Acta Orthop. Belg., 2014, **80**, 457-463

ORIGINAL STUDY

Growing rod instrumentation in the treatment of early onset scoliosis

Turgut Akgül, Fatih Dikici, Cüneyt Şar, Ufuk Talu, Ünsal Domaniç

From the İstanbul University, İstanbul Faculty of Medicine, Turkey

The goal of the treatment of early onset scoliosis (EOS) is correction of the deformity while still allowing for spinal growth. The aim of this study was to determine the safety and effectiveness of the single and dual growing rod techniques and which technique was the most effective in the management of EOS respectively. From 2003 to 2009, 23 patients underwent single (15) or dual (8) growing rod procedures using a pedicle screw construct and tandem connectors. The etiology of the patients' spinal deformities were as follows ; infantile, juvenile idiopathic, congenital and neuromuscular. Clinical evaluation included age, sex, diagnosis, follow-up, number and frequency of lengthenings, and complications. Radiographic evaluation included measured changes in Cobb angle, kyphosis, lordosis, frontal and sagittal balance. Overall 46 lengthening procedures were performed, the average number of lengthening procedures being 2.1 +/- 1.14 per patient. The average time between two lengthening procedures was 13 (2-28) months. Average follow-up time was 40.8 +/- 20.6 months.The mean coronal Cobb angle was improved from 64.8° +/- 16.6° to 39.7°+/- 16.4°.Statistically, at the final follow-up, early postoperative measurements in the coronal plane were better in the dual growing rod group than in the single rod group. Nine patients underwent fusion surgery. Their mean age was 11 (10-14) years, with a follow-up of 34.6 (14-54) months. The mean Cobb angle before fusion was 58.7° (40°-75°). There were 0.9 complications per patient in all groups, 0.38 in the dual rod and 1.2 in the single rod group, respectively. Dual growing rods result in better deformity correction and stability of correction with an acceptable complication rate.

No benefits or funds were received in support of this study.
The authors report no conflict of interests.

Keywords : early onset scoliosis ; Growing rod ; subcutaneous rodding without fusion.

INTRODUCTION

Management of early onset scoliosis (EOS) is a challenging problem. Infantile and juvenile idiopathic scoliosis, neuromuscular deformities and congenital scoliosis are grouped under EOS by Akbarnia (*3*). Several treatment modalities have been described. Initial treatment, involves observation, bracing and serial casting (*7,13,14,16,20*). The success of each type of treatment modality varies. Surgical treatment is indicated for a congenital deformity, progressive deformity or when the other treatment modalities fail to control the deformity (*2,4,6,9,10,15,17,19,22*).

Correction and maintenance of a deformity requires solid fusion. This has been the standard

■ Turgut Akgül, MD, Orthopaedic Surgeon.
■ Fatih Dikici, MD, Orthopaedic Surgeon, Assos. Professors.
■ Cüneyt Şar, MD, Orthopaedic Surgeon, Professors.
■ Ufuk Talu, MD, Orthopaedic Surgeon, Professors.
■ Ünsal Domaniç MD, Orthopaedic Surgeon, Professors.
Department of Trauma and Orthopaedics, İstanbul Faculty of Medicine, İstanbul, Turkey.
Correspondence : Dr Turgut Akgül, İstanbul Medicine Faculty, Department of Orthopaedic and Traumatology, İstanbul university, Çapa,Fatih, İstanbul, Turkey.
E-mail : doktorturgut@yahoo.com

surgical approach for a patient who has completed spinal growth. Some authors have proposed solid fusion for EOS as well. However, early fusion will effect the development of the thorax negatively and a crankshaft will probably occur at follow-up (*24*).

