Modulating Asymmetrical growth of scoliotic spine is the key to success treatment of scoliosis in growth children

Qibin Ye, Zhengda Kuang, Guanjun Wang, Xinyu, Zhang, Ming kui Du
Dept of Orthopaedic surgery, General Hospital of Chinese People’s Armed Police Forces & Peking Union Medical College, PUMC Hospital. CAMS Beijing (100039)
Correspondence to: Qibin Ye, Department of Spinal Surgery, General Hospital of Chinese People’s Armed Police Forces, 69 Yongding Road, Beijing 100039, China. E-mail: yeqibin@263.net

Background:
Over the years, though many nonfusion techniques are effectively in correcting the scoliosis deformity, they do not stop progression of scoliosis curvature. Scoliotic curve progression after surgical correction in growing children continues to be a problem. The rapid progression is thought to be still exist asymmetric growth after surgical treatment of childhood scoliosis resulting from asymmetric stress on the both sides of the scoliotic spine. Aronsson stated that in convex side, there are 10% more length growing than concave side in 30º scoliotic spine, a small lateral curvature of the spine can produce asymmetrical spinal loading that causes asymmetrical growth and a self-perpetuating progressive deformity during skeletal growth(2). Many factors can affect the longitudinal growth of vertebrae, but the most important one is stress (,3)

In recent years, all the researchers are looking for a way to modulate the asymmetric growth on both sides of the cartilage end-plate of the scoliotic spine to reverse such Volkmann effect. In the laboratory(animal model), scoliosis with vertebral wedging has been created by asymmetric mechanically loading and has been corrected by reversing the loading. The mechanical modulation of vertebral growth in the presumed asymmetrically loaded scoliosis spine with scoliosis was described by Stokes and Raof as a 'vicious cycle' (4,5,6), they addresses the concept of mechanical modulation of vertebral body growth in the pathogenesis of progressive adolescent scoliosis generally attributed to the Hueter-Volkmann law in which constant pathologic strong pressure inhibits endochondral longitudinal growth while reduced compression accelerates growth. We think that transference of idea from controlled animal studies to clinical application is possible if a new device which has modulating function be able to provide two kinds of effects: either to modify the vertebral growth asymmetrically, or to modify the forces acting on the spinal column and endplate physis.
Currently, several nonfusion instrumentation system are adopted in the clinical practice. These include: distraction based: Growing rods (7) VEPTR (8); guided growth: Luque-Trolley Shilla (9); compression based: Staple(10); Tether (11). All these devices have the merit to correct progressive early onset scoliosis (EOS). However, there is only VEPTR and Shilla was approved for non-fusion by FDA and they almost has no modulating efficiency, as that the above method not only provide strong and static fixation, but also tether tightly the both ends of the scoliotic curvature on concave side after operation. Actually, the effect of distraction efficiency only appears at the moment of distraction procedure during the operation, then turns to tethering efficiency on concave side after operation because upper and lower ends of the scoliotic curvature were tethered, this artificially-created static with sustained compression loading is near-symmetric loads in scoliosis spine to the immature vertebrae suppressing linear growth, so they could not automatically create tensile stress on concave side postoperatively in the children's later growth year, and almost need repeated instrument-lengthening operations (every 6 months on average). Besides, a definitive spinal fusion will be required later. Ideally a new device should be able to correct the deformity without fusion and maintain the correction results in one stage operation with growth potential of the instrumented segments. For this purpose Plate Rod System for Scoliosis (PRSS) was developed in PUMC Hospital in 1998 (12).

**Therapeutic Mechanism**

PRSS due to its characteristics of elasticity and curve structure, and the middle and bottom part of the instrumentation is not fixed and without fusion in the operation, thus, there is no tether fixation on concave side of the scoliosis, which allow PRSS rod migration upward and downward during patient's activity. In this manner, the stimulation of tensile stress is produced in concave side constantly by the lateral sidewise push over the convex side while compression stress on the convex side, the asymmetrical stress results in subsequently asymmetrical growth over both sides of the vertebrae in the coming growing year to realign of the spine; essential normal spinal movement can be obtained after removing the
implants when the skeletal growth terminated. (13) Several experiments were studied and has confirmed PRSS possesses the function of modulating asymmetrical growth of the scoliotic spinal segments.

