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Tarik Yazar
Ilksen Gurkan
Cengiz Yilmaz

A new approach to scoliosis

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T. Yazar · I. Gurkan · C. Yilmaz
Department of Orthopedics
and Traumatology,
University of Ankara Medical School
Ibn-I Sina Hospital,
Samanpazari, Ankara, Turkey

T. Yazar (✉)
Erdonmez Sok. 4/7,
TR-06570 Anittepe Ankara, Turkey
Tel.: +90–312–2150168
Fax: +90–312–3112522
e-mail: tyazar@bir.net.tr

Abstract Despite the advantages that new derotation-based systems have brought to the treatment of scoliosis, the debate continues, especially regarding adolescent idiopathic scoliosis. Problems like decompensation, junctional kyphosis, and insufficient sagittal plane alignment are met with new proposals. We now are using a technique and system, the Ibn-I Sina Spinal System (IBS), that we think is able to overcome these problems. It makes use of sublaminar wires, hooks, screws, and rods for correction. The main innovation is that the major corrective force is a controlled translation force acting *simultaneously* on all segments of the curve. A retrospective assessment of 25 patients treated with this system showed that besides dealing well with decompensation and junctional kyphosis problems, the technique was superior in sagittal plane adjustments, mainly in that it carried the normal kyphosis to its physiologic location. IBS has proved easy and successful in scoliosis treatment, especially with lordotic rigid curves. We encountered no neurologic injury or instrument failure. In addition to these advantages, ease of preoperative planning and application, decreased operation time, easy removal or revision, and versatility and safety of the system has made the Ibn-I Sina Spinal System (IBS) a treatment of choice, especially for adolescent idiopathic scoliosis cases, in some centers in Turkey.

Key words Idiopathic scoliosis · Posterior instrumentation

Introduction

The introduction of the Harrington system opened a new era for internal fixation of the spine. Initially, all efforts were concentrated on modifying the system step by step to reach the perfect correction and stable fixation. The Cotrel-Dubousset Instrumentation (CDI) concept for three-dimensional correction introduced a new gold standard for scoliosis surgery. The initial enthusiasm has now waned, and ways to overcome problems encountered with CDI have started to be sought [1]. Numerous modifications of the system and suggestions about the technique have been put forward. Still the debate on the problems of balance and junctional kyphosis caused by the derotation maneuver is going on. Sublaminar wiring, with all its superiority over the hook system, has been criticized for carrying too great a neurologic risk. We started to use a new spinal system and, more importantly, a new technique, especially for scoliosis surgery. We think this technique, besides providing more control over the deformed spine, overcomes the post-corrective balance problems in two planes encountered with the derotation systems. Our system mainly utilizes translatory forces for correction and to some extent derotation. Compression and distraction can also be applied. We make use of sublaminar wires. We have been applying the technique to all types of scoliosis safely for the past 5 years with satisfactory results. In this article a brief description of the technique and the system used in adolescent idiopathic scoliosis cases is presented.

Materials and method

Between 1993 and 1996, 25 patients with adolescent idiopathic scoliosis underwent Ibn-I Sina Spinal System (IBS) posterior instrumentation. Of these, 19 were female while 6 were male. Average age at operation was 14 years and 6 months (range 9 years–10 months to 23 years and 2 months). Our average follow-up time was 22 months, with a range of 13–42 months. All operations and all measurements were done by the same author (T.Y.).

For each patient frontal and lateral standing radiographs were taken preoperatively, 1 week postoperatively, and at the most recent follow-up. Lateral bending radiographs were only taken once, for preoperative assessment. Curves were classified according to the criteria provided by King et al. [13]. For King type I curves we preferred anterior fusion and instrumentation first and observed the secondary thoracic curve for a possible progression. There were only two cases that progressed despite brace wearing, requiring posterior thoracic instrumentation and fusion. There were 15 cases of King type II curves. We used the criteria proposed by Ibrahim and Benson for determining fusion levels in King type II curves [13]. In two cases with lumbar curves of more than 35° and less than 70% flexibility, i.e., type IIB, we applied fusion of both curves. The other 13 patients in the King type II group, who had lumbar curves of less than 35° and more than 75% flexibility, i.e., type IIA, underwent selective thoracic fusion. The type III group comprised five patients and the type IV group three. For these patients long posterior fusion was preferred. In cases of difficulty in differentiating the curve and for decisions regarding the upper fusion levels, especially in presence of shoulder asymmetry, we made use of traction radiographs.

