International Journal of Life Sciences, Biotechnology and Pharma Research Vol. 14, No. 1, January 2025 Online ISSN: 2250-3137
Print ISSN: 2977-0122

DOI: 10.69605/ijlbpr_14.1.2025.123

ORIGINAL RESEARCH

Results of posterior vertebral column resection for rigid spinal deformities, A single institute experience and a Retrospective analysis

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Received: 29 November, 2024 Accepted: 12 January, 2025 Published: 28 January, 2025

ABSTRACT

Background: Rigid and severe spinal deformities can result from several etiologies and can only be effectively treated by a three-column spinal osteotomy in the form of vertebral column resection which is a demanding surgical procedure and is fraught with complications. However a single stage posterior vertebral column resection (PVCR) has gained acceptance as a less morbid procedure than front back two stage surgery. **Aim:** This study aims to present the technique and results of PVCR our cases of rigid and severe spinal deformities in terms of its capability to correct the deformity clinicoradiologically and its complications. **Methods:** This was a retrospective study of ten cases of rigid spinal deformity of various etiologies treated at our institute over a period of two years from March 2022 to December 2023. The study aims to present short-term results of posterior vertebral column resection (PVCR) in the treatment of severe and rigid spinal deformities viz a viz its ability to correct the deformity and its complications. **Results:** The mean age of the patients was 26.4 years. Congenital deformity was seen in six, post traumatic deformity in two and post tumor and post laminectomy deformity in one patient each. Deformity involved dorsal spine in six, dorso-lumbar region in three and lumbar region in one patient. The average operative time was 7.4 hours with an average blood loss of 1800 ml. The average number of transfusions required was 3.9 and average number of days spent in Intensive Care Unit was 4.5 days. The average preoperative and post-operative kyphosis was 60.3 and 22.2 degrees respectively, scoliosis was 48 and 18 degrees respectively, and sagittal imbalance was 35.5 and 11.6 degrees respectively. The mean preoperative and post-operative coronal imbalance was 30 mm and 11 mm respectively. There was one case of mortality in our series. **Conclusion:** We have been able to demonstrate the ability of PVCR to correct severe and rigid deformities of the spine in both the coronal and sagittal planes of various etiologies and in different age groups.

Keywords: scoliosis; kyphosis; kypho-scoliosis; spinal deformity; vertebral column resection;

INTRODUCTION

Spinal deformities can result from a multitude of aetiologies with each having a specific age of onset and varying rates of progression which if not intervened can be severely hamper activities of daily living. (1) There are two types of spinal deformities, namely, lordosis and kyphosis, and they are mutually exclusive at the same site. Although Lordosis is rotationally unstable and buckles to the side with growth and spinal flexion, producing scoliosis and changes in transverse plane geometry as a secondary phenomenon, kyphosis does not buckle on the other hand. (2) Vertebral column resection (VCR) is a three-column spinal osteotomy used for the correction of severe and rigid deformities. It shortens the length of the vertebral column and allows the translation of vertebrae needed to correct and balance the spine in multiple planes. (3)

In 1922, MacLennan first illustrated vertebrectomy and demonstrated an apical resection from a posterior-only approach with postoperative casting for the treatment of severe scoliosis. (4) Luque in 1983, described the procedure of combined posterior instrumentation and spinal shortening for deformity

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correction which was then later modified in 1987, by Bradford who described a modification of the Luque technique through anterior column resection in rigid curves. (5) Leatherman described anterior resection of the vertebral body with later posterior fusion with Harrington instrumentation as safe and effective. (6) Boachie and Bradford described two-stage anterior and posterior vertebral column resection, fusion, and segmental spinal instrumentation for severe rigid spine deformities. (7) However, the anterior-posterior vertebral column resection has disadvantages of long operative time, significant blood loss, and risk of intraoperative neurologic impairment due to the spinal column segment instability during the resection and the correction procedure.

