Growth Modulation by Means of Anterior Tethering Resulting in Progressive Correction of Juvenile Idiopathic Scoliosis

A Case Report

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The treatment of juvenile idiopathic scoliosis continues to evolve with the search for ways to positively affect the natural history of deformity progression and disability while minimizing treatment morbidity[1]. Traction, bracing, and casting are often the first treatment attempts to control the deformity, although many deformities will progress to surgical intervention[1,2]. The goals of surgical treatment include correcting the deformity, or preventing progression of the deformity, while minimizing morbidity[1]. Currently, deformity correction with instrumentation and fusion is the most commonly recommended and performed surgical intervention[1]. Specific concerns associated with fusion include the cessation of spinal growth over the fused segments[3] (which may negatively affect pulmonary function[4,5]) and the potential for disc degeneration of segments adjacent to a long fusion. Because nonoperative treatment does not control progression in all cases[1,2], the search for alternative treatment of juvenile idiopathic scoliosis is warranted[1,6-12].

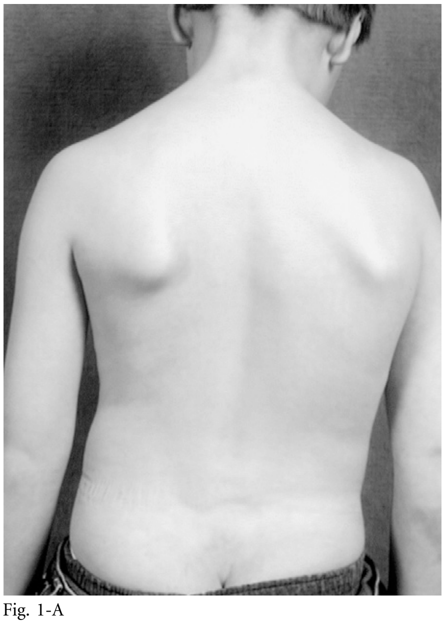

Fig. 1-A

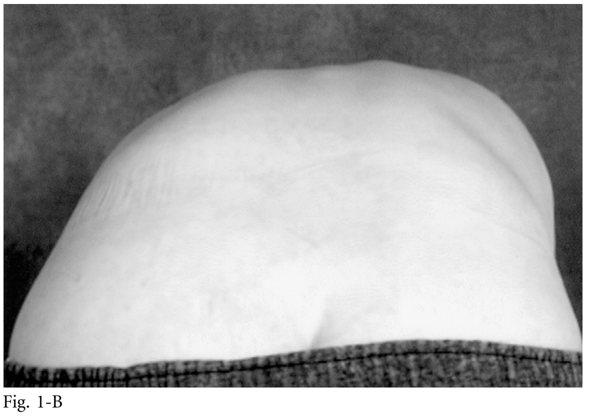

Fig. 1-B

Clinical photographs, made preoperatively (Figs. 1-A and 1-B) and at forty-eight months of follow-up (Figs. 1-C and 1-D), demonstrating correction of trunk shift, shoulder height, and rib hump, with maintenance of global balance.