On the preoperative radiographs, type of the curves, size of curves in the frontal plane, size of sagittal curves, rotation of the apical vertebra of the major curve, trunk lateral shift, flexibility of the curves, and cranial and caudal fusion levels were assessed. Classification of curve type and selection of fusion level were decided using the criteria of King et al. [12]. Frontal plane curve size was measured using the Cobb technique. On the sagittal plane we measured thoracic kyphosis between the 3rd and 12th thoracic vertebra using the Cobb technique. Lumbar lordosis was measured between 12th thoracic and 5th lumbar vertebra. Lateral trunk shift was determined as the distance of the mid-vertebral point of the apical vertebra of the major curve to the central sacral line.

All patients were mobilized on the 2nd postoperative day with a custom-molded thoracolumbosacral orthosis. They were made to wear the brace for 3 weeks only.

Ibn-I Sina Spinal System (IBS)

The system is mainly composed of rods, sublaminar wires, connectors, transpedicular screws, hooks, and plates for transverse linking. Rods are mainly of two kinds: one has a diamond-shaped surface for the whole length and the other a diamond-shaped surface only at the ends, with a smooth middle part. Diamond-shaped surfaces provide strong grip for the screws and hooks, while smooth surfaces allow sublaminar wires to slide on. Connectors are used to connect transpedicular screws to the rods. Bent connectors carry out a specialized duty; it becomes possible to fix the rod to the screw at a desired stable angle, which is very useful in fixing the lower end vertebra in the correct sagittal alignment, with a range of 35°. In the transverse plane, connectors allow 5 mm of adjustment. Pedicular screws are designed to have decreasing core diameter and a thread structure that changes from cortical to spongious, i.e., from shallow profile to deep profile toward the tip, providing stronger grip to the cortical pedicular and spongious corpuscular bone. The blade edges of the laminar hooks are rounded to prevent iatrogenic laminotomies.

Surgical technique

We describe the Ibn-I Sina technique in King type II adolescent idiopathic scoliosis, as these are the cases around which debate is greatest.

The rod to which sublaminar wires are to be connected is always applied to the concave side of the major curve. We prefer to use a double-surfaced rod in applications with sublaminar wires. On the upper end vertebra of the concave side a transversolaminar or transversopedicular claw is attached. For the lower end vertebra transpedicular screws are always preferred if possible. If not, a laminolaminar claw can be made. Resection of the spinous process provides access to interspinous ligament and the ligamentum flavum, which have to be resected as extensively as possible. This process is important for safe sublaminar wiring. A precontoured rod is first inserted into the hooks above and then into the screw below with the help of connectors. Proper adaptation of the rod and inserted transpedicular screw is provided by one slotted connector at each level. Bent connectors may be necessary where there are alignment problems or when an inclination between rod and the screw is planned preoperatively. Connectors are fixed onto the screw heads by 9.5-mm nuts. A wire twister is used to tighten the sublaminar wires on the part of the rod with a smooth surface, starting from the most distal parts and ending at the apex. A powered rod holder is used to derotate the rod under the tightened wires. Set screws on the hooks and the connectors are tightened over the rod. Sagittal plane fine tuning is an advantage that can be achieved by retightening the sublaminar wires. Distraction between a rod holder and the upper hook and the lower screw can be applied by temporarily loosening the set screws.

On the convex side of the curve, for the upper end vertebra a transversolaminar or transversopedicular claw and for the lower end vertebra a transpedicular screw, preferably, or a laminolaminar claw are attached. The precontoured rod that has a diamond-shaped surface along its whole length, and has crosslink eyebolts inserted on, is fixed to the hooks and the screw. Compression can be applied with the help of a rod holder. Two or three crosslink plates are attached to the rods. Articular fusion and decortication of the instrumented segments are supported with iliac grafts or, when not enough bone stock is found, with allografts.