More refinements by Suk and Lenke led to the introduction of his technique of a single posterior approach even to the lumbosacral junction beside thoracic and thoracolumbar regions to perform vertebral column resection that offered significant advantages over the combined anterior-posterior vertebral column resection. (8, 9) The surgery consisted of temporary stabilization of the vertebral column with segmental pedicle screw fixation, resection of the vertebral column at the apex of the deformity via the posterior route followed by gradual deformity correction and global fusion. (10, 11)

MATERIAL AND METHODS

This was a retrospective analysis of 10 patients with severe kypho-scoliotic deformity with very little or no flexibility managed by posterior vertebral column resection (PVCR) between 2017 and 2023. Preoperative and postoperative whole spine standing radiographs were evaluated for degrees of kyphosis, scoliosis and coronal imbalance (measured as deviation of C7 Plumb line from central sacral vertical line) and sagittal imbalance (measured as deviation of C7 plumb line from neutral passing through the postero-superior corner of S1). Preoperative neurological status was evaluated using ASIA grading system Average operative time, average estimated blood loss, neurological complications, other complications, postoperative neurological status (ASIA grade) and degree of kyphosis, scoliosis and coronal imbalance were recorded.

Operative Technique (8, 9, 10, 11)

1. The surgical technique for PVCR is technically demanding. Intubation is done under total IV Anesthesia and invasive BP monitoring. Tranexamic acid, an antifibrinolytic, is also utilized to minimize blood loss at a loading dose of 15mg/kg and a maintenance dose of 5 mg/kg/hr is typically provided. (12, 13)
2. Placement of neuromonitoring electrodes SSEP, MEP; Given spinal column shortening and possible neurologic risk inherent to the procedure, multimodality neuromonitoring is essential. (14)
3. Positioning: The patient is positioned prone on the Jackson frame or appropriately sized bolsters with well-padded bony prominences to avoid excessive pressure points, and peripheral nerve injury, and to assist in the reduction of the spinal deformity. The frame should allow full extension of the hips and a free abdomen (**Figure 1)**. Attention should be given to ensuring the facial structures and orbits are free of pressure. (8, 9, 10, 11)

4. Exposure is done up to the tips of the transverse processes and up to 5 cm of the medial portion of bilateral ribs are exposed at the PVCR level in the thoracic spine. Subperiosteal dissection of the posterior column is done meticulously to minimize blood loss. Inferior facetectomies are performed. PCOs are done at the periapical levels of the deformity corresponding to the levels around the planned vertebral column resection allowing a safe and efficient correction about the apex. The periapical PCOs also allow direct palpation of the medial border of the pedicle

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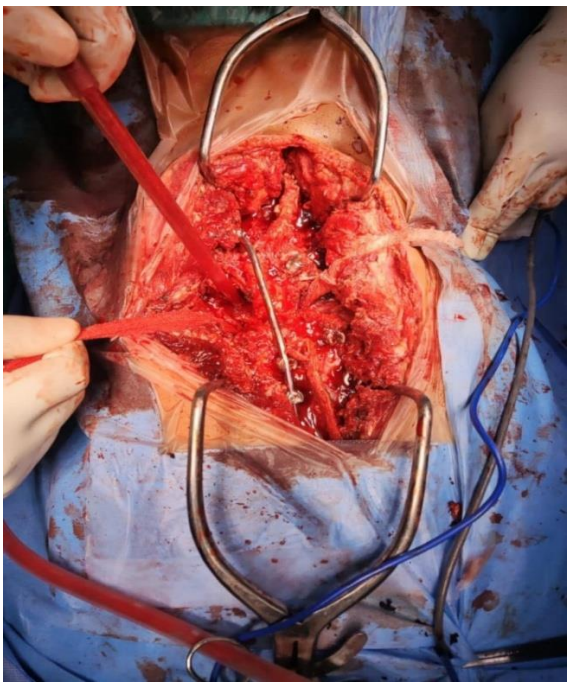
through the spinal canal, which facilitates pedicle screw placement under vision, particularly in the periapical portion of the concavity where the spinal cord often drapes over the medial wall of the pedicle. (8, 9, 10, 11)

