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Comparative Analysis of Shoulder Balance through Growth Guidance Techniques in the Surgical Treatment of Early-onset Scoliosis

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Abstract

Objective: The purpose of this study was to compare the efficacy of growth guidance techniques (single and dual growing rods, Vertical Expandable Prosthetic Titanium Rod-VEPTR) on shoulder balance, in the surgical treatment of early-onset scoliosis.

Methods: Thirty six patients with early-onset scoliosis (EOS) due to various etiologies who were operated on in two different institutions were included in the study and they were divided in 3 groups. Group 1 consisted of 11 patients (mean age 7.5 years) who were treated with a single growing rod, Group 2 had 13 patients (mean age 8.1 years) who were treated with dual growing rods, and Group 3 consisted of 12 patients (mean age 4.1 years) who were treated with VEPTR technique. The coracoid height difference (CHD), clavicular tilt angle difference (CTAD) and clavicula-rib cage intersection difference (CRID) were measured on standing anteroposterior X-ray images in the preoperative, early postoperative and the last follow-up periods. Data obtained from these measurements were subject to statistical analysis.

Results: The average postoperative follow up period was 3.04 (range: 2.3 to 4.8) years for Group 1, 2.23 (range: 1 to 3.1) years for Group 2 and 2.18 (range: 1 to 3.2) years for Group 3. Clinical improvement in shoulder balance was obtained for Group 1 and Group 2 post-operatively, but there was no significance in the comparison among the three groups.

Conclusion: The effect of growth guidance techniques on shoulder balance remains unpredictable in the surgical treatment of early-onset scoliosis.

Keywords: Growing rod; VEPTR; Early onset scoliosis; Shoulder balance

Introduction

While making surgical decisions regarding cosmesis for the treatment of scoliosis, in addition to the spine's coronal balance also shoulder balance is one of the most important criteria to be estimated [1]. The effect of growth guidance techniques on shoulder balance is temporary, and these techniques may play a role in establishing shoulder balance in the final fusion stage. Some surgeons may prefer to leave the patients with the implants that are used to perform growth guidance techniques, without performing the final fusion surgery [2]. Thus, with the use of growth guidance techniques, when the final fusion is not performed at the end of the lengthening period, the shoulder balance attained following the lengthening period gains greater importance.

The aim of this retrospective study was to evaluate the effects of the three distinct growth guidance techniques on shoulder balance in the coronal-plane, by measuring the following radiographical parameters of shoulder balance (difference of coracoid process height-CHD, clavicula-tilt angle-CTAD and clavicula-rib cage intersection point-CRID) [3-5] that were obtained in the preoperative, postoperative and final follow-up period which underwent statistical analysis in comparison with each other.

Materials and Methods

Thirty six patients with EOS due to various etiologies were operated on between the years 2004-2011 at two different institutions. Three different non-fusion techniques (single growing rod, dual growing rod, VEPTR) were performed. For all three groups, rod extensions were applied periodically. Group 1 consisted of 11 patients who were treated with single rod technique, where the side-to-side submuscular connector was placed on the concave side of the major curve. In Group

2, the dual rod technique was performed in 13 patients, where the side-to-side submuscular connectors were placed on both sides of the major curve. Finally Group 3 consisted of 12 patients who were treated with VEPTR technique, in which the implant was applied on the concave side of the major spinal curve.

In Group 1, there were 8 female and 3 male patients and the average age at the beginning of the treatment was 7.45 (range: 6 to 9) years. Group 2 consisted of 11 female and 2 male patients and the average age at the beginning of the treatment was 8.1 (range: 5 to 11) years. There were 7 female and 5 male patients in Group 3 and the average age was 4.1 (range: 1.6 to 9) years at the beginning of the treatment. Final fusion surgery was performed in 6 of the 11 patients in Group 1, in 5 of the 13 patients in Group 2 and in one of the 12 patients in Group 3. Demographic characteristics can be seen in Table 1.

The lengthening procedures were performed in 6 to 10 months' intervals. The numbers of distractions were noted for all three groups.