The goal of the treatment in EOS is correction of the deformity and allow spinal growth at the same time. Surgery without fusion can maintain sagittal balance and correct the deformity without impairment of spinal growth (*2,4,6,9,10,15,17,19,22*). It is the most common treatment for EOS despite requiring more surgery resulting in more surgical scars. Variable success rates have been reported.The growing rod is a common and useful technique for EOS. Several studies report the growing rod to be effective, with advantages and complications (*2,4,6,10,15, 17,22*). We performed single and double growing rod procedures, without fusion,using a pedicle screw construct for foundation.

The aim of this study was to determine the safety and effectiveness of single and dual growing rod techniques in terms of achieving and maintaining scoliosis correction for the growing spine and see which technique was more effective in the management of EOS.

MATERIALS AND METHODS

From 2003 to 2009, 23 patients (nine (39%) male and 14 (61%) female) underwent single or dual growing rod. procedures in the Istanbul University Faculty of Medicine Department of Orthopedics and Traumatology We performed 15 single (Fig. 1) and eight dual growing (Fig. 2) rod operations. The average age was 7.5 +/- 2.2 years for both groups. The etiology of the patients' spinal deformities were as follows ; nine infantile idiopathic, two juvenile idiopathic, ten congenital and two neuromuscular scoliosis. Twenty-two patients had no prior surgery for EOS. Curve types were thoracic in eight, thoracolumbar in nine, double major in four and lumbar in two.

Standard standing AP radiographs of the spine were used to determine the end vertebrae for pedicle screw constructs. There was no difference between single or dual rod groups in the determination of the instrumentation levels. The most distally instrumented vertebra was determined according to the stable vertebra criteria. Only the concave side of the main curve was instrumented in the single rod group.

A posterior midline longitudinal incision was made separately at the proximal and distal instrumentation sites,respectively. Facet joints were preserved as much as possible. Pedicle screws were inserted using fluoroscopy. We did not use any bone graft to obtain a solid fusion at the foundation site but decortication occurred due to the surgical approach. A titanium 4,5 mm rod and tandem connector (two of each in the dual rod group) were inserted through the paravertebral muscles using the subfascial plane and attached to the pedicle screw. The tandem connector was tightened after manuel distraction with a distractor. We did not use connectors for extra stability in the dual rod technique. Lengthening was performed under fluoroscopy through a small incision at the tandem connector site.

Clinical evaluation included age, sex, diagnosis, follow-up, number and frequency of lengthening, and complications. Postero-anterior and lateral orthoroentgenography were performed initially and during the follow-up period. Radiographic measurements included changes in Cobb angle, kyphosis, lordosis, frontal and sagittal balance. The data were collected before the initial operation, during the early postoperative period and before the final fusionoperation or at the last follow-up. Amount of initial correction and maintenance during follow-up were analysed.

Patients were mobilized on the first postoperative day, wearing a TLSO (thoracolumbar orthosis) brace during daytime.Only strenuous activities were restricted, allowing regular daily activities.

Iliac bone ossification was used to determine skeletal maturity. Patients with Risser 4 and 5 underwent fusion surgery. Fusion surgery was performed earlier in one patient with Risser 3 because of stiffness that did not allow effective lengthening.

NCSS (Number Cruncher Statistical System) 2007 and PASS (Power Analysis and Sample Size) 2008 Statistical Software (Utah, USA) were used for statistical analysis. The Mann-Whitney U test was used to compare radiological variables between the two groups. A Wilcoxon rank test was used to compare radiographic variables in each group. The significance level was set at $P < 0.05$.