5. Insertion of pedicle screws is done according to the freehand technique at least 3 levels cephalad and 3 levels caudal to the planned vertebral resection to allow for a temporary stabilizing rod. Poly-axial reduction screws are utilized in the periapical region, particularly caudal to the resection level. These caudal reduction screws may assist in preventing any ventral drift of the spinal segment inferior to the VCR. These also allow for expeditious temporary rod placement. Screws from sixth dorsal vertebra to first sacral segment are tested with an electromyography (EMG) probe to confirm intraosseous placement. (8, 9, 10, 11)
6. Laminectomy: Once the exposure is complete and pedicle screws are put. A wide apical laminectomy is carried from the inferior aspect of the pedicle above to the superior aspect of the pedicle below the area being resected to sufficiently visualize any dural buckling during resection. While doing a VCR within the thoracic region, the medial portion of bilateral ribs is excised 5 cm at the planned level. The transverse processes are resected bilaterally as well exposing the lateral portion of the pedicles and vertebral body. The lateral aspect of the pedicle and vertebral body are dissected with Penfield elevators. The thoracic nerve root on the convexity of the planned VCR level is usually ligated while the concave root is saved. Some authors advocate clamping the nerve root for 10 minutes while checking evoked responses to minimize the risk of compromising blood supply to the spinal cord. (15)
7. Temporary rod stabilization: Before anterior column resection, the spine is pre-emptively stabilized with a temporary rod connected to at least 2 or 3 levels of cephalad and caudal to the planned VCR level (**Figure 2)**.



8. Resection of the concave pedicle: This is done to decrease tension on the spinal cord by allowing the spinal cord to move medially from its original position draped over the medial aspect of the concave pedicle. The concave pedicle is often completely cortical, we use a high-speed burr for resection while protecting the dura.
9. The convex pedicle is straight in front and allows for a much more direct path for resection of the vertebral body.
10. Vertebral body Resection: Next the lateral vertebral body is dissected subperiosteally and a malleable retractor or spoon retractor is used to protect the pleura, vessels, and sympathetic chain. With the retractor in place, the vertebral body is then excised only to leave a portion of the anterior wall attached to the anterior longitudinal ligament to promote fusion. The posterior cortex is resected at the end to minimize epidural bleeding. (8, 9, 10, 11)
11. Discectomies above and below may minimize the potential bleeding surfaces, however, intravertebral resection is necessary in cases with previous anterior column fusion or pathologic ankylosis. Bipolar cautery and topical haemostatic agents are useful for bleeding control. Reverse-angled curettes, Kerrison rongeurs, or posterior wall impactors may be used

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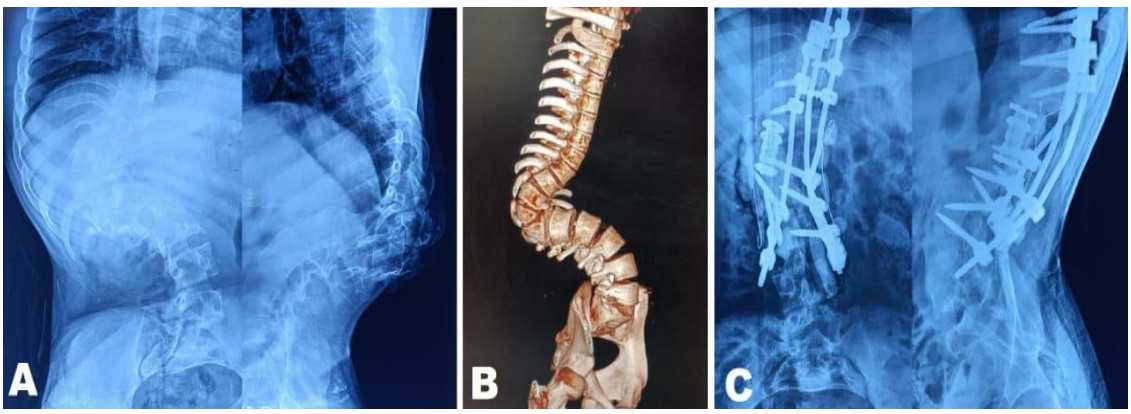
for the removal of the posterior wall. After making sure that the dura is free, the correction can be performed and the anterior column rigidly reconstructed. (8, 9, 10, 11)