Results

The average size of the major curve was 58° preoperatively, with a range of 38°–104°. On the postoperative 1st week it was measured to be 22° (3°–50°), giving an average correction rate of 62%. The most recent follow-up assessments revealed this measurement as 23.1°, indicating a correction loss of 5%. The average size of the secondary curves was 39° (29°–82°) preoperatively and 17° (2°–42°) postoperatively at the end of the 1st week. The correction rate was 57% for the secondary curves. In the sagittal plane, the results were as shown in Tables 1 and 2. We observed better correction of the trunk shift in type III and IV cases than in type I and II cases. An average of 21 mm of preoperative trunk shift in type I and II curves decreased to 7 mm. There was more substantial correction in type III and IV curves; from 45 mm to 10 mm (Table 3). At follow-up, the secondary curves of 5 of the 13 patients with King type II curves, who had undergone selective thoracic fusion, improved, while 6 did not change and 2 cases showed progression. These responded well to brace wearing.

Table 1 Change in the thoracic kyphosis (as measured between T3 and T12)

	Increased	Decreased	Not changed
No. of patients	13	6	6
Preoperative kyphosis: average (range)	18° (1°–26°)	37° (32°–65°)	31° (27°–34°)
Postoperative kyphosis: average (range)	32° (20°–38°)	34° (25°–39°)	31° (27°–34°)

Table 2 Change in lumbar lordosis (as measured between T12 and L5)

	Increased	Decreased	Not changed
No. of patients	2	15	8
Preoperative lordosis: average (range)	28° (25°–31°)	49° (47°–55°)	42° (39°–45°)
Postoperative lordosis: average (range)	37° (33°–41°)	41° (37°–45°)	42° (39°–45°)

Table 3 Change in the lateral trunk shift

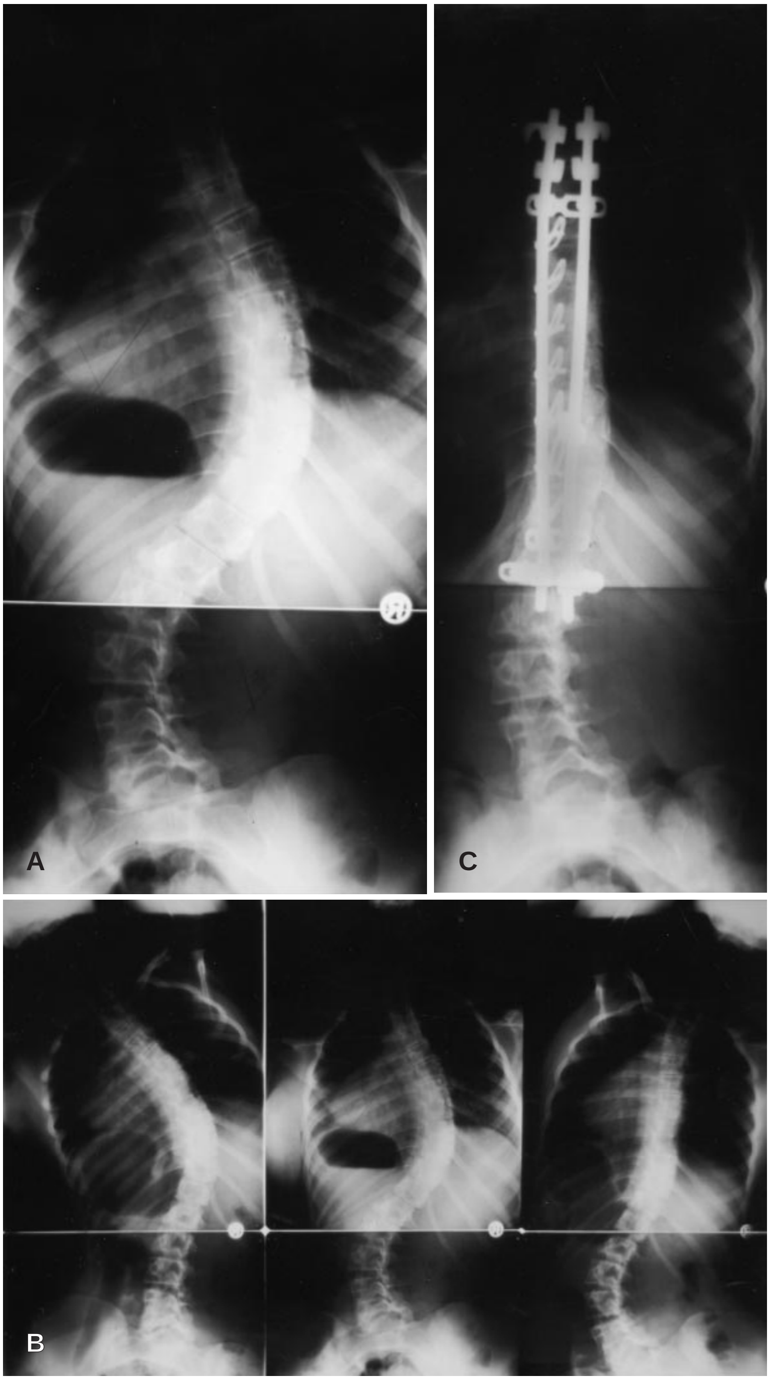
	Type I and II (*n* = 17)	Type III and IV (*n* = 8)
Preoperative shift: average (range)	21 mm (15–42 mm)	45 mm (22–68 mm)
Postoperative shift: average (range)	7 mm (3–15 mm)	10 mm (5–23 mm)
Correction rate	67%	78%

