliosis, however, has a rotatory component and includes congenital, neuromuscular, idiopathic, degenerative, traumatic, and iatrogenic scoliosis. The focus of this review will be on the conservative and surgical approaches for congenital and degenerative scoliosis in the adolescent and adult population.

Congenital, or idiopathic scoliosis, is a curvature of the spine caused from a birth defect leading to improperly formed vertebrae[3]. These defects occur within the first six weeks of embryonic formation. Congenital spinal anomalies can consist of vertebrae that are malformed or vertebrae that are connected to each other. When multiple vertebrae are connected to each other, growth is slowed on that side of the spine. This delayed growth rate compared to the non-joined side of the vertebrae causes the spinal deformity. The most common type of congenital scoliosis, however, is when the shape of the vertebrae is not properly developed. X-ray images show a triangular shaped vertebrae compared to the normal rectangular shape[1]. This triangle-shaped vertebrae has the ability to become wedged within the spine, causing it to tilt to one direction. Over time, asymmetrical weakness of the intrinsic back muscles develops due the abnormal positioning of the spine. This type of tilt can lead to kyphosis, lordosis, scoliosis, or a combination. Pediatric spine surgeons are able to classify how much growth potential may

be in the congenital anomaly. Congenital scoliosis is accompanied by a lower thoracic or lumbar rotational deformity. This rotation is easily detected during forward flexion of the spine.

Degenerative, or static scoliosis, occurs when the wear and tear on a person's spine over time causes asymmetries from the normal curvature. Many factors can play into spinal curvature changes: leg length discrepancy, a hemivertebra, osteoporosis, osteomalacia, or compression fractures. This type of scoliosis is becoming more common due to people living longer, more physical stress placed on the body over many years, and the higher rate of patients seeking medical attention from pain associated with this type of scoliosis. Degenerative scoliosis develops in adulthood due to degeneration of spinal motion segments. This deformity begins as the intervertebral disc starts to deteriorate, with ensuing degeneration and eventual lack of competency of the posterior elements, especially the facet joints. Degenerative scoliosis is observed in more than 30% of elderly patients with no history of spinal abnormalities. The prevalence of a 10º curve is 64%, 10-20º curve is 44%, and >20º curve is 24%. These curves have a 1:1 female to male ratio and have a mean age of 70.5 years at the time of diagnosis[4]. Osteopenia and osteoporosis can contribute to curve progression in an adult patient. Scoliosis curves progress 1-6º per year in the elderly population[4]. Many elderly degenerative scoliosis patients have other spinal changes; kyphosis is very common in conjunction with scoliosis. Asymmetries on the anterior and posterior side of the spinal segments cause forward head posture, rounded shoulders, and significant muscular imbalances at the shoulder girdle, chest, and back.

Adam's sign is indicative of a structural curve and can be observed by having the patient forward flex their spine. A positive Adam's sign shows irregularities and deformity in the spine or ribs upon forward flexion. The distortion of the thoracic spine is called a rib hump. The Adam's Forward Bending Test is used widely with adolescents. Any child with a positive Adam's sign should follow up with X-rays to determine the Cobb angle. The Cobb angle is used to measure and quantify the angle of the curve. On an X-ray, the vertebras with the most tilted endplates are located and a parallel line is drawn to the

highest and lowest vertebral endplates. The angle between these two lines is known as the Cobb Angle for that curve. The Risser Sign is another qualitative measurement used for scoliosis patients to provide information about skeletal maturity. This test uses an X-ray to look at the iliac crest growth plate. The iliac crest growth plate changes from cartilage into bone during maturation and is rated 0 through 5 based upon the stage of growth (0 being cartilage and 5 being complete bone).

Rotoscoliosis is used to describe the side of the spine by detailing how each vertebra is rotated and side flexed in relation to the vertebra below[2].

> With a left lumbar convexity, the L5 vertebra would be found to be side flexed to the right and rotated to the left in relation to the sacrum. The same would be true with regard to the relation between L4 and L5. This rotation, toward the convexity, continues in small increments until the apex at L3. L2, which is above the apex, is right rotated and right side flexed in relation to L3. The small increments of right rotation continue up until the thoracic spine, where the side bending and rotation return to the neutral position[2].

Rotation of the vertebral bodies causes the spinous processes to turn toward the concave side of the curve. Adaptive shortening of the intrinsic back muscles begin to take place on the concave side, while lengthening occurs on the convex side. Scoliosis is named according to the direction and level of the apex of the curve.

Treatment goals for patients with scoliosis include reversing curvature magnitude and/or preventing curvature progression, pain, and pulmonary dysfunction. Clinical outcome surveys reveal that the majority of scoliosis patients suffer from pain. One large, controlled survey interviewed young adults 10 years after their diagnosis of scoliosis and 1178 reported a significantly higher incidence of pain,

compared to the 1217 control subjects. Of the scoliosis patients, 23% described the pain as "horrible, excruciating, distressing", compared to 1% of the control group[5]. The magnitude of pain in adult scoliosis patients has been found to be inversely proportional to curvature flexibility. Other factors associated with pain include regional instability, balance, and pathological mechanical loads on the spine[6]. Asymmetrical loads on the spine continue to foster further deformity.