RESULTS

Overall 46 lengthening procedures were performed, the average number of lengthening procedures being 2.1 +/- 1.14 per patient. The average time between two lengthening procedures was 13

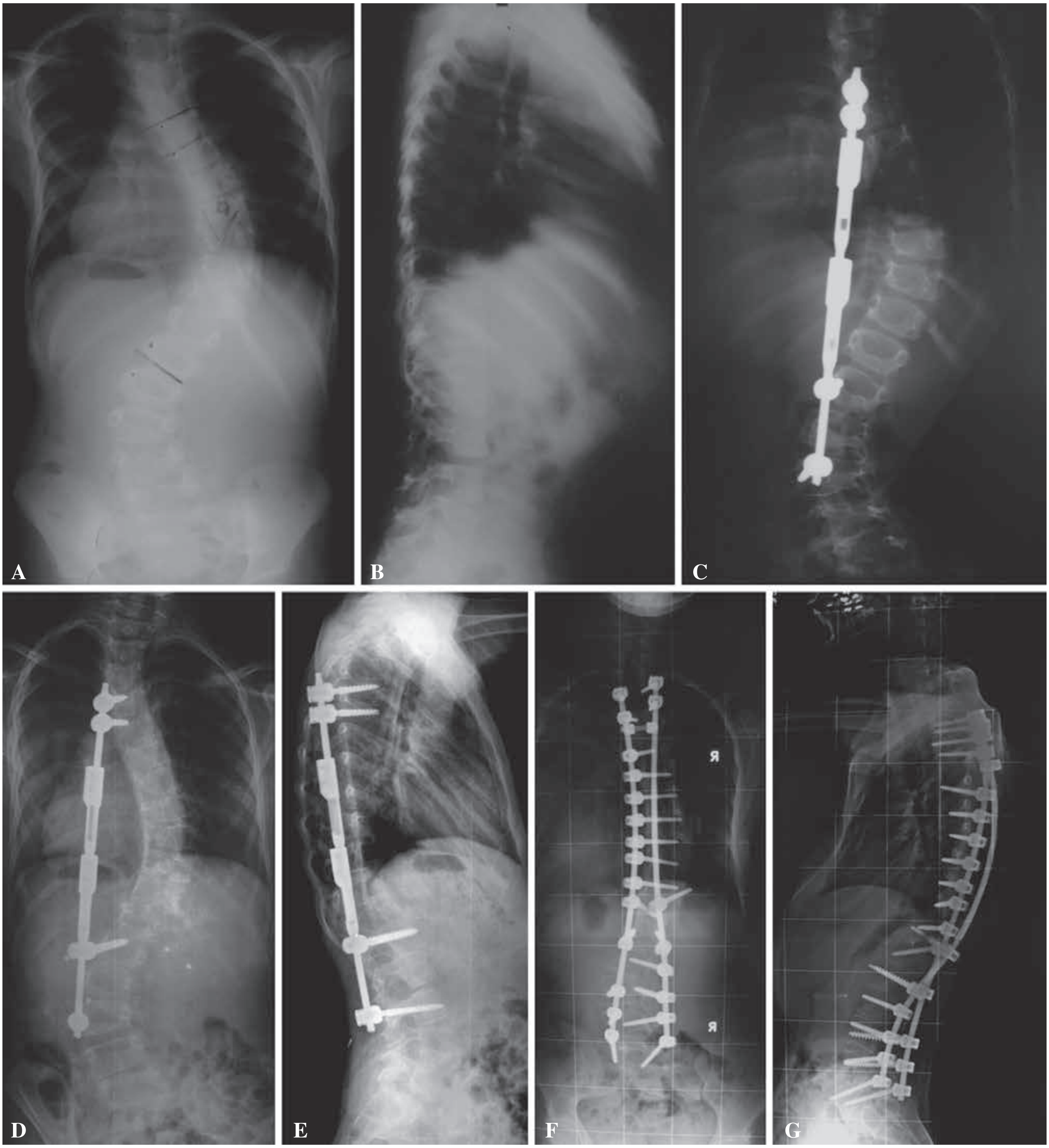

Fig. 1. — A, Preoperative PA standing spinal radiograph of a 7-year old female with infantile idiopathic scoliosis, with a 62-degree thoracolumbar curve. B, Preoperative lateral radiograph demonstrates normal sagittal alignment C, Postoperative radiograph after insertion of a single growing rod with pedicle screw proximally and distally. The major curve was reduced to 30 degrees. D, PA standing spinal radiograph, taken after routine lenghtening procedure showing thorocalumbar curve improvement (40×). E. Lateral radiograph showing acceptable maintenance of sagittal alignment. F. Postoperative PA standing radiograph after fusion surgery showed well balanced spine. G. Lateral radiograph showing acceptable maintenance of the sagittal alignment after fusion surgery.

