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Clinical and radiological outcome of the growing rod technique in the management of scoliosis in young children

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Objective: The aim of this study was to investigate the effects of growing rod treatment on the clinical and radiographic outcome and respiratory function of young children with scoliosis.

Methods: Data from 25 patients (24 females, 1 male) who underwent surgical treatment with growing rods for scoliosis between 1997 and 2007 were evaluated retrospectively. Dual growing rods were used in 16 patients and single growing rods in 9. Patients' average age was 7.38±3.8 years at the initial surgery. Cobb angle, T1-S1 length, and instrumentation length were measured radiographically. Respiratory functions were evaluated at the final follow-up.

Results: Patients received an average of 4.2 lengthening treatments over an average period of 44.9 months. Cobb angles improved from 56.7° to 25.1° after final fusion. T1-S1 length increased from 27.2±3.4 to 34.9±3.6 cm after the initial surgery and 38.6±3.7 cm post final fusion. Average growth was 1±0.4 cm per year. Mean values of respiratory parameters at the last follow-up were FVC: 83.5±3.5, FEV: 84.8±5.3, and FVC/FEV_1: 1±0.046. Twelve patients experienced complications, of which eight were instrument-related and four medical.

Conclusion: The growing rod technique is effective in the treatment of spinal deformity in young scoliosis patients and appropriate for improving both spinal column height and pulmonary function.

Key words: Growing rod; respiration; scoliosis; young children.

Progressive scoliosis may have deleterious effects on the spinal column and the thoracic cage.[1] In addition, chest wall deformities resulting from severe forms of three-dimensional curve patterns of the scoliotic spine may impair the development of adequate respiratory functions in children by inhibiting vascular development and physiologic growth of alveoli resulting in diminished lung capacity and functions.[2-4] Deformities of the thoracic cage are also termed the fourth dimension of scoliosis.[5] Considering that a large part of lung development takes place after the age of four, the control and reconstruction of chest wall deformities will help improve thoracic volume (TV) and functional capacity.

Application of growing rods has proven successful in the treatment of early onset scoliosis.[6] However, while

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sequential lengthening maneuvers are effective in correcting the frontal plan deformity, they may entail a flattening of physiologic sagittal curves, including lumbar lordosis and thoracic kyphosis. Loss of kyphosis may in turn result in the decrease of TV.[7] Compared to the single growing rod technique, the dual growing rod technique was found to be more effective in deformity correction and lengthening of the spine and results in fewer implant related complications[1,8]

In our study, the clinical results of the growing rod technique in young children with scoliosis were retrospectively evaluated. Our aim was to investigate the effects of the growing rods method on deformity correction in the frontal and sagittal planes, thoracic kyphosis and pulmonary function.

Patients and methods

All children treated with growing rod instrumentation at the same institute between 1997 and 2007 were retrospectively evaluated after the approval was obtained from the ethical committee of clinical studies of İstanbul Training and Research Hospital. Patients who were unreachable or had undergone any other additional procedure at other clinics were excluded from the study. Indication for surgery was unsuccessful conservative treatment (bracing or casting) with a curve progression of over 10° in a year. Of the 25 patients (24 females) who met the inclusion criteria, all had a Risser sign of 5 and were postmenarchal (for girls), confirming skeletal maturity. Of the 25 patients, 3 were diagnosed with infantile idiopathic, 12 with juvenile idiopathic and 8 with spinal congenital scoliosis, while one of the remaining two cases was related to a non-spinal congenital anomaly and one to a neuromuscular disease. Eight patients had thoracic and seventeen thoracolumbar curves. All patients had been diagnosed before the age of 5 and were under our follow-up. The average age at the time of initial surgery was 7.3 (range: 6 to 10) years.

Initial medical records of the patients were reviewed. Age, gender, type of pathology, treatment duration, physical examination findings, complications, and X-ray findings of pre- and early postoperative stages, post-final fusion and at the latest follow-up were recorded. Surgical data included operative techniques, levels fused and instrumentation used. Thoracic volume and respiratory function were measured at follow-up under the observation of the same technician.