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Fig. 1-C

Fig. 1-D

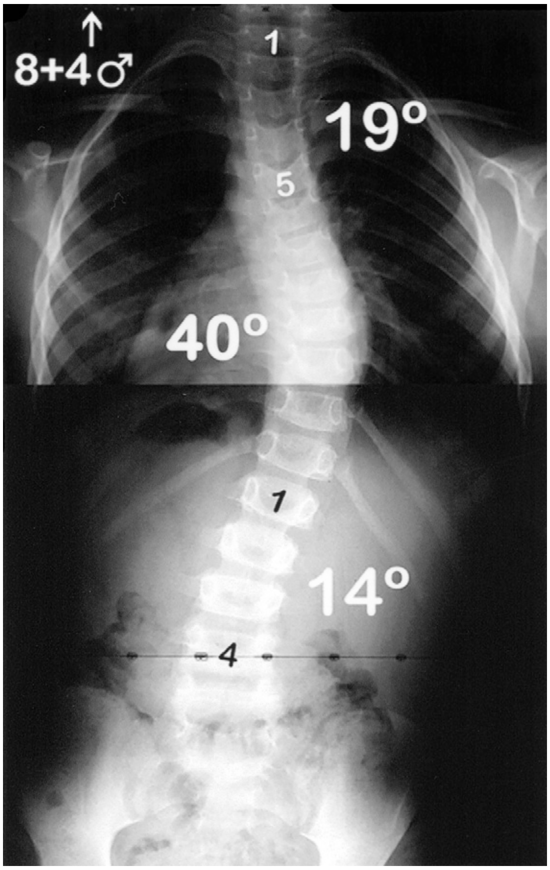

Fig. 2-A

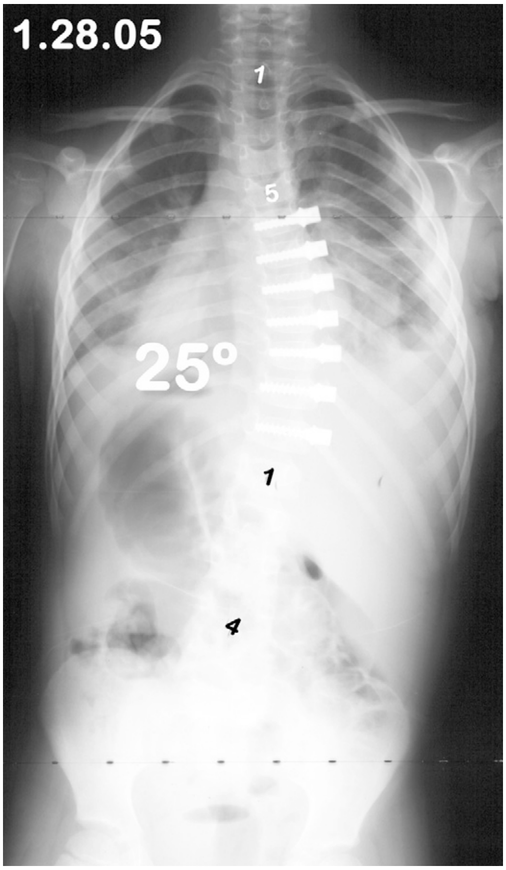

Fig. 2-B

Posteroanterior (Figs. 2-A through 2-G) and lateral (Figs. 2-H through 2-M) radiographs demonstrating a 40° main thoracic juvenile idiopathic scoliosis curve, with the apex at the T9-T10 disc, that progressively corrected over forty-eight months after anterior tethering of T6 to T12. Thoracic kyphosis and lumbar lordosis are maintained within the normal range. Bending radiographs at forty-eight months (Figs. 2-F and 2-G) demonstrate some limited flexibility through the instrumented segments.