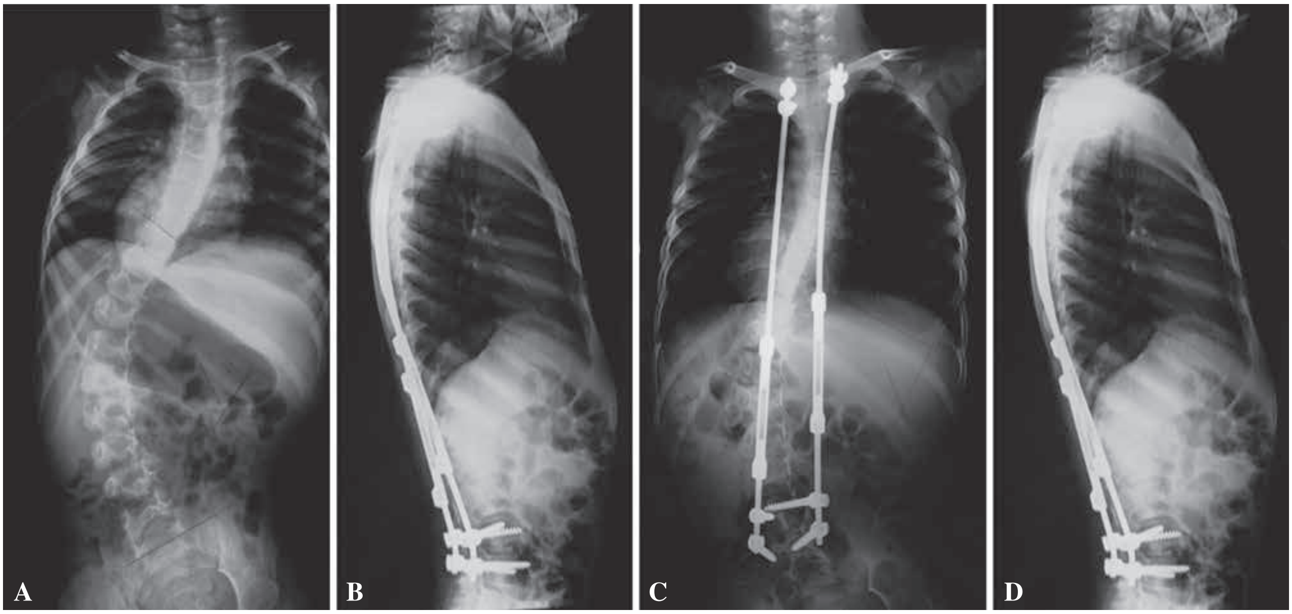

Fig. 2. — A, Preoperative AP radiograph of the spine of a 5-year old male with neuromuscular scoliosis demonstrating a 64-degree curve. He has been treated with serial casting for one year. B, Preoperative lateral radiograph demonstrating a 30 degree kyphosis and lordosis, respectively. C, Postoperative AP radiograph before the third lengthening of the dual growing rod instrumentation showing a 40 degree curve. D, Postoperative lateral radiograph showing acceptable maintenance of sagittal alignment.

(2-28) months. Average follow-up time was 40.8 +/- 20.6 months. Lumbar hemivertebrectomy and corrective osteotomy for lumbosacral hyperlordosis was performed along with a growing rod in one case.

