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Dual Growing Rod Technique for the Treatment of Early-Onset Scoliosis

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Abstract: Background: Early onset scoliosis (EOS) is known as bend of the spine in children >10° in coronal plane before 10 years old**.** This spinal malformation in early stage of life representing an important health risks for the child and a challenge to pediatric surgeon. **Objective:** To date the procedure, results, safety, effectiveness and general clinical outcome with the dual growing rod treatment technique in attaining and sustaining scoliosis correction while permitting spinal development. **Patients and Methods:** This retrospective study included 15 children with scoliosis in early stage. They were all treated with dual growing rode method in Atfal Misr Hospital orthopedic department. **Results:** The children were followed-up for 8-36 months (average 18 months) after first surgical treatment. The average number of lengthening was 2.6 (range, 1 – 5) per patient, the average age was 8.5 years (range, 7 – 10). **Conclusion:** The application of dual growing rod method is operative and safe. It upholds correction attained at first operation whereas allowing spinal growth to last. It upsurges the period of treatment, delivers acceptable constancy, and has a tolerable rate of complication matched with former reports using the single rod method. However, the complications are remains significant, and the long-term commitment before the therapy is initiated must be fully understand by the family. Moreover, to allowing persistent spinal growth, this technique of surgical treatment recovers the volume of thoracic cage in this challenging patients group. This is a continuing research, and long-term follow-up is required to approve our temporary results.
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1. Introduction

EOS is subclassified to infantile and juvenile according to the age of onset. Many different etiologies such as congenital vertebral anomalies, neuromuscular conditions, idiopathic scoliosis and various disorders may affect advanced spinal anomalies called collectively early-onset scoliosis ***(Helenius, 2018).***

The growth of spine is differ from stage to another, where it rapidly increased within the first 5 years, then after that it retarded. An average T1 to S1 segment length increase about 10 cm (2 cm/ year) during the 1st five years, after that this time the growth is up to 5cm (1cm/year) at age 5-10 years old. T1 to S1 grows an extra 10 cm (2 cm/year) from age 10 years to adulthood; this comprises the adolescent growth spurt ***(Dimeglio et al., 2016; Canavese, 2013; Dimeglio and Canavese, 2012).***

In EOS patient, the advanced spinal malformation happens during a serious period of lung growth. The lung volume and the number of alveoli elevate utmost quickly in the first several years of age and remain to rise at a lower rate during adolescence to adulthood ***(Herring et al., 2014).*** Children suffering from EOS show a variable harshness of restrictive lung illness resulted from small lung volumes, respiratory muscle dysfunction and compliance ***(Redding, 2015).***

Generally, treatment of EOS by non-surgical technique includes casting or bracing. Bracing can be applied for minor advanced bends. Furthermore, over the past decade the surgical operation techniques for EOS treatment have progressed considerably with the application of modern growth-friendly implants. The targets from the implants are a trial for enhancing the growth rates of the thorax and spine in the same time managing curve development to reservation normal lung volume. These implants can be divided into 3 separate subtypes: guided growth, distraction based, and compression-based techniques ***(Myung et al., 2014).***

One of the more applied devices which used in EOS treatment is the distraction-based implants. Where the traction is applied on the spinal column amongst distal and proximal anchors combined by stretchy rods. The rods are lengthened continuously parallel with growth of child in order to keep spine curve adjustment. Partial fusion is accomplished at the

distal and proximal anchor locations on the spine to offer hard places for spine distraction. The region between the anchors is deliberately not merged, permitting growth and move throughout this area ***(Yang et al., 2016).*** Lengthening are typically performed at ~6-month intervals ***(Helenius, 2018).***

The target from the growing rod method is to correct the deformity and sustain it along the treatment time while permitting persistent spinal development ***(Justis et al., 2018; Blakemore and Thompson, 2018).***

Aim of the Work

The aim of the search is to contemporary the method, outcomes, safety, effectiveness and general clinical practice with the dual growing rod treatment technique in attaining and preserving correction of scoliosis whereas permitting spinal development.