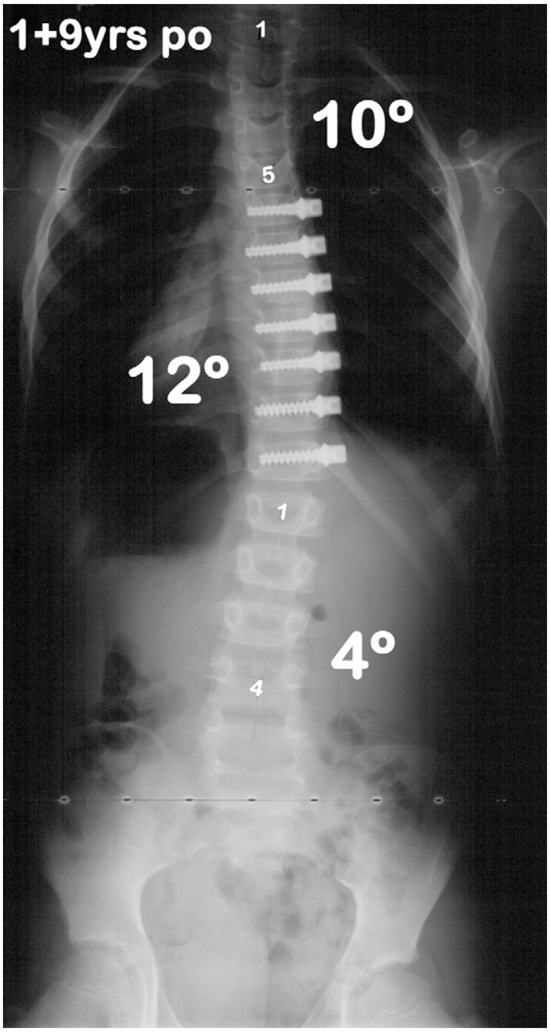

Fig. 2-C

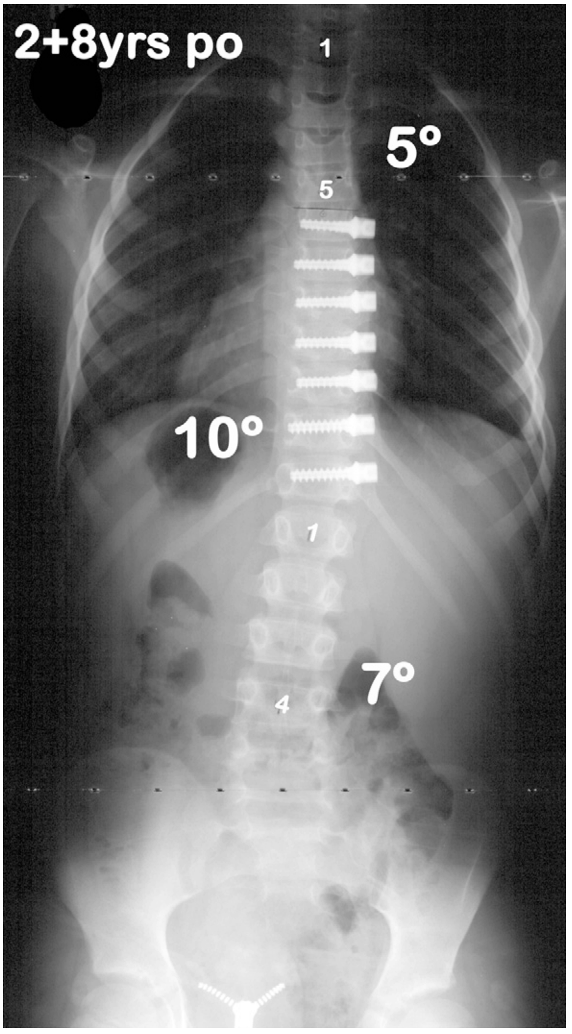

Fig. 2-D

Growth-modulating surgical treatments of scoliosis have interested surgeons for nearly a half century, although initial attempts at growth modulation were abandoned because of disappointing results[13,14]. Advances in surgical techniques and implant technology have renewed interest in fusionless growth modulation for the treatment of scoliosis[6-12]. Reported techniques for human use include posterior growing rods[7] and anterior vertebral body stapling[6,8]. Animal studies and computer simulation models have confirmed that mechanical tethering of the spine can induce and correct scoliotic deformities[15-19]. In the present report, we describe the case of a young boy with juvenile scoliosis in whom anterior tethering resulted in gradual correction over four years. We are not aware of any previous such report in the literature. The patient and his family were informed that data concerning the case would be submitted for publication, and they consented.

TABLE I Radiographic and Clinical Measurements

	Preoperative	Immediate Postop.	Follow-up 21 Months	Follow-up 32 Months	Follow-up 48 Months
Coronal Cobb angle, T5 to L1 *(deg)*	40	25	12	10	6
Sagittal Cobb angle, T5 to T12 *(deg)*	26	14	22	21	18
Standing height *(cm)*	129.9	131.1	139.3	148	166