Overall, at the initial examination, the mean coronal Cobb angle was 64.8° +/- 16.6°, the mean sagittal thoracal global kyphosis was 28.8° +/- 20° and the mean sagittal lumbar global lordosis were 35.2 ° +/- 17.7°. Post-operatively the Cobb angle improved to 39.7° +/- 16.4°, kyphosis to 28.2° +/- 20.2° and lordosis to 28° +/- 14.4°.

In the single rod group, the Cobb angle improved from 68° +/- 17.2° to 44.9° +/- 15°. Kyphosis improved from 34.5° +/- 29° to 33.7° +/- 20.7°. Lordosis improved from 36.7° +/- 20.4° to 29.9° +/- 14.4°. After a mean follow-up of 43.6 +/- 23.2 months, the mean Cobb angle measured 60.6° +/- 28.5°.

In the dual rod group, the Cobb angle improved from 58.8° +/- 14.5° to 30.25° +/- 15.5°. Kyphosis improved from 18.25° +/- 20.2° to 17.8° +/- 15.5°. Lordosis improved from 32.5° +/- 11.6° to 24.8° +/- 14.8°. After a mean follow-up of 35.7 +/- 14.6 months, the mean Cobb angle measured 36.5° +/- 13.3°.

There was no significant difference between the two groups in the measurements of the preoperative coronal and sagittal planes. Statistically, at the final follow-up, early postoperative measurements in the coronal plane were better in the dual growing rod group than in the single one. The single rod group had a statistically significant greater loss of correction in the coronal plane compared to the dual rod group. No statistical difference was found between the two groups for the mean follow-up period and age distribution.

Nine patients, (eight single and one dual rod) underwent fusion surgery. The mean age at the time of the fusion surgery was 11 (10-14) years with a mean follow-up of 34.6 (14-54) months. The mean Cobb angle before fusion was 58.7° (40°-75°). Fusion surgery was performed via a posterior approach in all patients except one, in whom a combined anterior and posterior approach was used. Three patients with single rods were revised with dual growing