12. Correction involves shortening and translation of the spine. Distraction is performed only after sufficient shortening has produced adequate slack of the concave dura/spinal cord. Compression is done on the convex side through individual pedicle screws in patients with good bone stock. Construct-to-construct closure mechanism using dominoes at the apex of the resected area may be employed in osteoporotic bone. Correction proceeds slowly through the use of the temporary stabilizing rod to prevent subluxation and dural impingement. An intervertebral cage is then placed at the VCR level to provide anterior column support, prevent anterior shortening, correct kyphosis, and provide shear force stabilization. This is particularly important for patients with severe angular kyphosis since the anterior cage functions as a fulcrum for kyphosis correction and protects it from both over-shortening and ventral buckling of the cord. After the majority of the correction is achieved, the contralateral permanent rod is placed and the ipsilateral temporary stabilizing rod is exchanged for a permanent rod. (16)

Decortication and bone grafting ensue while the laminectomy defect is covered with the previously garnered ribs and morselized bone graft. The rib graft is immobilized by a cross-link or sutures.

RESULTS

Our study included ten patients including, six females and four males. Age of the patients ranged from 12 to 50 years (average 26.4 years). Five patients had deformities in the dorsal spine, four in the dorso-lumbar junction and one in the lumbar region. Six patients had congenital kyphoscoliosis deformity due to one or multiple hemi-vertebrae with associated dislocated spine. Two patients had post-traumatic fracture dislocations with one having an old L4 Burst fracture with L3-4 dislocation and bilateral complete foot drop. The other patient had an old spinal cord injury of dorso-lumbar junction with a spondyloptosis of D12 over L1 with residual weakness of bilateral ankles. One patient had post-laminectomy kyphosis and dislocation of D11-12. Neurologically four patients were almost intact (ASIA E), four had ASIA D and two patients had ASIA B neurological grading. Post-operative neurological deterioration occurred in two, having a major neurological deficit of whom one recovered his neuro-deficit in one month time completely and other showed insignificant improvement of her power at last follow up. Six patients had resection of one vertebra and four had two vertebrae resected (average 1.4). Average blood loss was 1800 ml (range 1000-3000 ml). Average number of transfusions required was 3.6 (range 3-5). Average number of days spent in ICU was 4.5 (range 1-7) days. The average preoperative kyphosis was 60.3 degrees (range 40-100 degrees). Immediate average postoperative kyphosis was 22.2 (range 10-35 degrees) which corresponds to 63.3% correction. Five out of ten patients had significantly associated scoliosis with an average scoliosis of 60 degrees (range 0-60 degrees, median 37.5 degrees). Immediate average postoperative scoliosis was 22 degrees, a correction of 63 %. Average preoperative sagittal imbalance was 35.5mm (range 22-45). The average postoperative sagittal imbalance was 11.6mm (correction of 23.9mm). Average preoperative coronal imbalance was 30mm (range 0-40 mm, median 23.5 mm). The average postoperative coronal imbalance was 11mm (correction of 19 mm) **(Figure 3; Figure 4)**. The average operative time was 7.4 hrs. Postoperatively two of our patients got infected with one having superficial surgical site infection and the other having deep infection needing debridement and prolonged intravenous antibiotics. One patient died on the 4th postoperative day due to massive pulmonary oedema. Two of our patients developed psychological abnormalities with profound sleep disturbances.