Preoperative, early postoperative, post-final fusion and follow-up radiographs (standing anteroposterior and lateral) were evaluated by one independent observer. Length of the spinal column, deformity type, ratio of the sagittal and coronal curves, coronal and sagittal balances were measured on the X -rays. Magnitudes of each curve were measured separately in the coronal and sagittal planes using the Cobb method. Measurements of the translation of the T1 vertebra from the central sacral line and of the distance between the C7 plumb line to the anteroposterior corner of the S1 vertebra provided the values for the coronal and sagittal plane balance, respectively. Spinal length was calculated adding the length increase of the T1-S1 segment over the course of treatment to the preoperative spine length. The growth was confirmed by the increase of instrumentation length from post-initial to pre-final fusion or latest follow-up.

The type of surgery was decided on and performed by the same surgical team for each patient. All patients underwent posterior surgery with growing rods and hybrid constructs with hooks and pedicle screws. Upper and lower foundations were connected with domino connectors. Double growing rods were used in 16 patients with conspicuous rotational deformity (Fig. 1). Single growing rods were preferred in the remaining 9 patients (1 male and 8 female) (Fig. 2). The Stagnara wake-up test was used for neurological monitoring during all surgical procedures. The average number of vertebral segments instrumented was 11.3 (range: 9 to 14). The upper level of instrumentation was at T2 in 3, T3 in 19, T4 in 2 and T6 in 1 patients. The lower level of instrumentation ended at L2 in 10, L3 in 7, L4 in 5, and L5 in 3.

Lengthening procedures were planned for all patients at least once a year after the initial operation. During the treatment period (initial surgery to final fusion), which averaged 44.9 (range: 23 to 63) months, the average number of lengthening procedures was 4.2 (range: 3 to 7) times per patient at an average interval of 10.2 (range: 6 to 14) months. Lengthening was terminated in patients in whom final lengthening was less than 5 mm. Final spinal fusion was performed with new rods at an average age of 12.4 (range: 12 to 13) years. Patients were observed for a minimum of two years after the final fusion. The mean follow-up time after the initial surgical treatment was 79 (range: 39 to 116) months. The mean age at the final follow-up was 14.52 (range: 12 to 18) years. There were five unplanned procedures in four patients due to complications encountered during the treatment period and one following final fusion. During the treatment period, rods were changed in 4 patients, domino connectors were changed in two patients and dislodged hooks were changed in 5 patients.

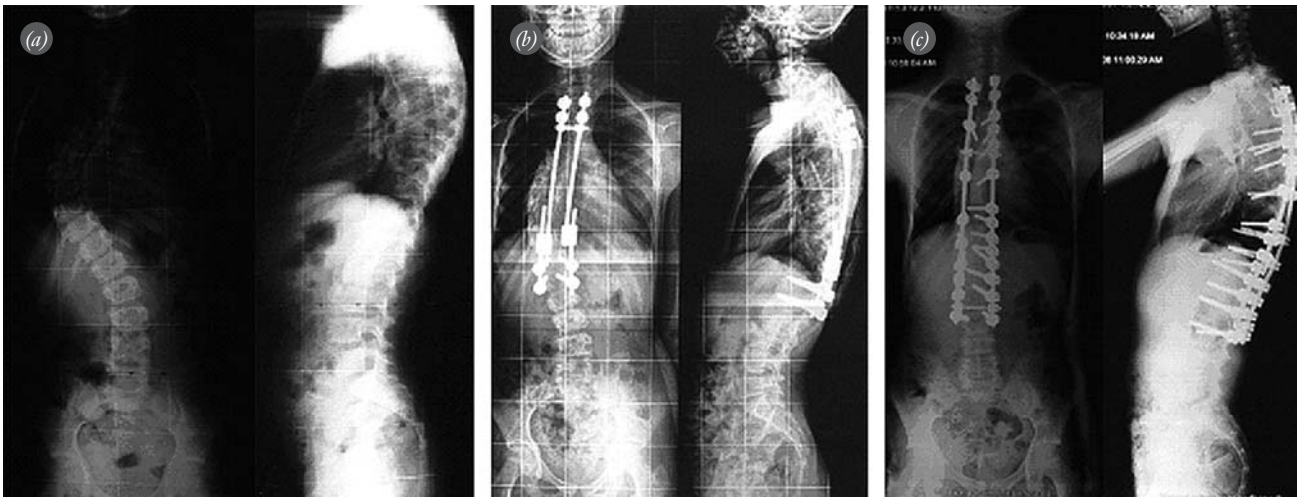

Fig. 1. Direct X-rays of a patient in dual-growing rod group. **(a)** Preoperative, **(b)** postoperative, and **(c)** post-final fusion follow-up views.