Table I

Pts	Age	Gndr	Diagnosis	Growing rod	Follow up	Pre Cobb	Post. Cobb	Pre Kyph	Post Kyph	Pre Lord	Post Lord	Level	Lngt	Lat. Cobb	Lat Kyph	Lat Lord	Latest	Complication
1	8,7	F	Congen.	Single	14	90	60	0	17	15	2	T1-12	1	75	30	8	Fusion	
2	7,2	F	Infantile	Single	60	60	45	44	35	50	45	T5-L4	1	61	42	35	Dual	
3	7,40	M	Congen.	Single	84	80	68	20	10	20	16	T1-L4	2	65	20	25	Single	Rod brkg, infect.
4	9,3	M	Neuro.	Single	72	44	40	40	36	-2	48	T1-L4	1	30	30	40	Single	Rod brkg, infect.
5	9,6	M	Juvenile	Single	20	50	35	18	48	55	22	T2-12	0	30	40	32	Fusion	
6	10,3	F	Juvenile	Single	39	60	40	34	35	50	35	T2-L1	1	55	55	45	Fusion	Screw fracture
7	5,1	M	Congen.	Single/ oste.	54	60	25	30	20	80	30	T1-S1	3	55	10	40	Fusion	Rod brkg
8	7,5	F	Infantile	Single	32	65	40	-16	-4	44	20	C7-L4	2	75	-5	30	Fusion	Rod brkg*2
9	9,2	F	Infantile	Single	23	92	70	90	60	35	30	T1-L4	2	130	70	60	Spon.F	Rod brkg
10	8,4	M	Infantile	Single	24	100	55	87	77	54	60	T4-L1	2	60	70	40	Fusion	Rod brkg, screw loss., wound irrita.
11	8	F	Congen.	Single	24	78	60	68	54	46	30	T2-L4	3	50	80	60	Fusion	Rod brkg
12	5,6	F	Congen.	Single	28	55	30	35	38	32	30	T2-10	2	30	55	55	Dual	
13	3,6	M	Infantile	Single	84	45	25	28	15	20	20	T3-L2	5	43	32	30	Dual	Rod brkg
14	5,9	F	Congen.	Single	44	72	50	20	30	32	40	T2-L5	4	110	45	60	Single	Menengitidis,nut loss.
15	9,8	F	Infantile	Single	52	70	30	20	35	20	20	T5-L3	2	40	85	30	Fusion	Screw loss.
16	10	M	Congen.	Dual	48	50	30	30	18	40	40	T2-L1	3	40	30	70	Fusion	
17	4,3	F	Congen.	Dual	45	30	10	10	20	30	20	T11-L5	3	28	25	20	Dual	
18	9,2	F	Infantile	Dual	44	70	35	45	40	50	50	T11-İl.	1	60	40	50	Dual	
19	9,7	F	Congen.	Dual	12	56	17	10	20	30	20	T4-L5	2	24	20	20	Dual	Rod brkg*2
20	4,9	M	Neuro.	Dual	52	64	40	30	30	30	30	T1-L5	3	45	25	42	Dual	
21	6,6	F	Infantile	Dual	32	70	20	30	18	40	10	T2-L5	3	20	25	12	Dual	Screw loss.
22	10	F	Congen.	Dual/vert.	36	55	30	-35	-13	10	5	T1-İl.	2	30	-10	5	Dual	
23	3,5	M	Infantile	Dual	17	75	60	26	10	30	24	T2-L3	1	45	15	25	Dual	
*	0,87				0.18	0.30	0.04	0.31	0.10	0.43	0.45		0,72	0.007	0,02	0,2		
**	**Single rod Cobb angle**			preop-postop p = 0,001 postop-control p = 0,01			**Single rod kyphosis** preop-postop p = 0,90 postop-control p = 0,015			**Single rod lordosis** preop-postop p = 0,12 postop-control p = 0,02				**Dual rod Cobb angle** preop-postop p = 0,002 postop-control p = 0,21				**Dual rod kyphosis** preop-postop p = 0,73 postop-control p = 0,15

*Statistical result comparing the two groups.** Statistical result comparing values in each group.

Pts: Patient, Gndr:Gender,F: female, M:male,Congen:Congenital, Neuro: Neuromuscular, Osteo:osteotomy, vert.: vertebrectomy, Follo up: Follow-up, pre: Preoperative, post: Postoperative, Kyph: kyphosis, Lord: Lordosis , Lngth: lengthening , Lat: Latest, Spon. F.: Spontan Fusion, Rod brkg: rod breakage, Loss. Loosening, İnfect: İnfection, wound irrita: Wound irritation.

rods because of implant failure (one patient) and uncontrollable curve progression (two patients). Spontaneous long segment fusion was noted in one patient in the single rod group during the follow-up period.

Twenty-one complications were noted, in the single rod group, such as superficial wound infections (n = 2), rod breakage (n = 12), wound irritation (n = 1), pedicle screw loosening (n = 3), pedicle screw breakage (n = 1), screw nut loosening (n = 1), and meningitis (n = 1). In the dual growing rod group, two rod breakages (in one patient) and one pedicle screw loosening was observed (Table I).

DISCUSSION

Scoliosis surgery without fusion was first described by Harrington in 1962 (*8*). Harrington and Luque reported a high complication rate that included implant failure and spontaneous fusion (*8,18,24*).

The growing rod technique without fusion has been popular in treating EOS while allowing for spine growth. In the literature, dual or single growing rod instrumentation has been reported with varying rates of success (*2,4,6,10,15,17,22*). Klemme *et al*. reported a coronal Cobb angle improvement from 67° to 47°, with a satisfactory sagittal curve management in a study of 63 patients with early onset scoliosis treated with a single growing rod. They recommended using an external support (*10*). Blakemore *et al*. report that a single growing rod is useful in the managing of EOS, although it has a high complication rate (*6*). Minerio *et al*. reported a 40% improvement in the measurement of the initial curve, using a single rod (*15*). It appears from the literature that a single rod is useful in the management of EOS. In our study,however, a single rod corrected the deformity and allowed spine growth, but it did not maintain this correction and had a high complication rate, which is also consistent with the literature. Acaroglu et al reported that a single growing rod allows for spine growth but can not stop the apical rotation and involves a high complication rate (*1*).