Bracing of a patient is warranted primarily with a child or adolescent with progressive idiopathic scoliosis that has a curve between 25 and 40 degrees[7]. Bracing does not generally correct a curve, but it keeps the curve from progressing as the patient continues to grow. Physicians can easily keep track of a patient's curve and bracing has shown to slow down that progression throughout the skeletal maturation years. Elderly patients with scoliosis may also be braced for correction of co-existing spinal deformities, such as kyphosis. A TLSO (thoracolumbosacral orthosis) may also help with pulmonary function by keeping the patient more extended, but does not ultimately correct the scoliosis in an adult.

The Milwaukee Brace was the first modern brace designed for treating scoliosis in 1945, with final revisions completed in 1975. It is used today for high thoracic curves. Metal bars placed in the front and back of the brace extend the length of the torso and are attached to a form-fitting plastic pelvic girdle. A throat mold or ring encircles the neck. Straps attached to metals bars hold pressure pads, which are precisely placed depending on the individual's curve pattern. While the bars hold the body erect, the neck ring keeps the head centered over the pelvis and the pads push against the curve[7].

> Lonstein and Winter reviewed 1020 adolescents treated with the Milwaukee Brace, with the average time in the brace being 3.8 years, and 54% of the patients had more than two years follow-up out of the brace. Two thirds of the pre-brace curves were between 20 and 39 degrees, and the single right thoracic pattern was the most common, constituting of one third of the cases. The overall surgical rate was 22%, the most

common indications for surgery being an initial response in the brace and then curve increase, or no improvement in the curve with bracing. The surgical rate increased with increasing curve magnitude for initial curves over 30 degrees, and it was also greater in immature patients with a Risser sign of 0 or 1 compared to more mature patients with a Risser sign of 2 or more.[8]

The Boston Brace was a very popular TLSO brace in the 1970's. It was the first brace to utilize symmetrical standardized modules, which eliminated the need for casting. This brace extends from the chest to the pelvis anteriorly, and from the scapulae to the buttocks posteriorly. It is designed to keep the lumbar spine in a slightly flexed position and pads are placed to provide pressure to the curve.

The Charleston Bending Brace was introduced in 1978 and was designed for wear only at night. This brace was molded to the patient to over-correct the curve while they slept. The goals of this brace were to maintain the patient's scoliotic curvatures throughout their growth period and to promote better brace wear compliance. The advantages of this brace are that it allows full, unrestricted skeletal development, allows the opportunity for athletic participation, causes fewer and less severe complications, delayed complications since the brace is worn less frequently, results can be assessed without long-term follow up, and determination to whether the brace is a success or failure can be made earlier[9].

In a study[10] comparing the Boston and the Charleston brace, it was found that the Boston Brace was more effective in preventing curve progression and in avoiding the need for surgery. In a group of 319 adolescent idiopathic scoliosis patients with curves of 36-45 degrees, 83% of patients wearing the Charleston Brace had a curve progression of more than 5 degrees compared to only 43% of patients wearing the Boston Brace.

Bracing is a very important component in the correction of scoliosis with growing children and adolescents. It is a conservative way to help reduce any further progression of the curve without having to turn to an invasive approach right away. Adults are typically not given a brace for scoliosis with hopes of correcting their curve. The vertebrae and spine of an adult is not as malleable and is already set in a fixed position, as compared to growing children.

Physical therapy and exercise may be done in conjunction with bracing to facilitate better results with the brace and less progression of the curve. A licensed physical therapist is able to conduct an individual evaluation and needs assessment, measure the patient's strength and flexibility, and evaluate such aspects as body control, dexterity and proprioception. An exercise program is then established to meet the goals of the therapist. Goals of this type of program would be to maintain or increase muscle strength, tone and flexibility, promote correct postural alignment, and to increase the patient's awareness of body position. Sample components of such a program are pelvic tilts, abdominal, gluteal, shoulder girdle, hamstring, hip flexor and pectoral strengthening, as well as diaphragmatic and other deep breathing exercises. In a study by Mooney et al[11], the effect of progressive strength training in torso rotation in patients with adolescent scoliosis was tested. Twenty-five adolescents with scoliosis ranging from 15-41 degree curves were treated with a progressive resistance training program for torso rotation. Each patient was treated twice a week until skeletal maturity or documentation of a reduction of their curve was noted. No bracing was done during this time. Each patient started at a resistance of one-third their body weight, and equal resistance was used for right and left rotation. After each patient was able to complete 20 repetitions, resistance was increased by 5%. Eighteen of the twenty-five patients showed a reduction in their curve with this treatment. The average percentage of improvement was 20% and there was a 132.5% increase in strength. This type of approach needs to be consistent and maintain good compliance of the patient. Exercise alone will not correct or prevent the progression of structural scoliosis. However, exercise used in combination with other approaches, such as bracing, have shown to

be favorable[12,13]. Mild to moderate idiopathic scoliosis patients using the Milwaukee brace in conjunction with exercise have shown up to a 50 percent curve correction and nearly 70 percent showed a halt in progression altogether[14,15].