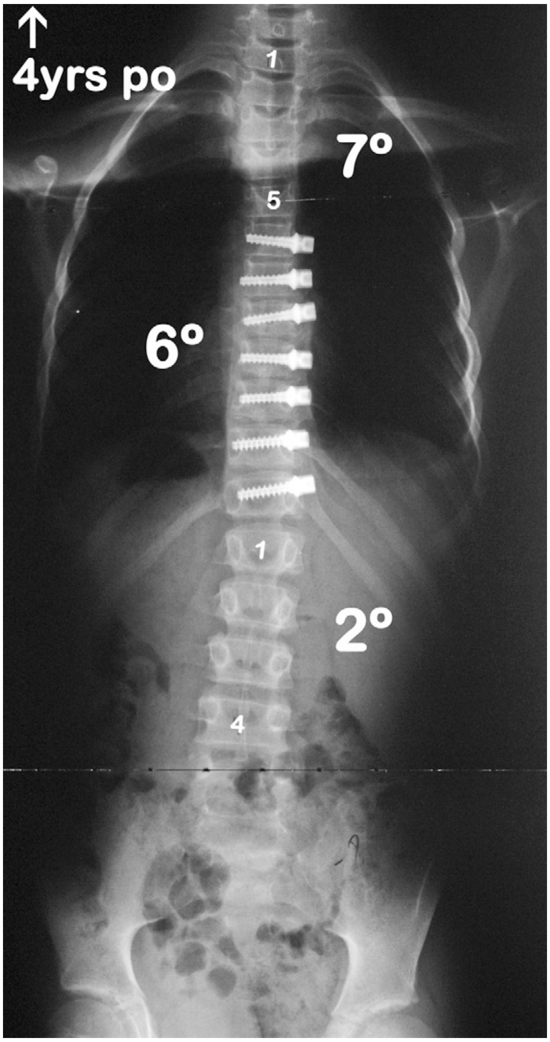

Fig. 2-E

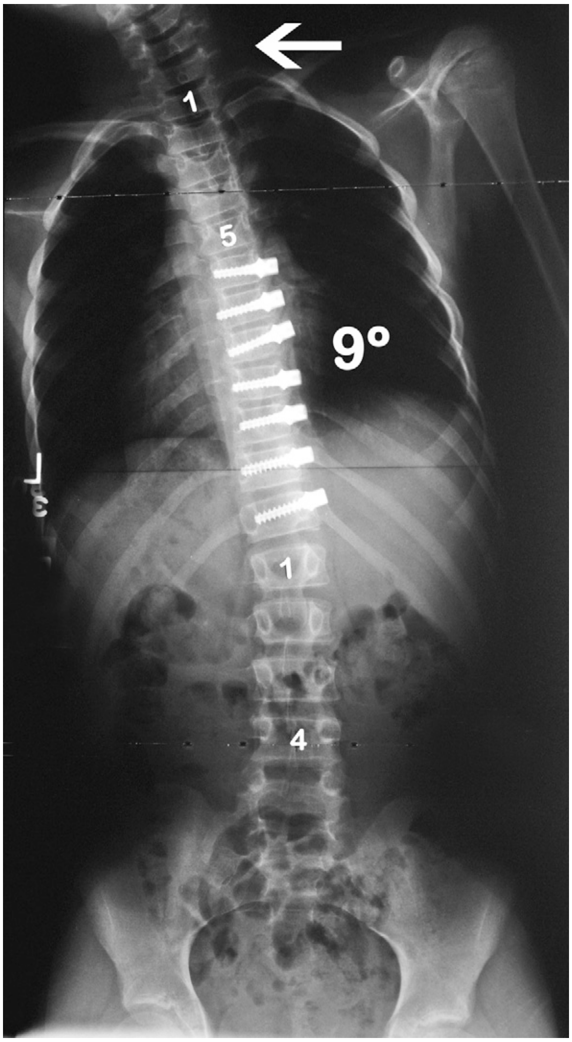

Fig. 2-F

Case Report

A five-year-and-four-month-old boy presented with a 25° right thoracic curve from T6 to T12, with the apex at the T9-T10 disc. The patient was in the ninety-seventh percentile in terms of height (129.9 cm), with an appropriate body habitus (Figs. 1-A through 1-D). He had a right trunk shift with minimum right shoulder elevation. Clinically, the lower limbs were equal in length, with level iliac crests. The abdominal reflex and the findings on the neurologic examination of the lower extremity were normal. On forward-bend testing, the right rib hump was 6° as measured with a scoliometer. There was no hairy patch or sacral dimpling. The medical history included a diagnosis of attention deficit hyperactivity disorder; otherwise, the patient was healthy. There was no family history of scoliosis. A total spine magnetic resonance imaging scan showed a normal neuraxis with no evidence of syrinx, tethered cord, or Chiari malformation, with the conus at L1. Disc spaces had normal signal, and no vertebral anomalies were noted. The patient was diagnosed with juvenile idiopathic scoliosis. Boston brace treatment was initiated, with instructions to wear the brace for twelve hours daily. The patient was followed at regular intervals with serial examinations

TABLE II Measured Changes in Vertebral Height on Radiographs

	Growth Between Upper End Plate of T6 and Lower End Plate of T12 *(mm)*	Growth Between T6 Screw and T12 Screw *(mm)*
Concave side growth	24	22
Central growth	20	11
Convex side growth	16	0