Akbarnia *et al*. advised a dual growing rod in the treatment of EOS (*2,3,4*). They showed that a dual growing rod can provide better correction and maintenance of correction compared to a single rod. A dual growing rod also had a lower complication rate than a single rod (*3,23*). In our study, a dual growing rod showed a statistically better coronal curve correction ($p = 0.002$) and maintenance of the correction ($p = 0,007$). Also, a dual growing rod is better in maintaining the sagittal curve ($p = 0,04$), although the correction is minimal ($p = 0,45$).

In our study,the time between two lengthenings was 13 months on average, which is much longer than in most studies (*2,3,4,6,9,10,15,17,22,23*). The reason of this difference is that, in the early period we have preferred to follow the patients closely after initial surgery and when an increase in the Cobb measurement was noted we proceeded with lenghtening. Minerio *et al*. and Blakemore *et al*. reported that they performed a lengthening after approximately Cobb angle increase of 20° (*6,15*). Akbarnia *et al*. recommended to perform a lengthening at 6 month intervals (*3,23*). Subsequently we have changed our protocol and started performing lengthenings at 6 month intervals on a routine basis. We clinically realized that in patients with a long interval between two lenghtenings, the major curves were stiffer than in other patients at the time of final fusion surgery.The average T1-S1 length increase was reported to be 1.2 cm per year in a multicentric study (*3*).

Hook complication, rod breakage, implant prominence and skin irritation were the major complications of the two techniques (*2-6,10,15,17,21-23*). Surgery without fusion has a high complication rate regardless of the surgical technique (*5,21*). We used a pedicle screw foundation to decrease the number of implant related complications. Mahar *et al*. showed in a biomechanical study that a pedicle screw construct provides better strength and stability compared to other implant constructs (*12*). Some authors recommend foundation site fusion to decrease implant related complications (*3,5,18*). We had five (22%) complications with pedicle screws. This seems to be an acceptable rate, being lower in the dual growing rod group (14%) than in the single rod group (28%). We had eighteen implant related complications that required surgical revision. There were 0,9 complications per patient in all groups, but this rate was 0,38 per patient in the dual rod group and 1,2 per patient in single rod group. Sankar *et al*. reported a rate of 2.06 implant related complications per patient (*21*).

In the treatment of early onset scoliosis, the growing rod is effective in correcting the deformity without restricting growth and maintaining the sagittal balance. Single and dual growing rods can be used. However, dual growing rods result in better deformity correction and maintenance with an acceptable complication rate. Parents should be well informed and warned about the length of treatment, recurrent operations and complications inherent with both of these techniques.