We encountered no neurologic injury or instrument failure. We had two cases with superficial infection. They responded well to antibiotic treatment. We did not observe any deep or late infection.

Discussion

Strong derotational forces, once widely accepted, are now suspected of causing decompensation of the secondary curves and thus shifting the trunk to the left in right thoracic curves. This well-documented phenomenon creates a problem mainly in King type II idiopathic scoliosis cases, in which selective thoracic fusion is preferred and the secondary lumbar curve is expected to compensate [2, 5, 14, 16, 18, 19]. King type II cases with thoracic curves greater than 60° and lumbar curves greater than 45° are especially prone to this complication [14, 15]. The derotation maneuver force applied to the rod is transferred to the column mainly with the help of two intermediate hooks, causing a strong en bloc torsional force on the uninstrumented lower vertebrae [6, 15, 19]. The addition of rigid internal fixation anchors this force, hampering the attempt of the lumbar vertebrae to correct themselves. Holding the fusion level one segment shorter or using reverse bent rods with reverse hooks at lumbar levels is recommended to prevent decompensation. However, stopping short loads more torsional force on the transitional segment, increasing the risk of junctional kyphosis [15, 16, 19]. Cases of decompensation have been reported despite fusion stopping short of the instrumentation [14]. The rate of decompensation may be lower, but is not nil, in the reverse bending technique [5, 19]. As stated by Thompson et al., using the CDI, their average result in trunk balance was worse than it had been preoperatively [19]. On account of these consequences, King recommends avoiding the derotation maneuver [13]. The ability to instrument the apical vertebra for effective approximation of the column to the central sacral line is especially useful in King type III curves. IBS enables instrumentation of the apical vertebra as well as the other segments, thus providing greater corrective power. However, the major goal in the IBS technique is not to exert excessive force on the apical rigidity but to create two balanced smaller curves (Fig. 1). The derotation force applied by the rod is not so great as to transmit a torsional force down to the lumbar segments that would prevent them gaining their own balance. We would like to emphasize that the derotation process in the IBS technique involves derotation of the rod but not the spinal column. IBS is a stable internal fixation device, but it is not rigid at all. The flexibility provided by sublaminar wiring further enhances the ability of secondary curves to compensate. We have seen that King type II cases to whom selective thoracic fusion was applied achieved better compensation than the ones treated using CDI and similar systems [14, 16, 19], while the average postoperative apical vertebra translation was 10 mm or less, which is the accepted limit for balance of trunk [19].