2. Patients and Methods

This retrospective study included 15 children with EOS. They were all treated with dual growing rode method in Atfal Misr Hospital orthopedic department.

Children were usually first seen at out patient clinic. They were examined clinically and radiologically. Moreover, neurological statues assessed also.

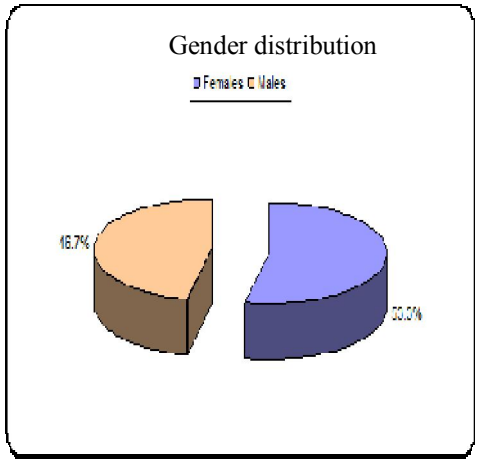

Figure (1): Gender distribution.

Inclusion criteria: Age; between 6 to 10 years. Etiology; patients with neuromuscular, congenital, infantile and juvenile idiopathic scoliosis, and other known or unknown causes. Curve children have curve development over 10° after unsuccessful casting or bracing, or have a curve of more than 50 degree from the start. No previous surgical intervention for the treatment of scoliosis.

Exclusion criteria: Age; children with age less than 6 years. Growth; patients have no potential growth. Curve; patients with curve less than 30° or have rib vertebral angle difference less than 20°. Previous surgical intervention for the treatment of scoliosis. There were 8 girls and 7 boys.

Surgical Technique:

Initial Procedure: Comprises the following, preparation of foundation positions for rod contouring, anchors or screws, insertion of tandem connectors and subcutaneous or subfascial rod insertion. An incision in the skin may be performed as one along the midline or two separate incisions in midline according to the surgical technique and length of the child's spine.

Foundations: Foundations are well-defined as presence of minimally one or two rods and two anchors that are steady and robust sufficient to resist deforming loads and to receive corrective loads without displacement of the anchors or plastic deformation of the rod. The original corrective load of the dual rod construct is applied by using upper and lower foundations. The subperiosteal of the caudal and cephalad contacts are used for attachment of anchors. The lasting space of contact is subfascial or subcutaneous to avoid early unwanted union. The place of anchor placement is depending on many factors such as the kind and site of the curve in addition to the diagnosis and child's age. For example, in child with neuromuscular disorder, is preferred longer instrumentation. The upper foundation is frequently fixed at the levels of T2–T4. Hooks and/or screws can be applied for both upper and lower foundation. In the current study, we used hooks for upper foundations, however pedicle screws can too be applied, if viable, depended on anatomic variations and convenience of posterior elements, where the pedicle screws seemed to augment extra solidity to the construct. The upper hooks are located a supra-laminar site or above the transverse process. The lower hooks are situated upward under the facets in a claw fashion. In case of there is worry concerning requirement of additional stability or the small size of the spinal canal, then the hooks can be stunned over 2 levels. Two or three levels below the scoliosis inferior end vertebra are generally the caudal foundation levels. Insertion either bone graft extenders or local bone graft at the visible levels of foundations permits for a minimum union or gives more of firmness at the anchor places.

Dual Rods: the characteristics of the Pediatric Isola rods are made from stainless steel and the diameter are 3/16 inch. The rods are cut into two parts, 2/side, and contoured for sagittal position. If the malformation is flexible, proper contouring of the rods habitually modifies kyphosis by a cantilever movement. The rods are linked to the anchors and a transverse connector at the foundation levels, before tightened all the screws. There should be two rods

attached to each foundation, the proximal and distal rods are then linked by a tandem connector on each side.

Postoperative Care: Children are braced postoperatively with a thoracolumbosacral orthosis, beginning when they have been upright for up to 6 months and continuing until fusion of the foundations. Rehabilitation proceeds according to the patient's tolerance and ability.

