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Construct Levels to Anchored Levels Ratio and Rod Diameter Are Associated With Implant-Related Complications in Traditional Growing Rods

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Abstract

Introduction: In addition to patient characteristics, consideration of length of construct to number of anchored levels ratio and rod diameter should be a part of preoperative planning to minimize implant-related complications (IRCs). IRCs including rod breakage, anchor dislodgement, and pullout are among the most common adverse events in traditional growing rods (TGRs). The current study hypothesized that anchor type and configuration are associated with IRC.

Methods: Patients with (1) age ⩽10 years at surgery; (2) spine-based dual TGR; (3) minimum 2-year follow-up; and (4) available imaging. Cephalad and caudal foundations were grouped based on the number of instrumented levels and anchor type. All radiographs were reviewed. Based on the results, a "construct levels / anchored levels" (CL/AL) ratio was calculated, which is the number of levels spanned by instrumentation divided by the number of levels with bone-anchor fixation. Receiver operating characteristic curve was used to define the CL/AL threshold.

Results: 274 patients divided into patients with complications (IRC+, n = 140) and without complications (IRC−, n = 134) groups. Mean follow-up was 6.3 years (2.1−18.0 years). No significant differences in age, gender, body mass index, ambulatory status, etiology, primary curve size, T1−S1 height, coronal and sagittal balance, and rod material were observed between the two groups. Comparative analysis showed that connector type, presence and location of crosslinks, number of levels instrumented, number and type of anchors, presence of pelvic fixation, and mirroring of cephalad and caudal foundations were not different. However, maximum kyphosis and rod diameter were significantly different. The CL/AL ratio threshold was 3.5. Multivariate analysis of kyphosis, rod diameter, and CL/AL ratio showed a significant association with IRC ($p < .05$).

Discussion and Conclusion: Although patient characteristics like kyphosis have been proven to be associated with instrumentation failure, it is a combination of characteristics that include rod diameter and CL/AL ratio that showed significant correlation with IRC. Validation of the CL/AL ratio is recommended.

Keywords: Traditional growing rods; Dual growing rods; Implant-related complication; Foundation; Anchor type and characteristics

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Introduction

Since the introduction of Harrington instrumentation by Harrington [1] and instrumentation without fusion by Moe et al. [2], it has been shown that growing rod surgery is associated with a high rate of complications. These complications span from surgical site infections to alignment-related and implant-related complications (IRCs). IRCs are among the most common adverse events in traditional growing rod (TGR) surgery and include rod breakage, anchor dislodgement, and pullout [3-5]. The risk factors for IRC in TGR have been addressed in few yet worthy publications. Several risk factors including rod metal type, rod diameter, location of rod insertion (subcutaneous or submuscular), age at the index surgery, mobility status, amount of the curve correction at index surgery, major curve size, maximum kyphosis, and underlying diagnosis have been recognized [5-8]. So far, very few authors have studied the correlation of TGR anchor types and foundation characteristics with IRC [9-11]. To the authors' knowledge, no study has systematically analyzed the entire spinal construct relative to the incidence of IRC in a large series of TGR patients. The current study hypothesized that both the cephalad and caudal anchor types and their configurations are influencing IRCs in TGRs.

Methods

A multicenter early-onset scoliosis (EOS) database was queried after obtaining institutional review board at all participating centers. Patients who met the following inclusion criteria were included in this study: (1) age <10 years at the time of index surgery; (2) spine-based dual TGR; (3) minimum of 2-year follow up; and (4) availability of 36-inch-long anteroposterior and lateral radiographs. Patients who had single growing rod constructs, rib-based anchors, Vertical Expandable Prosthetic Titanium Rib (VEPTR), and patients with additional apical instrumentation were excluded. Of the 721 TGR cases, 284 were excluded owing to lack of availability of required radiographs. From the remaining 437 TGR cases, 163 were excluded because of not meeting the two-year follow-up, which left us with 274 cases that met the inclusion criteria. With the use of the EOS database, all available radiographic imaging at each time point for each patient in the series were reviewed. All radiographic measurements and construct data were recorded, including the anchor number, type, anatomic location, and configuration at both cephalad and caudal foundations, number of levels with and without anchors within the instrumented segments, density of constructs (calculated by number of fixation points divided by number of levels), rod diameter, rod metal type, growing connector type (tandem or side to side), presence and location of crosslinks, and presence of pelvic fixation. The authors also compared the configuration of the cephalad and caudal foundations (not left to right) based on the similarity of the anchor type (screw, hook, and mix) and levels (how many implants at each level on either side of the spine) and referred to it as "mirroring." For example, four pedicle screws (one screw in each pedicle at two levels) in the cephalad foundation and four pedicle screws (one screw in each pedicle at two levels) in the caudal foundation was considered a mirrored construct. On the other hand, a construct with four pedicle screws in the cephalad foundation at three levels (two pedicle screws in one level on either side, one pedicle screw at the next level on one side, and the last pedicle screw in the lower level on the other side) was not considered the mirror image of a caudal foundation, with four pedicle screws with one screw in each pedicle at two levels.

IRC was defined as rod fracture, anchor prominence, loosening, and pullout. Loosening was defined as the loss of bone-implant contact without implant migration, and pullout was considered as the loss of bone-implant contact with implant migration. In regard with anchor prominence, only the cases that required revision surgery for their prominence were considered as IRCs. The authors reviewed all the radiographs and confirmed all IRC findings that were reported in the EOS database. Radiographs were evaluated until the very first IRC occurrence since all of these patients underwent surgical instrumentation revision, which eventually changed the instrumentation characteristics compared with the initial characteristics at the time of index surgery.

Initially, a univariate analysis was used to assess risk factors for IRC among the entire cohort of 274 patients. Subsequently, the entire cohort was tested with a multivariate analysis with controlling for all significant risk factors previously identified by the univariate analysis to test their association with IRC. For all of the statistical analyses, the p value was set at $<.05$.

Table 1
Classification of proximal and distal anchor foundations.

	2 levels, n (%)	3 levels, n (%)	>3 levels, n (%)
Cephalad foundation			
Pedicle screw	89 (32.5)	39 (14.2)	0
Hook	2 (0.7)	10 (3.6)	1 (0.4)
Mix	93 (34.0)	36 (13.1)	4 (1.5)
Caudal foundation			
Pedicle screw	209 (76.2)	22 (8.0)	7 (2.5)
Hook	12 (4.4)	0	0
Mix	22 (8.0)	2 (0.7)	0