As Ferguson et al. demonstrated, axial corrective forces, i.e., compression and distraction, can exert greater force as the curve angle increases [9]. As curve size decreases the corrective vector component of the axial force decreases. Transverse corrective forces have more effect on smaller curves. Sublaminar wiring creates a lateral force, reducing the need for distraction. Distraction forces are able to correct the deformity in the frontal plane and the already present hypokyphosis as far as the lamina can sustain [20]. The major difference between IBS and Luque Instrumentation is that IBS makes it possible to apply both axial and transverse forces and to provide proper sagittal alignment. Multisegmental instrumentation becomes very useful, especially for the sagittal plane alignment of the curve, in which hook-based derotation systems are not very satisfactory [3, 4, 15, 16, 19] (Fig. 1D, E). In IBS, sublaminar wires first apply transverse traction to each segment one by one (at least six segments recommended), which effectively corrects deformities in the frontal plane. The following derotation of the rod provides a strong force *simultaneously* on the whole curve, inviting the vertebrae to align in the sagittal plane. Fine-tuning by twisting the sublaminar wires on the prebent rod allows better



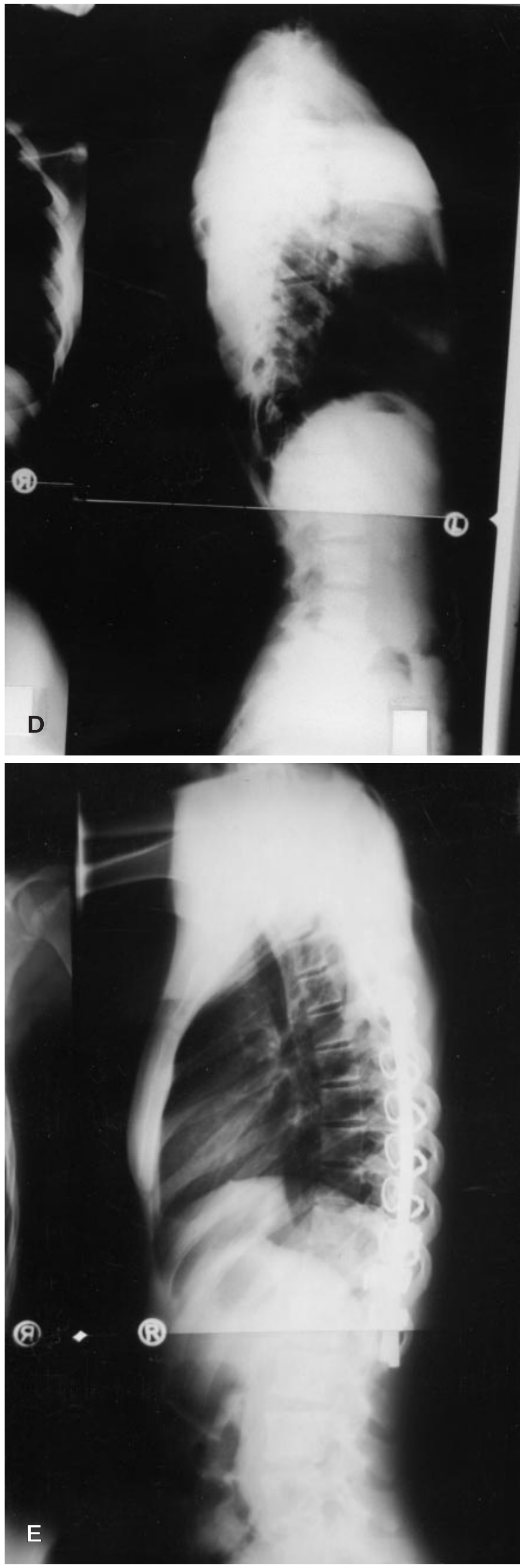


Fig. 1 A–E A King type II curve. The preoperative thoracic curve of 65° was corrected to 11° (83% correction). The lumbar curve was 50° preoperatively and was corrected to 16° (68% correction). Curve flexibility was 63% for the thoracic curve and 68% for the lumbar curve. The residual lumbar curve was greater than the corrected curve on bending radiographs, and a brace had to be used to obtain two balanced curves. **A** Preoperative standing postero-anterior radiograph. **B** Preoperative neutral and side bending radiographs. **C** Postoperative postero-anterior radiograph. **D** Preoperative sagittal radiograph of the same case. **E** Postoperative sagittal radiograph