REFERENCES

1. **Acaroğlu E, Yazıcı M, Alanay A.** Three dimensional evaluation of scoliotic curve during instrumentation without fusion in young children. *J Pediatric Orthop* 2002 ; 22 : 492-6.
2. **Akbarnia BA, Blakemore LC, Campbell RM, Dormans JP.** Approaches for the very young child with spinal deformity : What's new and what works. *İnstr Course Lect* 2010 ; 59 : 407-24.
3. **Akbarnia BA, Marks DA, Boachie-adjei O, Thompson AG, Asher MA.** Dual growing technique for the treatment of progressive early onset scoliosis : a multicenter study. *Spine* 2005 ; 30 : 46-57.
4. **Akbarnia BA, Marks DS.** Instrumentation with limited arthrodesis for the treatment of progressive early onset scoliosis. *Spine* 2000 ; 14 : 181-90.
5. **Bess RS, Akbarnia BA, Thompson G**. Complication in 910 growing rod surgeries : Use of dual rods and submuscular placement of rods decrease complications. *Spine* 2008 ; 8 : 13-4.
6. **Blakemore LC, Scoles PV, Thompson GH.** Submuscular Isola rod with or without limited apical fusion in the management of severe spinal deformities in young children : preliminary report. *Spine* 2001 ; 26 : 2044-8.
7. **Nash CL.** Current concepts review : scoliosis bracing. *J Bone Joint Surg Am* 1980 ; 62 : 848-52.
8. **Harrington PR.** The history and development of Harrington instrumentation. *Clin Orthop Relat Res* 1973 ; 93 : 110-2.
9. **James JIP.** The management of infants with scoliosis. *J Bone Joint Surg Br* 1975 ; 57 : 422-9.
10. **Klemme WR, Denis F, Winter RB.** Spinal instrumentation without fusion for progressive scoliosis in young children. *J Pediatr Orthop* 1997 ; 17 : 734-42.
11. **Luque ER.** Segmental spinal instrumentation for correction of scoliosis. *Clin Orthop Relat Res* 1982 ; 163 : 192-8.
12. **Mahar AT, Bagheri R, Oka R, Kostial P, Akbarnia BA.** Biomechanical comparison of different anchors for the pediatric dual growing rod technique *Spine* 2008 ; 8 : 933-9.

Mehta MH. The rib vertebra angle in the early diagnosis between resolving and progressive infantile scoliosis. *J Bone Joint Surg Am* 1972 ; 54 : 230-43.

13. **Mehta M, Morel G.** In : Zorab P, Siezler D, eds. The non-operative treatment of infantile idiopathic scoliosis. London, *Academic Press*, 1979.
14. **Minerio J, Weinstein SL.** Subcutaneous rodding for progressive spinal curvatures : Early results. *J Pediatr Ortop* 2002 ; 22 : 290-5.
15. **Moe JH, Kettleson DN.** Idiopathic scoliosis analysis of curve patterns and the preliminary results of Milwaukee brace treatment in one hundred sixty nine patient. *J Bone Joint Surg* 1970 ; 52 : 1509-33.
16. **Moe JH, Kharrat K, Winter RB, Cummine JL.** Harrington instrumentation without fusion plus external orthotic support for the treatment of difficult curvature problems in young children. *Clin Orthop Relat Res* 1984 ; 185 : 35-45.
17. **Moe JH, Valuska JW.** Evaluation of treatment of scoliosis by Harrington instrumentation. *J Bone Joint Surg* 1966 ; 48 : 1656-7.
18. **Sanders JO, D'Astous J, Fitzgerald M, Khoury JG, Kishan S, Sturm PF.** Derotational casting for progressive infantile scoliosis. *J Pediatr Orthop* 2009 ; 29 : 581-7.
19. **Sanders JO, Herring JA, Browne H.** Posterior arthrodesis and instrumentation in the immature risser grade 0 spine in idiopathic scoliosis. *J Bone Joint Surg Am* 1995 ; 77 : 39-45.
20. **Sankar WN, Acevedo DC, Skaggs DL.** Comparison of complications among growing spinal implants. *Spine* 2010 ; 35 (23) : 2091-6.
21. **Tello C, Bersusky E, Francheri A.** Severe infantile scoliosis treated with repetitive distractions followed by definitive arthrodesis. *Scoliosis Research Society Annual Meeting, Seattle*, 2002.
22. **Thompson GH, Akbarnia BA, Kostial P.** Comparison of single and dual growing rod techniques followed through definitive surgery : A preliminary study. *Spine* 2005 ; 30 : 2039-44.
23. **Winter RB.** Scoliosis and spinal growth. *Orthop Rev* 1977 ; 6 : 17-20.