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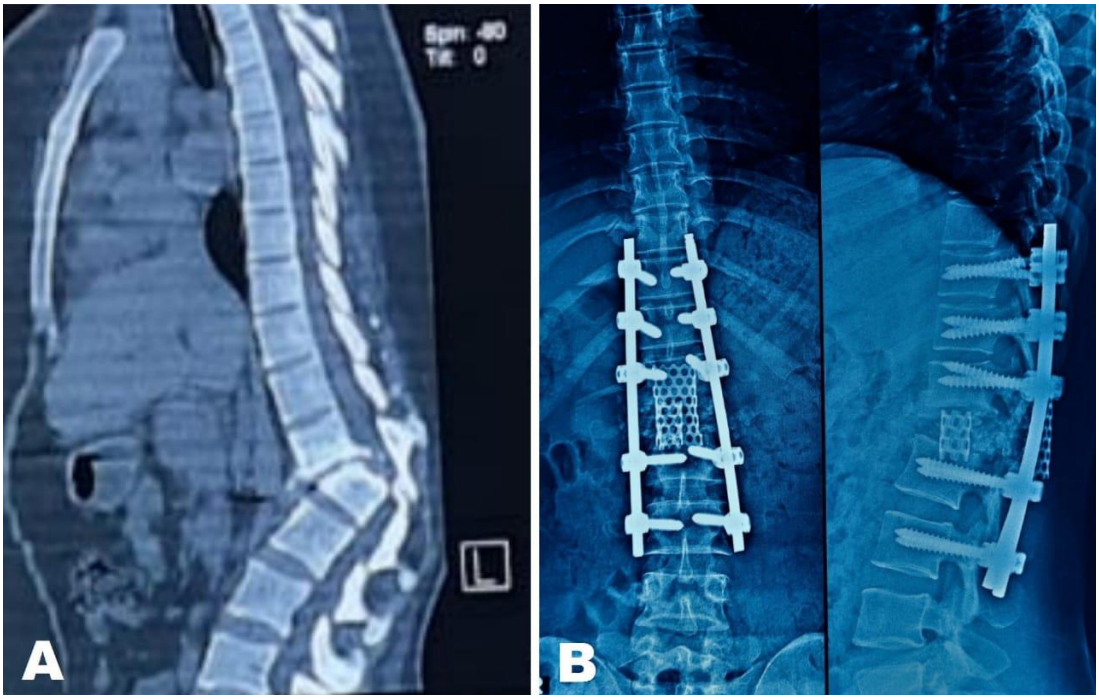

DISCUSSION

Rigid spinal deformities can result from neglect of congenital and acquired deformities including trauma, tumours, infection and iatrogenic causes. The grotesque and rigid nature of these deformities makes them non-amenable to the conventional surgical methods of deformity correction and as such additionally need a three-column osteotomy of the spine. First described by MacLennan in 1922, the correction of complex deformities by VCR was subsequently modified by several authors. (8, 9, 10, 11) Vertebral column resection creates an unsupported gap in the vertebral column that needs to be supported by an interbody device or a tri-cortical strut whereas in a spinal osteotomy, the gaps are closed by apposition of the osteotomy surfaces. (5) In 1997, Suk developed a one-stage posterior vertebral column resection combined with pedicle screw instrumentation and anterior column reconstruction for correction of fixed kyphotic deformity (10). This technique was subsequently performed in rigid scoliosis, such as severe adult scoliosis and congenital kyphoscoliosis. (17, 18) Although our series of cases included spinal deformities from multiple aetiologies, the procedure for the correction i.e., posterior vertebral column resection happened to be the same in all. Average correction of 63.3% and 59% respectively in the sagittal and coronal plane of our patient is comparable to Suk et al who reported a correction of 61.9% in the coronal plane and 47.5° in the sagittal plane, with 25.3 mm and 27.7 mm restorations of coronal and sagittal imbalance, respectively. (18) Suk et al in a subsequent study of 25 patients with fixed lumbosacral deformity who underwent PVCR showed 60% correction and 1.1 cm improvement in the coronal plane and 40% correction and 4.7 cm correction in the sagittal plane. (10) Lenke et al in a heterogeneous group of kyphoscoliosis and scoliosis patients reported a scoliosis correction rate of 69%, global kyphosis correction of 54%, angular kyphosis correction of 63% and combined kyphoscoliosis correction of 54%. (11)

PVCR is a technically demanding procedure with the potential for significant blood loss, operative time, and risk of postoperative infection. The average estimated blood loss and average operative time in our study were 1800 ml (range 1000-3000 ml) and 7.4 hrs respectively. Suk et al in the study of 70 patients who underwent PVCR for fixed spinal deformity reported a reduced mean operative time of 4.5 hours and an average Estimated blood Loss of 2333 mL. (8) Subsequently, they reported an operative time of 4.67 hours and an estimated blood loss of 2810 mL. (10) However, a third study by Suk et al of 25 patients with severe rigid scoliosis (>80degrees, <25% flexibility) who underwent PVCR showed a higher mean operative time of 6.17 hours and significantly higher estimated blood loss of 7034 mL. (9) Lenke et al in a study of 43 adult and paediatric patients with severe spinal deformity who underwent PVCR reported an average operative time of 9.62 hours and an average blood loss of 1103 ml. (19) In a follow-up study of only paediatric PVCR patients, Lenke reported an average operative time of 7.67 hours and an average estimated blood loss of 691 ml. In a multicentre study of paediatric VCR patients by Lenke et al, the average operative time was 9.07 hours with an average blood loss of 1610 mL. (21)