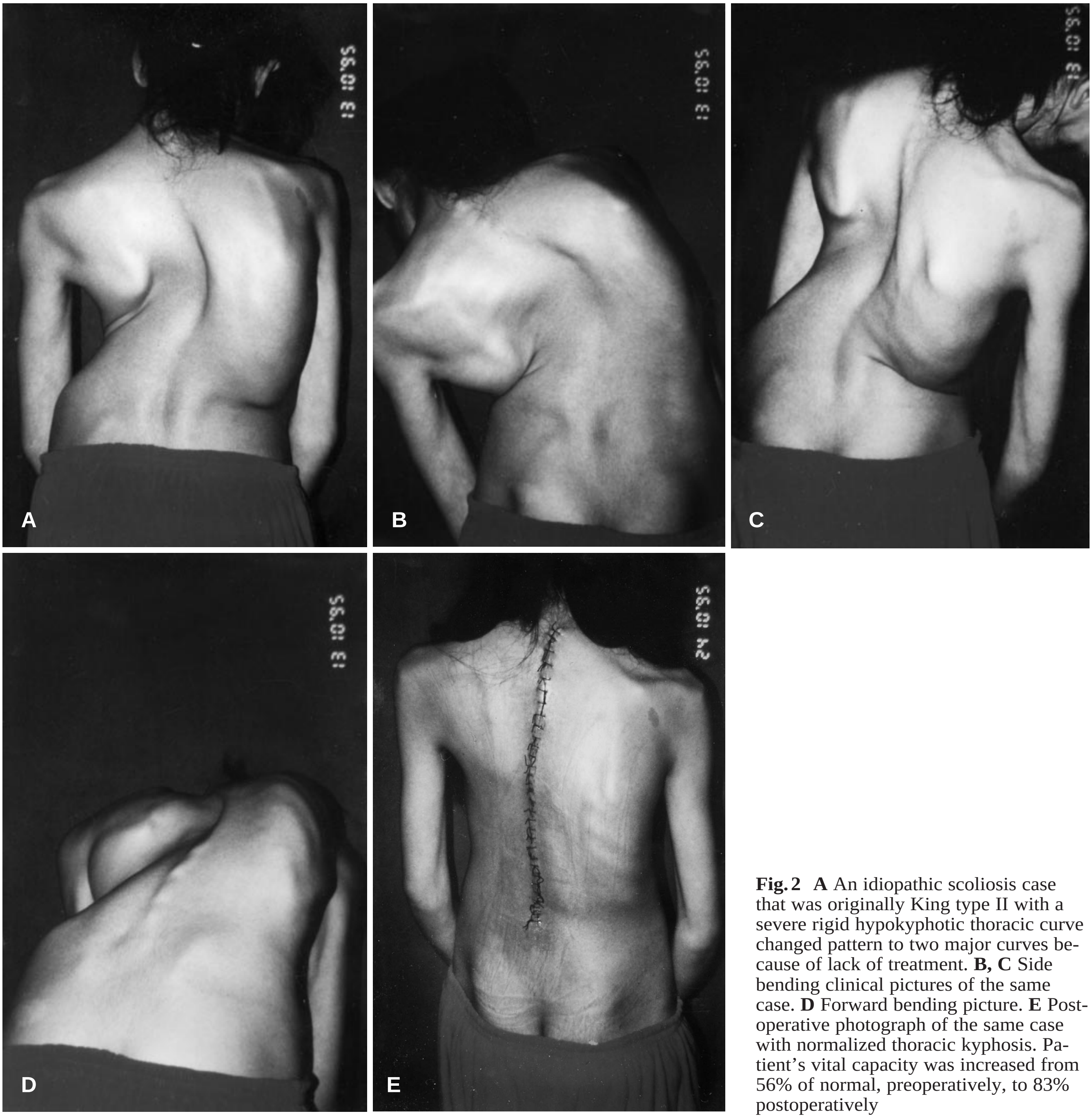


Fig. 2 **A** An idiopathic scoliosis case that was originally King type II with a severe rigid hypokyphotic thoracic curve changed pattern to two major curves because of lack of treatment. **B, C** Side bending clinical pictures of the same case. **D** Forward bending picture. **E** Postoperative photograph of the same case with normalized thoracic kyphosis. Patient's vital capacity was increased from 56% of normal, preoperatively, to 83% postoperatively

alignment in the sagittal plane. With the IBS technique we have obtained good results especially in hypokyphotic thoracic curves (Fig. 2).

As much translatory force as desired can be applied without risk of iatrogenic laminotomy, since the whole force is distributed over all the segments and, within each vertebra, on the whole lamina. Also, the distribution of the load over multiple segments prevents rod flattening during the derotation process, which is a reported draw back for hook-based systems [4, 7, 14]. In contrast to the 3D derotation systems, which define two levels as the strategic ones (the two intermediate vertebrae to be instrumented) using IBS all vertebrae of the curve are strategic. As calculated by Dunn, one thoracic lamina can withstand a 700 N [8]. In systems using hooks, load is concentrated on the two intermediate hooks, which only hold part of the lamina, so careful application of the derotational force is vital. Theoretically, 1400 N is the maximum force that can be applied on the concave rod with the two intermediate hooks. Since hooks hold only part of the lamina, this endurance is less in practice. With a minimum of six segments to be wired, covering the whole laminar thickness, IBS allows at least three times more force to be applied on the spinal column. This protects against hook pull-out and fractures of the lamina, which have been reported on several occasions of forceful derotation using other spinal fixation systems [3, 7, 11, 16]. Even with severe rigid curves, we have not encountered such complications. The distribution of the force across the segments makes IBS an instrument of choice, especially in osteoporotic and severe cases.