Lengthening Procedure: As an operative technique the lengthening is carried out every 6 months. Throughout a small midline incision, the tandem connector is palpated and incompletely uncovered. The set-screws at one end of the proximal connectors, are released, and disruption is talented amide the two rods by locating a special distractor inside the tandem connector. After that must tighten the set-screws. Diversion can similarly be performed by using the rod holder and regular distractor amide the tandem connector and the rod on either side. Avoidance of excessive distraction force is necessary particularly during the first time of lengthening. The decision time taken for the lengthening during our initial practice with dual growing rods, depend on many factors such as the diagnosis, age, curve progression and sitting height. The time between lengthening is generally between 5 and 9 months and in greatest cases about 6 months (Standard interval). In case of no further distraction can be achieved no need for more traction and the procedures for lengthening must be stopped. The patients then undertake the last correction and arthrodesis.

Final fusion: The final arthrodesis generally requires subtraction of implants, reconstruction, and reinstrumentation. The levels are generally the same as the early surgical technique except progression of the curve either below, above the fusion, or both has happened.

Follow up evaluation: All patients evaluated subjectively and objectively in at least 12 months duration.

Subjective: a score questionnaire conducted to all patients "Health-related quality of life (HRQoL) questionnaire 24".

Objective: post-operative clinical and radiological evaluation.

Radiological evaluation:

Pre operative: X-ray all spine AP and lateral, standing. MRI.

Post operative: X-ray all spine AP and lateral, standing.

3. Results

The patients were follow-up for at least 8 months after first surgical treatment with an average of 18 months follow up (range, 8 – 36 months). The average number of lengthenings was 2.6 (range, 1 – 5) per patient, the average age was 9.5 years (range, 7 – 10).

Table (1): Gender and age distribution, follow up duration and no. of distractions.

		Total no. = 15
Sex	Females	8 (53.3%)
	Males	7 (46.7%)
Age (years)	Mean ± SD	8.53 ± 1.41
	Range	7 – 10
Follow up duration (month)	Mean ± SD	17.87 ± 6.91
	Range	8 – 36
No. of distractions	Mean ± SD	2.60 ± 1.35
	Range	1 – 5

Measurement of curves:

Measurements of both cobb angel and T1 to S1 length were done by Surgimap program.

The scoliosis cobb angel improved from an average of 73.8 (range, 54 – 96) to an average of 51.7 (range, 34 – 66) till the time of the study.

Table (2): Pre And pos operative cobb angel measurement

CA	**Pre**	**Post**	**Mean difference ± SD**	**Paired t-test**		
				t	**P-value**	**Sig.**
Mean ± SD	73.85 ± 12.90	51.73 ± 12.01	-12.27 ± 32.24	14.944	0.000	HS
Range	54 – 96	34 – 66				

Growth:

The increase in the growth of the spinal was determined from the quantity of elongation of T1 to S1 after the first procedure plus the following development from post initial to latest follow up or post final union.

The T1 – S1 length increased from 246.6 mm (range, 145 – 293) pre initial to 315 mm (range, 266 – 374) till the time of study.