The ability of PVCR for significant correction in rigid spinal deformity there is a high risk of neurologic complications. Two of our patients (20%) had neurologic worsening from ASIA grade D to ASIA grade B of whom one recovered his neuro in a two month time. Suk et al reported 6% transient nerve root

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injuries and 3% postoperative permanent complete spinal cord injury, particularly in patients with pre-existing neurologic impairment. (18) Suk et al reported 8% transient nerve root injury in PVCR for fixed lumbosacral deformity and 6% (1 patient) complete paralysis in PVCR for severe rigid scoliosis. (6, 9, 10) In a multicentre study of 147 paediatric VCR patients published by Lenke et al, the rate of intraoperative neurologic events was 27%. Postoperative transient neurologic deficit was seen in 3% of cases, and no patients suffered permanent paraplegia. (21) Papadopoulos et al reported intraoperative neuro-monitoring changes in 22% of patients undergoing PVCR for rigid kyphosis, presumably due to hypotension, extreme cord manipulation, or osteotomy closure. Two patients (4%) suffered isolated nerve root injuries (1 transient, 1 permanent) and 1 patient (2%) suffered permanent complete spinal cord injury. (3) Kim et al noted a 13.8% incidence of transient neurologic deficit with PVCR and a 3.3% incidence of permanent neurologic deficit (22).

Xie et al in a study of 76 patients with rigid kyphoscoliosis identified following as risk factors for postoperative neurologic deficits such as pre-existing neurologic dysfunction (odds ratio [OR] ¼ 49.32) and intra-spinal and brainstem anomalies (OR ¼ 18.42). Other risk factors were potential scoliosis associated with hyper-kyphosis (OR ¼ 11.88), and level of vertebral column resection (OR ¼ 8.77), preoperative neurologic deficit (OR ¼ 3.04) and resection of 2 or more vertebrae (OR ¼ 4.73) both increased the risk of the postoperative neurologic deficit as reported by Kim et al. (22, 23)

Extensive surgical exposure and prolonged operative time are potential risk factors for surgical site infection. We had two surgical site infections which grew methicillin resistant staph aureus and required prolonged antibiotic therapy among which one had superficial surgical site infection and other was managed with multiple debridements. Pull ter Gunne et al reported a significantly higher risk of deep surgical site infections with PVCR (9.7%) than pedicle subtraction osteotomy (PSO) (3.4%) and posterior column osteotomy (PCO) (1.5%), which the authors attributed to the wider exposure required to perform PVCR. VCR has the highest surgical site infection rate of 11.1% as compared with PSO (4.8%) and PCO (2.9%). (24) Several qualitative studies in the literature have reported a 3% to 9% incidence of infection which require incision and drainage after PVCR. (3, 8, 21, 25, 26)

There was one mortality in our study due to massive transfusion-related pulmonary oedema. Kim et al have reported an overall complication rate of 40% and they reported one death due to heart failure. (22)

We also saw one pseudo hernia after the resection of two hemi-vertebrae in an adolescent patient after the resection of two intercostal nerve roots which resolved over several months. These are rare complications and may occur during correction of spinal deformities in children. This condition is a transient disorder of the anterior abdominal wall muscles, the cause of which may be neuropathy caused by infection, metabolic disorders, or mechanical damage. The main principles of treatment of this condition include active observation and symptomatic therapy. The prognosis is usually favourable. (27) Two of the patients who underwent D-12 PVCR had post-operative sleep disturbances for four to five months and needed psychiatric extension. There are reports that patients undergoing scoliosis surgery with an intraoperative wake-up test using remifentanil had impaired sleep quality that lasted up to 6 months postoperatively. (27) But in our case, we did not use any wake-up testing.

CONCLUSION

Posterior vertebral column resection is a technically demanding three column spinal osteotomy that allows correction of rigid spinal deformities which is otherwise not possible with the conventional procedures but should be done in tertiary care setup with neuro-monitoring control. All though the technique is over all safe but complications can happen. We have demonstrated its ability to correct deformities in both the coronal and sagittal plane.

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