Although successful results can be obtained by the application of hooks, we strongly recommend usage of transpedicular screws at the lower fusion levels, especially for rigid curves. Screws create a stronger lever arm supporting the junctional segment. For preventing formation of junctional kyphosis, one vital step in preoperative planning of IBS is choosing the sagittal plane location of the lowest instrumented vertebra. Postoperative alignment of this vertebra in normal lumbar lordosis can be adapted with the help of bent connectors, which provide a 35° range between the rod and the connector, and by arranging the insertion angle of the screw into the pedicle. This arrangement contributes greatly to a smooth passage between the instrumented and the non-instrumented segments of the spine. As Bridwell et al. have stated, loss of lumbar lordosis, meaning a hypolordotic lumbar spine, leads to early degenerative changes with the development of low back pain [4]. We believe the near normal lordotic lumbar spine obtained allows us to call the IBS a lumbar lordosis enhancing instrument.

Sublaminar wires do not have resistance to axial loads, thus minimizing the stress-shielding effect of the instrument and enhancing fusion mass formation [3]. Richards and Johnston proposed increased pseudoarthrosis rates with the use of more hooks [15, 17]. Application of fewer hooks has the benefit of being able to fuse more facet joints [7]. There were no pseudoarthrosis cases in our series.

Although sublaminar wires have been criticized for having a high neurologic injury risk, the hook systems now being widely used have three times the neurologic injury risk of the Harrington system, as reported by the Scoliosis Research Society Morbidity and Mortality Committee (1987) [7]. This committee have determined the risk for sublaminar wires to be four times that of the Harrington system. Using our surgical technique we encountered no neurologic injury, and the risk can be minimized by being meticulous about wiring techniques [10].

Conclusion

We think the major factor in the choice of IBS is that it allows better compensation of secondary curves, with a good sagittal correction and maintenance of near normal thoracic kyphosis and lumbar lordosis. Ease of preoperative planning and application are of other important factors.

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