Statistical analysis was performed using SPSS 13.0 (SPSS Inc., Chicago, IL, USA) software. Wilcoxon signed-rank test for evaluation of measurements and Spearman nonparametric correlation coefficients were calculated to assess pairwise associations, including different measures of deformity. P values of less than or equal to 0.05 were considered statistically significant.

Results

Mean T1-S1 length increased from 27.2 (range: 20.8 to 28.2) cm pre-initial surgery to 34.9 (range: 25 to 39) cm post-initial and to 38.6 (range: 28 to 42) cm at the final follow-up. Average growth was 10.44 (range: 5 to 21) mm per year.

The thoracic scoliosis Cobb angle decreased from an average of 56.7° (range: 44° to 88°) preoperatively to 23.19° (range: 12° to 38°) post-initial surgery and 25.1° (range: 13° to 44°) at the final follow-up. The preoperative to post-initial surgery change in thoracic scoliosis Cobb angle was 55.8% (range: 40.3% to 77.1%; $p<0.05$) and 47.8% (range: 36.2% to 70.3%; $p<0.05$) from pre-initial surgery to the final follow-up. The lumbar scoliosis Cobb angle improved from an average of 43.4° (range: 44° to 88°) preoperatively to 13.57° (range: 5° to 36°; $p<0.05$) post-initial surgery and 20.71° (range: 6°-40°; $p<0.05$) at the final follow-up. The preoperative to post-initial surgery change in the lumbar scoliosis Cobb angle was 68.7% (range: 32.3% to 71.1%; $p<0.05$) and 52.3% (range: 30.2% to 65.3%; $p<0.05$) from the pre-initial surgery to the final follow-up. The improvement in thoracic and lumbar scoliotic Cobb angles was more significant in the dual growing rod group than in the single growing rod group ($p<0.05$).

Mean angle of kyphosis was 49.4° (range: 36° to 70°) preoperatively, 34.4° (range: 24° to 56°) following the initial surgery and 38.5° (range: 32° to 63°) at the final follow-up. Average reduction in kyphosis from pre- to post-initial surgery was 30.1%. Average increase in kyphosis from the initial surgery to the final follow-up was 10.6% (range: 3 to 22%) and was not significant ($p=0.673$). Lordosis from L1 to S1 measured 42.3°

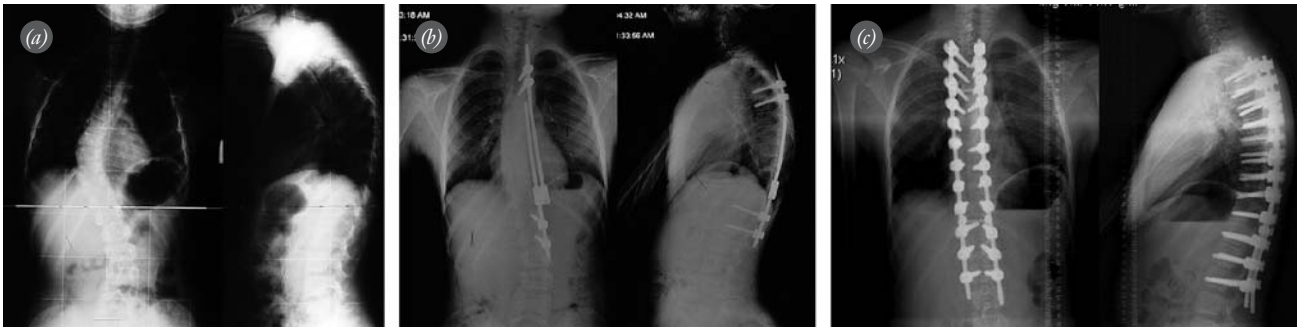

Fig. 2. Direct X-rays of a patient in single-growing rod group. **(a)** Preoperative, **(b)** postoperative, and **(c)** post-final fusion follow-up views.

