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ORIGINAL ARTICLE

Effects of posterior distraction forces on anterior column intradiscal pressure in the dual growing rod technique

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Abstract
Background Little evidence is available addressing biomechanical properties of posterior distraction forces and their effects on anterior spinal column in the growing rod technique. The question is often asked if posterior distraction forces may be kyphogenic. The goal of this study is to determine whether posterior distraction forces transmitted anteriorly through different foundation constructs (i.e., screws vs. hooks) affect intradiscal pressure.
Methods Six skeletally immature porcine spines were harvested leaving soft tissues and rib heads intact. Pedicle screws served as the lower foundation on a L3–L4 motion segment while pedicle screws and laminar hooks were randomly used at T3–T4 levels. Proximal constructs (hook vs. screw) were switched after initial distraction testing. The dual rod distractor was instrumented with strain gauges and calibrated using a custom force transducer. During distraction, intradiscal pressures immediately inferior to the superior foundation and the level equidistant between foundations were measured using needle pressure transducers. Maximum distraction force and maximum anterior disc pressure change were compared between hook and pedicle screw anchors using one-way ANOVA ($p < 0.05$).
Results Upper foundations with pedicle screws had significantly greater distraction forces (416 ± 101 N) than those with upper level hooks (349 ± 100 N). There were no significant differences in disc pressures between levels or between upper foundation constructs. Disc pressures adjacent to the upper foundation demonstrated greater reduction (disc expansion) than the level equidistant within the construct. Pedicle screw constructs demonstrated greater endplate separation (distraction) compared to hook constructs.
Conclusions Posterior distraction forces result in anterior disc separation (distraction) and are distributed across multiple levels rather than delivered to the disc immediately adjacent to a foundation. Constructs with upper foundation hooks had lower distraction forces possibly due to hook motion during distraction. The load distribution at multiple levels may assist with curve control and may affect vertebral growth. The distraction forces may not be kyphogenic as is commonly believed.

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Introduction

Early onset scoliosis (EOS) can often present an extremely challenging clinical scenario. While bracing/casting can be utilized as initial treatments, these techniques may often fail to stop progression and may be considered only as delaying tactics [1, 2]. Spinal fusion and instrumentation are the gold standard for adolescent or adult deformity correction; however, it is contraindicated in the EOS patient population since spinal fusions will limit thoracic growth and adversely affect pulmonary development/function [2–4]. Growth-sparing surgical treatment that allows both deformity correction and spinal growth has existed since 1962 when Harrington [5] advocated for instrumentation without fusion in patients less that 10-years-old. In