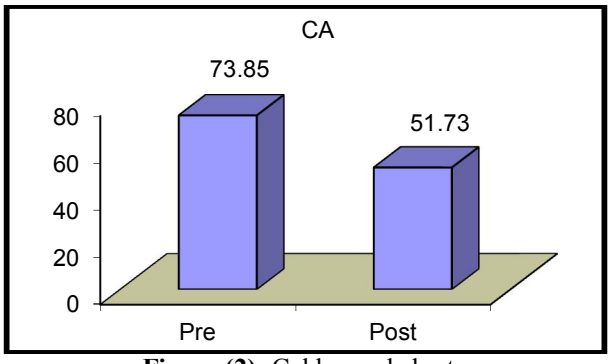

Figure (2): Cobb angel chart

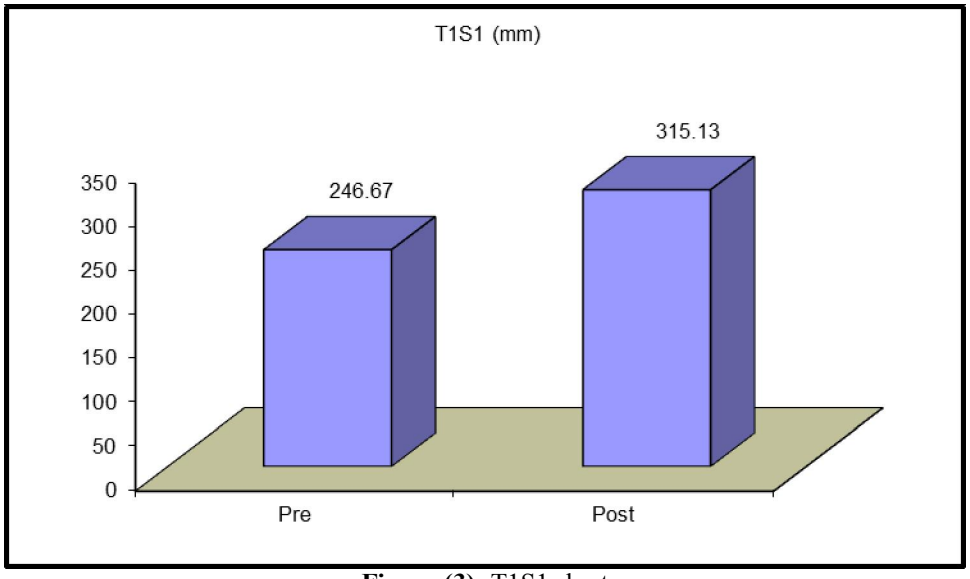

Figure (3): T1S1.chart

Table (3): Pre and pos operative T1S1 measurement

T1S1 (mm)	Pre	Post	Mean difference ± SD	Paired t-test		
				t	P-value	Sig.
Mean ± SD	246.67 ± 52.95	315.13 ± 24.62	117.80 ± 109.53	-4.317	0.001	HS
Range	145 – 293	266 – 374				

Complications:

The complications arises along the treatment period and included the treatment period from starting of surgery to nearest recent follow up or to final union, were averaged 33.3% (5 of the 15 patients) which participating in the study. Most complications were talented to be taken in consideration during planned lengthening.

There were 4 subjects were suffering from superficial injuries infection. Implant related complications include 2 screws pull out in one patient.

Health-related quality of life HRQoL questionnaire 24 scores analysis.

This questionnaire developed by scoliosis research society SRS. The Arabic version has been printed and explained to all patients and their relatives.

Responses collected and interpreted according to score sheet key. The questionnaire measure seven aspects regarding to the out come of the surgery and patient satisfaction. Scores ranging from 1 to 5, as 5 means best and 1 means worst.

Pain:

The average score of pain was 2.6 (range, 2-4), which is considered a borderline score; however, it

may be due to pain from surgical sutures or wound infection.

General self image and self image after surgery:

With a 1.9 (range 1-2.6) score of the general self image, which is considered a slightly low score, compared to a score of 4.7 (range, 3-5) of self image after surgery, that indicates a dramatic improvement in patient's self image and high degree of satisfaction after surgery.

General function:

The average score of general function was 2.4 (range, 1.6-3.3).

Function activity:

The average score of function activity was 2.5 (range, 1-5).

Function after surgery:

The average score of function after surgery was 4.7 (range, 3-5), which indicates marked improvement in function and daily activity after surgery.

Satisfaction with surgery:

The average score of satisfaction with surgery was 4.9 (range, 4.6-5), which reveals a high degree of satisfaction with surgery.

Total score:

The average overall score of all the 15 patients was 3.2 (range, 2.7-3.9).

Table (4): Summery of Health-related quality of life HRQoL questionnaire 24 scores result.