(range: 28° to 70°) preoperatively, 33.2° (range: 25° to 58°) post-initial surgery and 38.8° (range: 35° to 66°) at the final follow-up (p=0.916). The reduction in thoracic kyphosis and lumbar lordosis was more statistically significant in the dual growing rod group than in the single growing rod group (p<0.05).

The sagittal displacement between T1 and S1 was 3.72 (range: 0 to 4.20) cm preoperatively and decreased to 2.33 (range: 3.00 to 6.80) cm at the final follow-up. The coronal balance (deviation from midline) was 2.81 (range: 0 to 5.40) cm preoperatively and 1.76 (range: 0 to 3.90) cm at the final follow-up.

Scoliosis correction deteriorated more than 5 degrees from post-initial surgery values to post-final fusion or final follow-up in 6 patients (5 single rod patients and one dual rod patient). However, there was significant improvement from the preoperative deformity in all patients. There were 12 complications; 8 were implant-related (5 hook dislodgements, 4 rod breakages) and 4 medical (3 superficial infections and 1 transfusion related hemolytic reaction). Two-thirds of all complications were encountered in the single growing rod group. Patient profiles are given in Table 1.

Preoperative and final follow-up spinal lengthening measurements were correlated with the thoracic scoliotic curve (r=0.63) and lumbar scoliotic curve (r=0.44). However, correlation coefficients were lower for thoracic kyphosis (r=0.10) and lumbar lordosis (r=-0.25). Weak Spearman correlation values were calculated between respiratory functions and thoracic scoliosis (r=0.16) as well as between respiratory functions and kyphosis (r=0.14). There was no statistically significant difference in respiratory functions between the dual and single rod groups (p>0.05).

Discussion

The treatment of spinal deformities in infants and juveniles is challenging.[9] Bracing is the preferred non-surgical treatment modality aimed at preventing curve progression of the growing spine.[10] Curve progression beyond a Cobb angle of 40° or more than 10° in one year as well as loss of coronal and sagittal balances are accepted criteria for surgical treatment in young children.[11,12] Epiphysiodesis, excision of malformed vertebrae or wedge resections are among the preferred surgical techniques in congenital scoliosis patients with a poor prognosis.[13] Prediction of curve progression remains difficult in a subgroup of patients with idiopathic curves, congenital scoliosis affecting multiple levels and scoliosis related to systemic or neurologic disease.[14] Growing rod techniques allow for curve correction while controlling spinal growth.[15] Dual growing rods have been reported to result in better correction and fewer complications than single growing rods.[8] Our study included patients treated with both single and dual growing rods. Implant-related complications we encountered refuted our assumption that less aggressive instruments were suitable for correcting flexible and minor curves and this accounted for our preference for the use of the dual growing rod techniques in the majority of our patients (72%). Thompson et al.[8] retrospectively investigated two groups of patients with early onset scoliosis treated with single and dual rods, respectively, and found that dual rods are stronger than single rods and, therefore, provide better initial correction and maintenance of cor-

Table 1. Patient data.