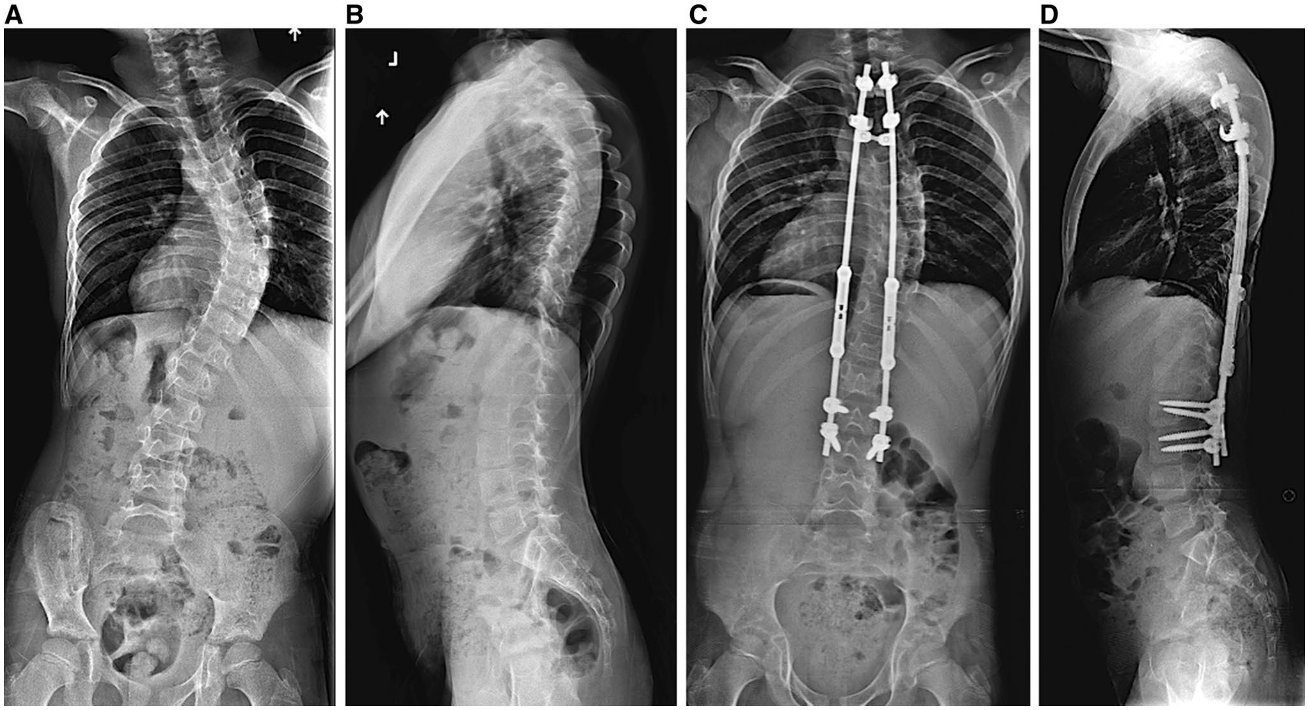

Fig. 1 Radiograph of instrumentation and deformity correction with dual growing rods. Preoperative anteroposterior (**a**) and lateral (**b**) radiographs and postoperative anteroposterior (**c**) and lateral (**d**) radiographs of an early-onset scoliosis (EOS) patient are shown

1979, Moe et al. [6] used a "subcutaneous rod technique" specifically for children with remaining growth potential. The original growing rod technique used a single distraction rod to lengthen periodically - the spine, but it did not provide stable fixation and was associated with a high rate of implant failures [7, 8].

Modifications to surgical implants and techniques have evolved into the modern dual growing rod procedure [9–12]. The use of dual growing rods allows improved initial curve correction and maintenance of the correction over time, greater overall spinal growth, and fewer complications compared to previously used single rods [8]. In the dual rod technique, the construct typically utilizes laminar hooks and/or pedicle screws to create "foundations" to which the system is anchored (Fig. 1a–d). Previously reported data has shown significantly greater biomechanical stability with pedicle screw foundations compared to laminar hooks [13]. Increased stability of pedicle screws offers the surgeon greater control in applying the distraction force during spinal lengthening. While screws may be more stable than hooks, it is unclear whether the use of one system facilitates greater distraction force application to the spine [13].

It is also unclear whether posterior spinal distraction maneuvers adversely affect the anterior column by altering intradiscal biomechanics or if the distractions have kyphogenic properties. It is theoretically possible that the distraction maneuver primarily affects a single motion segment (likely the disc space adjacent to the foundation) rather than affecting multiple segments. It is also possible that the posterior distraction forces cause a focal kyphotic deformity as the motion segment used for the foundation levers on the adjacent disc creating a compressive load. Each of these scenarios may adversely affect the potential for growth of the axial skeleton and should, thus, be further explored [14]. The purpose of this study was to determine the effects of posterior distraction forces as well as different anchors on intradiscal pressures when using the dual growing rod technique for correction of EOS.

Methods

Six skeletally immature 12-week-old (~25 kg) porcine spines were harvested from T3 to L4 leaving soft tissues and rib heads intact. Similar porcine spines were used in a previous study to explore the utility of pedicle screw placement [15]. That study reported pedicle widths of approximately 5–6 mm that accommodated standard pediatric ISOLA spinal instrumentation (Depuy Spine, Raynham, MA, USA) consisting of 4.75 mm pedicle screws. In the current study the L3–L4 motion segments were instrumented with 4.75 mm pedicle screws with an appropriate length for each vertebral body. The T3–T4 motion