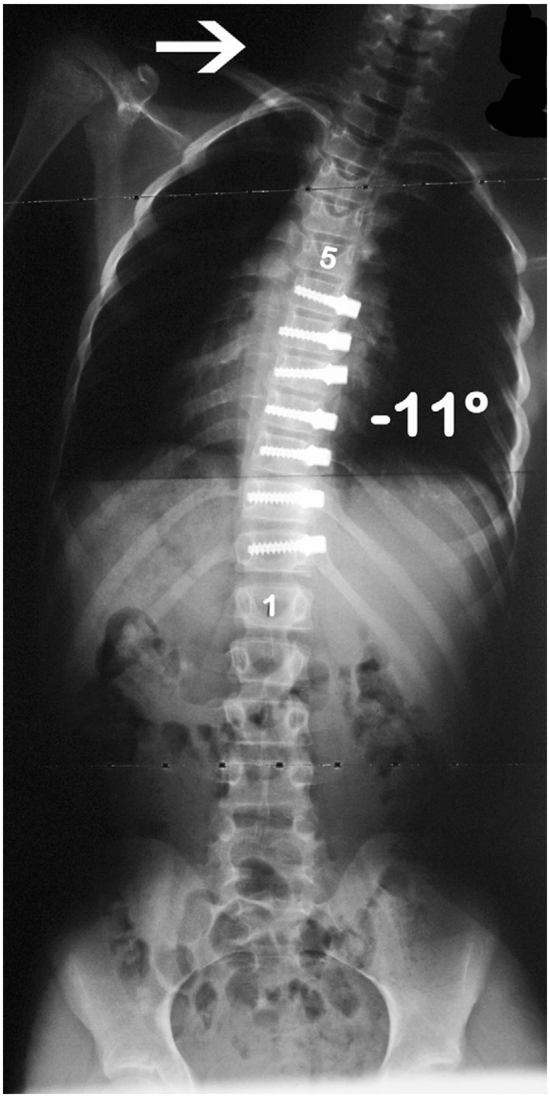

Fig. 2-G

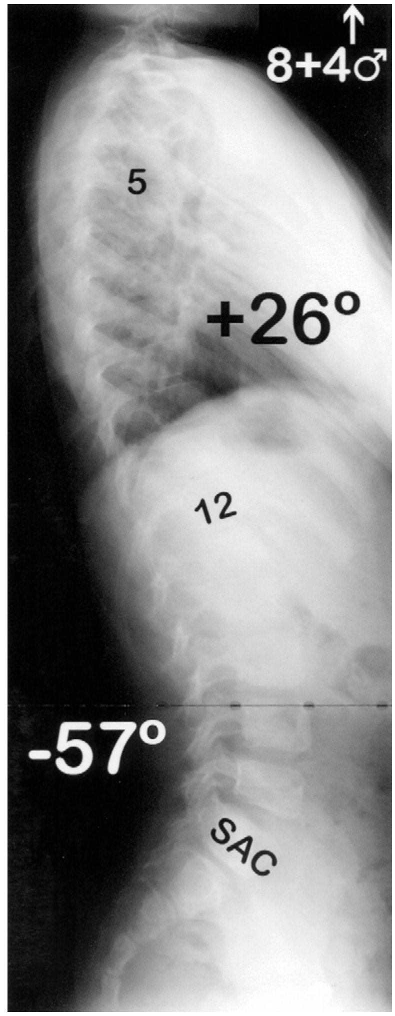

Fig. 2-H

and radiographs. The curve gradually progressed from 25° to 40°, with evidence of vertebral body wedging in the coronal plane and associated rib asymmetry. Surgical intervention consisting of the placement of anterior vertebral body screw anchors attached to a flexible tether from T6-T12 was proposed. The risks, benefits, and alternative treatments were discussed with the family, who consented to surgery.

At the age of eight years and six months, the patient underwent surgery under general anesthesia. An endotracheal tube with a right bronchial blocker was inserted, and the patient was positioned in the left lateral decubitus position with the right side up and the arms in front. After skin preparation and draping, a 2-cm skin incision was made along the sixth rib. With use of a Kelly clamp, the pleural space was entered just rostral to the sixth rib in the anterior axillary line, and the lung was retracted. A more posterior incision was then made along the same rib, and the pleural space was entered. A Kirschner wire was placed in the T8-T9 interspace, and the location was confirmed with fluoroscopy. Because of an unfavorable lung volume-to-chest cavity ratio that made the planned thoracoscopic approach impossible, the posterior incision was converted into a mini-thoracotomy. The segmental vessels were isolated, cauterized, and divided sequentially. Screws were placed at each level from T6 to T12 at the midpoint of the body, just anterior to the rib head, under direct vision. The length of the screws was predetermined on the basis of preoperative radiographs and was assessed after placement by means of palpation. Following the placement of the screws, a 4.5-mm-diameter polypropylene tether was secured into the screw heads with set plugs, starting at the most rostral level and proceeding caudally. Compression was performed with a standard rod compressor, with use of two to three “clicks” to compress the screws prior to locking the tether at each level. A chest tube was tunneled through the anterior incision and was placed at the apex of the lung. A full-length radiograph was made intraoperatively to confirm appropriate instru-