	Single rod	Dual rod	All patients
Gender	8 girls / 1 boy	16 girls	24 girls / 1 boy
Age at follow-up (range in years)	15.6 (15-18)	13.9 (12-17)	14.5 (12-18)
Follow-up time (range in months)	89 (67-116)	62 (39-102)	79 (39-116)
Improvement of thoracic scoliosis (pre-initial surgery to final follow-up)	41.1% (36.2-66%)	51.6% (46-70.3%)	47.8% (36.2-70.3%)
Improvement of lumbar scoliosis (pre-initial surgery to final follow-up)	42.9% (30.2-59%)	57.6% (42-65.3%)	52.3% (30.2-65.3%)
Change in thoracic kyphosis (pre-initial surgery to final follow-up)	15.8% (8-23%)	25.6% (13-42%)	22% (8-42%)
Change in lumbar lordosis (pre-initial surgery to final follow-up)	5.6% (-9-22%)	9.7% (-5-30%)	8.2% (-9-30%)
FVC	82.8 (68-91)	84.3 (69-93)	83.5 (68-93)
FEV_1	80.5 (75-86)	85.2 (82-96)	84.8 (75-96)
FEV_1/FVC	1.02 (0.86-1.02)	0.98 (0.88-1.05)	1.01 (0.86-1.05)
Number of lengthening per patient (range)	3.4 (2-5)	4.5 (3-7)	4.2 (2-7)
Complications	6 implant-related 2 medical	2 implant-related, 2 medical	8 implant-related, 4 medical

FVC: forced vital capacity, FEV: forced expiratory volume

rection. Although they recommended the use of growing rods as an effective method for controlling severe spinal deformities and allowing spinal growth, they refrained from making any comparison between single rods and dual rods because the groups were not randomized.

Compared with the series of Akbarnia et al [16,17] where the average age was 6.6 years and Mineiro and Weinstein's[1] series with an average age of 5.6 years, our patients were slightly older at the time of the initial operation. In our series, the youngest patient was 6 years old at the time of the initial operation and the mean age of the patient group was 7.2 years.

While the interval between lengthening of the rods has dropped to 6 months in the literature,[16] the mean period between lengthening procedures was 10.6 months in our study. Lengthening numbers per patient were also fewer than in Akbarnia et al.'s series.[16,17]

Muschik et al.[18] reported better clinical results in the growing spine with anterior fusion than posterior non-fusion instrumentation. Our patients were operated with posterior instrumentation. We measured a spinal growth of 28.7% between the T1-S1 after the final fusion. Deterioration of the scoliotic curve remained in only 12% of the patients.

Campbell at al.[19] measured thoracic space available for lung (SAL) using software and found an improvement in their measurements. Asymmetric ventilation and perfusion were found between the right and left lungs in more than 50% of children with severe scoliosis. Elsebai et al.[20] also reported an improvement in SAL in patients who underwent growing rod surgery. Redding et al.[21] did not find any correlation between lung function and Cobb angle measurements. They concluded that lung function was influenced by all three dimensions of the chest wall deformity and could not be ascertained by chest radiographs alone. We measured respiratory functions to provide a better understanding of lung involvement rather than relying on theoretical SAL values. Respiratory function results showed slightly restrictive changes. Weak Spearman correlation values were calculated between respiratory functions and thoracic scoliosis (r=0.16) or kyphosis (r=0.14), accounting for the lack of predictability of lung function improvement resulting from scoliosis treatment with growing rod surgery.

Posterior instrumentation was found to be effective for the control of the deformity in scoliotic patients[22] despite possible disadvantages on thoracic kyphosis. A decrease in the thoracic kyphosis may also affect lung development and respiratory capacity.[7] We did not find any correlation between the amount of lengthening and the decrease in sagittal plane curves. However, the correlation coefficients between lengthening and thoracic (r=0.63) and lumbar (r=0.44) scoliotic curves showed that growing rod treatment has a beneficial effect on coronal plane curves during lengthening.

In conclusion, in our series, growing rod spinal instruments allowed for the controlled growth of the immature spine and deformity correction. While the coronal plane curves were reduced by 47.8%, this reduction was more statistically significant in patients undergoing dual growing rod lengthening than single growing rod. Contrary to our expectations, the curve reduction in the sagittal plane was also more statistically significant in dual growing rod patients (34%). The decrease in the thoracic kyphosis did not affect respiratory function and values at the final assessment were near normal in both methods. The heterogeneity of patients in the dual and single rod groups limits our ability to make conclusions in favor of the dual rod technique. However, it appears that dual growing rod treatment is more effective when correction and complication rates are taken into consideration. We recommend the use of the growing rod treatment technique as a means to improve the respiratory functions in young children with scoliosis.

Conflicts of Interest: No conflicts declared.

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