When conservative techniques do not control the progression of the curve, surgical means may be necessary. The type of surgery most beneficial is dependent upon what type of spinal anomaly is present and the progression of the patient's scoliosis. Scoliosis patients are monitored closely by a physician and radiologic studies to determine an accurate assessment of their progression.

Spinal fusion is a procedure that is performed to stop further growth of the spine and prevent further deformity. The joints within each vertebra affected by the scoliosis are removed, and a bone graft is put in place to create one solid piece of bone. Occasionally rods, hooks, and screws may be used to act as an internal support system. Bracing or casting may be necessary after this type of surgery to support the spine as the bone graft heals over 4-6 months. Spinal fusions are not typically recommended for young children due to unpredictability as their spine continues to grow[3]. Typical indications for a spinal fusion to correct scoliosis are patients with a curve between 40º and 70º with the Cobb method, and patients between ages 10 and 21-years old. This age group make good candidates because the vertebrae are usually fully formed and the spine remains flexible compared to older patients. When instrumentation is used during this procedure, it can add a larger angle of kyphosis. Therefore, a patient with less than 20º of kyphosis is ideal[16]. In a study by Betz, Clements, and Balsara, 30 patients (28 female, 2 male) underwent thoracoscopic fusion. The age range was 8-12 years old and 6-9 vertebral segments were fused. The average preoperative thoracic curve was 47.6º (range of 40-58º), with postoperative curve of 15.4º (range of 5-44º). Although this study yielded good results, complications included temporary peroneal palsy, pleural effusion, and hardware breakage.

Other types of fusions are used depending upon the deformity of the patient. Hemi-epiphysiodesis is a surgical procedure aimed at stopping growth on one side of the spine, while allowing

for growth on the other. The growth centers are removed and the spine is fused on the convex side, allowing the concave side to grow. This surgery can be unpredictable in children with abnormally shaped vertebrae. Hemi vertebrae resection is a surgical procedure used with young patients that have misshaped vertebrae. In this procedure the abnormal-shaped vertebra is removed and the segments above and below are fused together. There are more complications, such as bleeding and neurologic injury, with this type of surgery, but good spinal correction is often achieved[3].

A different surgical approach is taken for younger children with scoliosis. Growing rods are designed for children that have not yet fully developed. This type of surgery uses expandable instrumentation, which can control the progression of the scoliosis while allowing for growth of the spine. Expandable rods are surgically attached to the spine to control the patient's scoliosis; and they return for an outpatient procedure every six months to have them lengthened. The follow-up visits are minimally invasive, as the rods can be adjusted approximately one centimeter through a small incision[17]. In a study by Li et al, 11 children with severe scoliosis received dual growing rod treatment. The patients were 2.1 to 10.9 years old, with 8 thoracic curves and 3 thoracolumbar curves averaging 67.64º. After the initial surgery the average Cobb angle was 34.64º, and after the final lengthening there was an angle of 36.82º. Complications during this study were primarily problems with the hardware; three cases of hook displacement, one case of pedicle screw loosening, and one broken rod. None of the patients in this study have finished the whole treatment course of final internal fixation and bone graft fusion.

Scoliosis continues to be a topic of interest among healthcare professionals. This type of spinal deformity tends to come up frequently when further investigation is done for back or neck pain and for postural irregularities. Studies have shown that children with scoliosis with an angle between 25 and 40 degrees are good candidates for bracing. Bracing does not necessarily correct their spine, but ideally it helps to prevent any progression of the angle while the patient continues to grow. Downfalls of this treatment option are most often with compliance. Children and adolescents do not have great success

with wearing their brace as consistently as possible. Non-compliance will certainly skew the outcome of the effectiveness of the brace. If the brace isn't the solution, then surgery may be the next step. Surgical correction of scoliosis has not yet been perfected; there are still incidences of hardware malfunction and complications from it being such an invasive procedure. In the study by Betz, Clements, and Balsara, as well as the study by Li et al, complications involving the hardware were recorded. Bracing the spine and exercise to improve strength are the most conservative options before surgery. The study by Mooney et al, was one of the few studies completed to show the benefits of strengthening the rotational muscles of the trunk. There was not enough concrete evidence, due to lack of research, that exercise alone was beneficial in improving scoliosis. The majority of the studies were based on bracing the patient and proceeding with surgery if there was no halt in the progression of the curve. There was also a gap in the research regarding bracing and exercise for older adults with degenerative scoliosis. In the future, it would be favorable to link evidence that exercise should be used in conjunction with bracing and pre- and post-operative scoliosis patients.

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