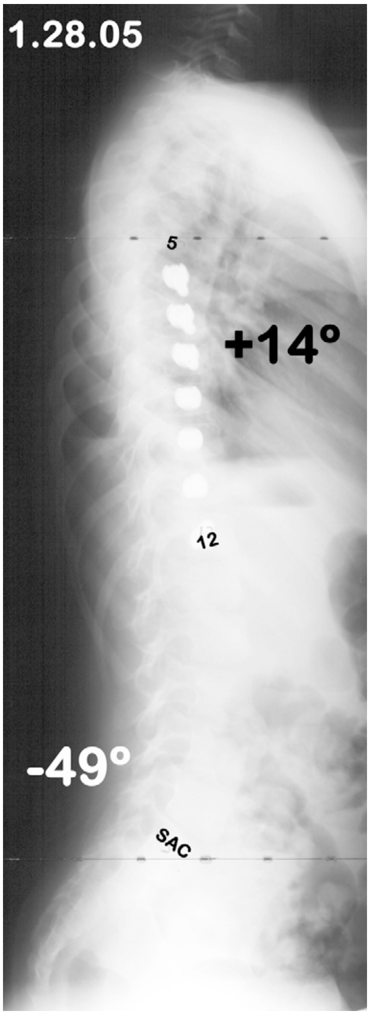

Fig. 2-I

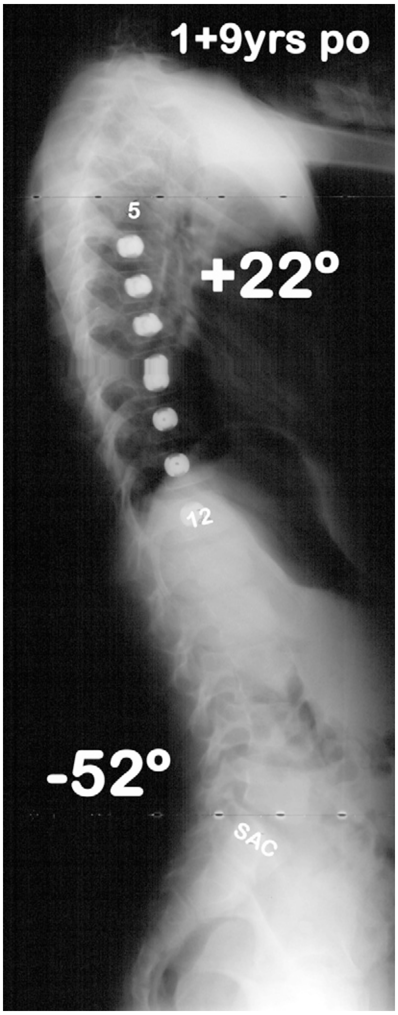

Fig. 2-J

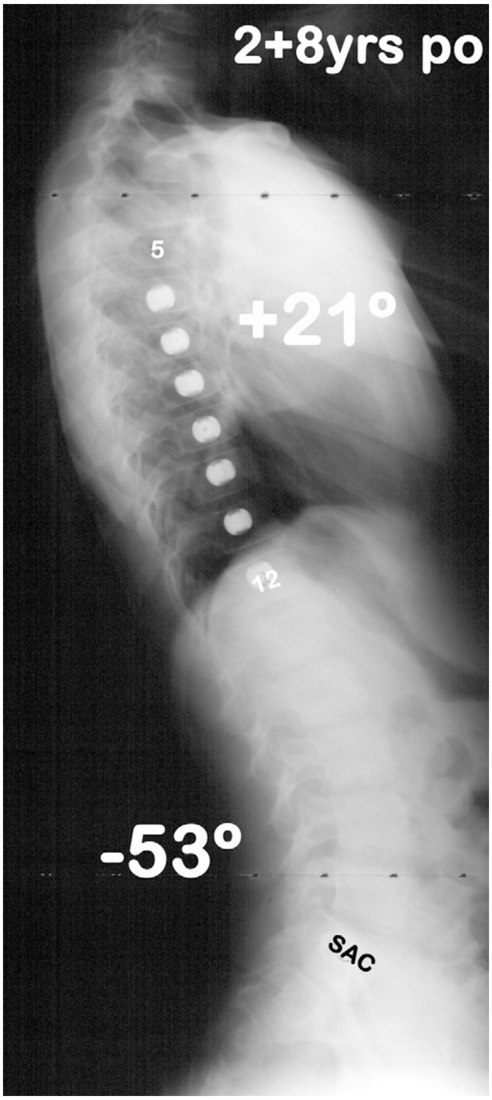

Fig. 2-K

ment placement and spinal balance. Electrophysiologic neuromonitoring was unchanged throughout the procedure, and a wake-up test confirmed intact lower extremity motor function. Postoperatively, the patient stood and began progressive walking on the first postoperative day. No external orthosis was used. The chest tube was discontinued on the third postoperative day, and the patient was discharged on the sixth postoperative day.

Standing full-length radiographs that were made prior to discharge showed an immediate correction of the curve to 25° in the coronal plane. After a period of moderate activity restriction, the patient was released to full activity at three months postoperatively.

Follow-up radiographs and physical examinations at six, twelve, twenty-one, thirty-two, and forty-eight months demonstrated gradual correction of the coronal plane deformity (Figs. 2-A through 2-M and Table I). The patient maintained balance of the shoulder height as well as global balance in both the coronal and sagittal planes. Over the forty-eight months of postoperative follow-up, the total height of the patient increased by 36.1 cm (Table I) and the length of the tethered thoracic spine increased by >2 cm (Table II).

Discussion

The orthopaedic principle of growth plate modulation attributed to the Hueter-Volkmann law[20] states that the rate of growth of a physis can be decreased by compression and increased by distraction. This principle has wide applications in orthopaedics, including its use for the treatment of angular deformities of the limb in growing children[21,22]. There has been substantial work and interest in the use of this biomechanical concept for the treatment of scoliosis in the growing child[6,8,15-19]. Although previous animal studies and computer simulation models have demonstrated the ability of growth modulation to affect scoliotic deformities[15-19], vertebral column growth and modulation is not completely understood in humans[11]. In their review of this body of work, Sarwark and