**Roengenological analysis** When PRSS is put in place, asymmetrical stress is created by the lateral sidewise push of the plate-rod, compressive stress exerted over the convex side, while tensile stress is exerted over the concave side of the curvature which is expressed in the change of the width of the disc spaces (Fig 2 A,B), in this manner affects, the subsequently asymmetrical growth over both sides of the vertebral cartilaginous end plate happened. Over the years wedging vertebrae was gradually remodeled to normal shape (Fig 2,A & C),

![Photo-elastic test](image)

**Photo-elastic test** Photoelastic study was used to show the mechanical properties of PRSS A model of scoliosis and correcting clamp was built on the base of similar principle. According to the factual situation, the in-situ stress was measured by using photoelastic and strain gage method. ANSYS method was also applied to simulate the experiment process and evaluate the reliability of measurement. The results indicated that the relational changes variation of stress on both sides of scoliotic spine was reflects by the change on the color band in the photoelastic test, Color stripe showed: when the lateral push was applied over the convex more concentration of color stripe appeared on convex side indicating compressive stress increase on this side and tensile stress was
produced on concave side (fig 3 (1)). It was also shown that the stress values was in proportion to the correcting load. The asymmetrical stress data were expressed in a linear formulation of green line as change of compressive stress on concave side; red one on convex side (fig-3-(2)), indicating PRSS has a significant power to altered the asymmetric mechanical loading on both side of the scoliotic spine.

Fig 3, photo-elastic study shows PRSS provides asymmetrical stress on both sides of the end plates of the vertebrae.

**TypeⅩcollagen study.** TypeⅩcollagen has also been studied to express the therapeutic mechanism. Type Ⅹ collagen is used to reflect chondrogenesis, subchondrobone formation and cartilage degeneration. Type Ⅹ collagen was studied as growth mark of cartilage end plate using semi-quantitative RT-PCR method, more type Ⅹ collagen expressed on convex side than concave side (Fig.4), it suggest that compressive stress leads to increase earlier cartilage degeneration of end plate in convex side correlating as well as he decreased growth of the end plate of this side, and resulting in maximum spinal realignment.
The clinical outcome showed that PRSS has a modulating efficiency to low or prevent the risk of scoliotic curve progression after-op.

In our clinic, the outcome of a series of 23 juvenile scoliosis and a group of 66 adolescent scoliosis treated with PRSS showed that PRSS has a significant efficiency to low the risk of scoliotic curve progression (Fig.5) due to its modulating function. In the latest follow up, there were no significant loss of correction. Most of the patients in our hospital were treated in single operation with PRSS and were without fusion, attempt. Repeated procedure was not required and spinal motion was preserved after removing PRSS when children growth terminated. Fig.5.

Fig 5. YXF 4 yrs old
boy with Cobb angle 64°(A), the curvature was corrected to 0°(B). At recent 6 years post-operative follow-up, scoliotic curve was 5°(C), the instrumented spinal column has gained 4.5 cm increase (see arrow at B C).

Curve correction continue improving itself after op, which is an evidence of the modulating efficiency of PRSS.

In our clinical practice, studies have shown that 3 cases had curve correction continued improvement after PRSS instrumentation in the later growing year. Figure6 showed a 10 years old boy with T9 Hamivertebae scoliosis of 58°(Fig.6A), posterior operation was performed to remove the hamivertebae using transpdyicular approach and fixed with PRSS. Scoliotic curve correction continued improvement from 58° to 40 °(B), in the resent followed-up 4 years after operation, scoliotic curve correction continued improvement from
40° immediately after operation to 25°(C), instrumented segments growth 5.5 cm (see B and C arrow). This is another evidence to show that PRSS possesses the function of modulating asymmetric growth of the scoliotic spinal segments in later growing year after operation.

![Images showing spinal growth and correction](image1)

**Fig.6.** Zhao xx a 10 years old bay with T9 Hemivertebrae scoliosis of 58°(A), After operation scoliotic curve was 40°(B). In the resent followed-up 4 years after operation, scoliotic curve correction continued improvement 25°(C), instrumented segments growth 5.5 cm (see B and C arrow).

Our clinical data showed that **Progression of scoliotic curve after operation could be gradually corrected again by reversing the Huetter-Volkmann effect with PRSS** fig 7, and the fusion developed on convex side over the apical area several years after operation in same case H, white arrow) while in concave side disc space is still intact.(H, black arrow). indicating that there is a potential growth ability in concave side,
Fig. 7. Zuxx a 3 year old boy with a scoliotic curve of 98° (A) After operation scoliotic curve was 37° (B) the IVDA was 10° (C, black arrow) seven years after operation the scoliotic curve 63° (D), after 2nd-operation scoliotic curve was reduced to 40° (E), IVDA was reduced to -5° (F) See arrow In the recent follow-up scoliosis was 28° (G), curve correction maintained and fusion developed on convex side over the apical area (H-I) good posture was seen (J,K,L)

Our studies has introduced a new idea for the treatment of children scoliosis, that is a new device should be no tethering on concave side. Correction mechanism for growing scoliosis
should be changed from distraction on concave side to the lateral sidewise push on convex side and from Static lording to dynamic lording.

Conclusion: The PRSS which has significant modulating efficiency is an effective instrumentation for correcting growing scoliosis, especially for EOS. However, our studies are of one instrumentation—PRSS, multicenter study is need to evaluate real merit of this technique.