		Total no. = 15
Pain	Mean ± SD	2.69 ± 0.57
	Range	2 – 4
General self image	Mean ± SD	1.96 ± 0.50
	Range	1 – 2.6
Self image after surgery	Mean ± SD	4.72 ± 0.54
	Range	3 – 5
Function after surgery	Mean ± SD	4.73 ± 0.59
	Range	3 – 5
General function	Mean ± SD	2.45 ± 0.43
	Range	1.6 – 3.3
Function activity	Mean ± SD	2.52 ± 1.43
	Range	1 – 5
Satisfaction with surgery	Mean ± SD	4.97 ± 0.10
	Range	4.6 – 5
Total score	Mean ± SD	3.24 ± 0.36
	Range	2.7 – 3.9

4. Discussion

Scoliosis surgery without fusion was first described by Logroscino in 2016 ***(Logroscino et al., 2016).*** Some investigators recorded a high incidence of complications that involved spontaneous fusion and implant failure ***(Sanders et al., 2009).***

The expanding rod method has been popular in treating EOS without fusion while permitting for spine development. In many researches, dual growing rod technique has been documented with changeable rates of achievement ***(Akbarnia et al., 2010).***

Akbarnia et al. recommended a dual growing rod in the overcome of EOS among children ***(Akbarnia et al., 2005).*** In another study, the authors added that a dual growing rod can offer best maintenance and correction in comparison with a single rod. One of the benefits of a dual growing rod included a minor incidences of complications than a single rod ***(El-Hawary and Akbarnia, 2018).***

Akbarnia et al. reported improvement of the scoliosis angel from 82° (range, 50°–130°) to 38° (range, 13°–66°) ***(Akbarnia et al., 2005).*** In this study the scoliosis angel improved from 73° (range, 54°-96°) to 51° (rang, 34°-66°).

According to Akbarnia et al. T1-S1 length was increased by about 5cm, which averaged from 23.01cm (range, 13.80– 31.20) to 28.00 cm (range, 19.50–35.50) ***(Akbarnia et al., 2005).*** In this study T1-S1 length increased from 24.66 (rang, 14.50-29.30) to 31.51 (rang, 26.60-37.40).

In this study, the time between two lengthening was 6 months on average. Many authors found that the lengthening was carried out after approximately Cobb angle elevate to 20° ***(Blakemore et al., 2001).*** While some authors suggested to do a lengthening at interval of 6 months ***(Akbarnia et al., 2005).***

The foremost complications of this technique involved rod breakage, skin irritation hook complication and implant prominence ***(Ridderbusch***

et al., 2017; Wynne and Hresko, 2017). In the current study a pedicle screw foundation was used to diminish the number of implant related complications. A biomechanical investigation proposed that a pedicle screw construct offers suitable stability and strength parallel to other implant constructs ***(Mahar et al., 2008).*** In a study carried out by many researchers suggested foundation place fusion to decrease implant related complications ***(Akbarnia et al., 2005; Bess et al., 2008; Sanders et al., 2009).***

In this study, five of the 15 patients (33.3%) had complications along the treatment time which extended from start of operation to the nearest recent follow up or to final union. we have 2 complications with pedicle screws, and there were 4 patients with superficial wound infection. This seems to be an acceptable rate. Akbarnia et al. reported a total of 13 complications (11/23 patients,48%) occurred along the "treatment period", There were 4 cases had four superficial wound problems, 2 cases with deep wound infections, 2 hook dislodgements, Implant-related complications involved 2 rod breakages, and 1 screw pull-out in 5 patients ***(Akbarnia et al., 2005).***

In the current work, only the patients treated with dual rod instrumentation. There has been a few preceding documents of patients were subjected for treatment with dual growing rod method completely.

Conclusion

We can concluded from this study that the dual growing rod method is efficient and safe. It preserves correction achieved at initial operation in addition to allowing spinal development to last. It maximize the duration of treatment time, offers satisfactory stability, and has an tolerable rate of complication matched with former researches applying the single rod method. However, the family should completely understand the long-term commitment before the begun of treatment because the complications observed in this work are remain significant. Moreover, to allowing sustained spinal development, this technique of surgical treatment recovers the thoracic cage volume in this challenging patient population. This is an continuing research, and long-term follow-up is required to approve our interim outcomes.

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