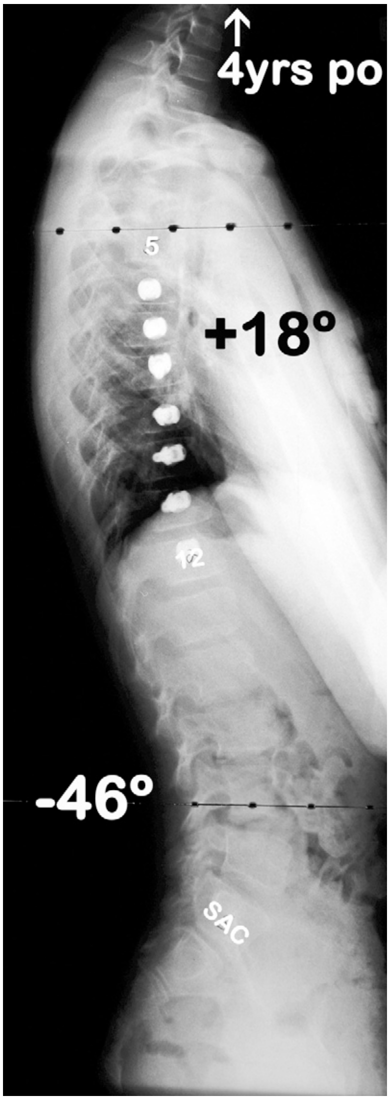

Fig. 2-L

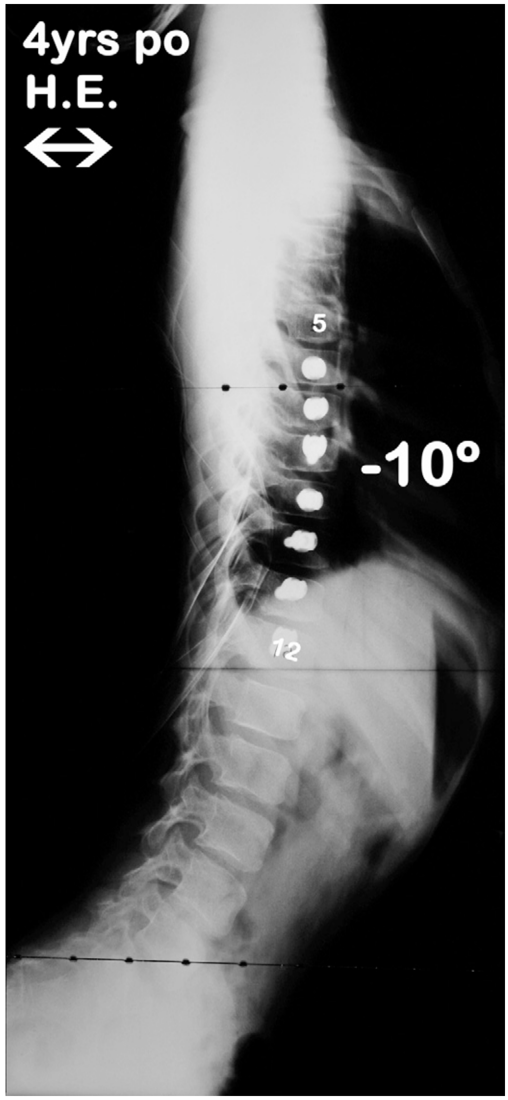

Fig. 2-M

Aubin predicted that growth modulation with appropriately applied forces could obtain 1° to 2° of correction per year per level[11]. In the case of our patient, six segments were tethered and approximately 34° of correction was obtained over a four-year period, resulting in an average of 1.4° per level per year.

According to Diméglio[3] and Winter[4], the predicted shortening of spinal column growth with fusion is 0.7 mm per year per segment. The potential loss of spinal column growth of the six instrumented segments in this case over four years would be 16.8 mm. Using a string to measure the curved distances, we observed 2 cm of growth between the central upper end plate of T6 and the central lower end plate of T12. While the concave side grew 2.4 cm, the convex side grew 1.6 cm, demonstrating the effect of tethering on the convex side. The change in distance between the screw heads along the path of the polypropylene cord was 0 mm, demonstrating that there was no failure or elongation of the cord. The change in distance between the screw tips on the concave side was 22 mm and was secondary to changes in the angulation of the screws with vertebral growth without loss of fixation, as is well demonstrated on the radiographs.

Previous reports of attempts at surgically induced growth modulation of scoliosis in humans include the historical series of Roaf[13,14] and the more recent experience with vertebral body stapling as reported by Betz et al.[7,8]. Most recently, Betz et al.[8] reported on thirty-nine consecutive growing children who underwent vertebral body stapling for the treatment of scoliosis. Thirty-one patients were more than eight years of age at the time of surgery, and eight patients were younger. Refinements in staple design were made throughout the course of the series. The authors recommended vertebral body stapling for immature patients with adolescent idiopathic scoliosis (Risser grade 2 or less) with curves of between 20° and 45°, with 5° of documented progression for curves of <25°.

It is unknown whether the correction obtained in our patient will be maintained if the tether is removed. Potentially, the restoration of normal alignment and the resulting biomechanical loads will allow normal growth without the continued wedging and torsion typically associated with progressive scoliosis[23]. As demonstrated on the radiographs, the vertebral wedging that existed preoperatively corrected with time, apparently through growth modulation of the end plate physes. Despite the anteriorly based tether, overall sagittal alignment was well maintained, with no increase in thoracic kyphosis.

The potential for overcorrection in association with this technique is evident in the case described here. Longer follow-up throughout the adolescent growth spurt into maturity will be needed to determine if additional interventions, such as cutting of the polypropylene cord or fusion, will be needed. Optimum timing of this intervention during the child's growth may decrease the need for additional surgery. These risks must be carefully evaluated and weighed against the risk of additional interventions and the morbidity associated with much more established treatments such as spinal fusion.

The present report demonstrates the intermediate-term safety and efficacy of a novel procedure in a single patient. Careful ongoing assessment of our patient and others is needed to determine if this procedure will become accepted for the treatment of spinal deformities in the growing child. ■

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