The radiological evaluation was performed on standardized lateral and posteroanterior X-ray images obtained in the preoperative, in the early postoperative and during the last follow-up periods (Figures 1-3). Cobb's

	GROUP 1 Single growing rod	GROUP 2 Dual growing rod	GROUP 3 VEPTR
Number of patients	11	13	12
Age	7.5 (6–9)	8.1 (5–11)	4.1 (1.6–8)
Follow-up period	3.04 (2.3–4.8)	2.23 (1–3.1)	2.18 (1–3.2)
Average number of distractions	5.4 (3–6)	4.1 (2–7)	4 (2–5)
Diagnosis	1 congenital 10 idiopathic	3 congenital 2 syndromic 8 idiopathic	6 congenital 2 syndromic 1 neuromuscular 3 idiopathic

Table 1: Patient Demographics.

Figure 1: Posteroanterior X-ray images of a patient from Group 1 obtained in the preoperative, early postoperative periods and during the last follow-up period.
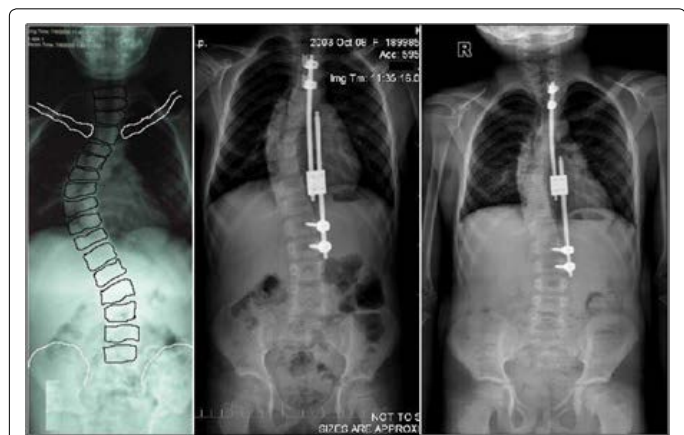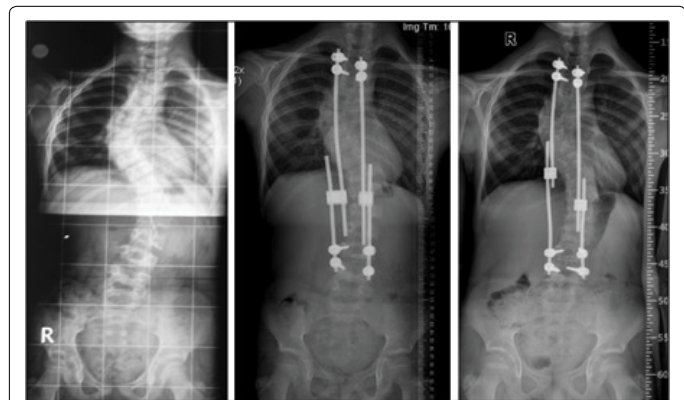

Figure 2: Posteroanterior X-ray images of a patient from Group 2 obtained in the preoperative, early postoperative periods and during the last follow-up.

angle of the main curve, shoulder balance (CHD, CTAD and CRID), coronal balance were measured on the radiographies. Comparison of the preoperative, postoperative and last follow-up coronal plane parameters of the three groups are listed in Table 2.

Coracoid height difference (CHD) was calculated by measuring the distance between the horizontal lines drawn through the superior aspects of the both coracoid processes. Clavicle-rib cage intersection difference (CRID) is known as the distance between the horizontal lines drawn through the intersecting points of the superior aspects of each clavicle with the outer edge of the second rib's insertio (Figure 4) [3-5]. The clavicular tilt angle difference (CTAD) is the difference between the angles formed by the bisection of the lines of the proximal

portions of the clavicle with the horizontal (Figure 4) [4].

The patient was classified as shoulder imbalanced if CHD was more than 9 mm and/or CTAD was more than 4.5˚ and/or CRID was more than 7.1 mm (Figure 4) [4]. The measurements that are expressed in millimeters were calibrated according to the scale on the digital X-ray images.

Complications were noted.

Demographic and radiographical data of the groups were analysed statistically using computer software (PASW ver. 15.0; SPSS). Mann-Whitney U test and Kruskal-Wallis test were used ($P<0.05$ was significance set value) for the analysis of the parameters of age, lengthening numbers, follow-up time and lengthening intervals. To compare sex and other categorical data, Pearson Chi-Square test was performed. CHD, CTAD, CRID, main curve and coronal balance values for each group were analyzed using Friedman test and Pillai Trace ($P<0.05$ was significance set value). Bonferroni test was used for the comparison of radiological data among the 3 groups ($P<0.05$ was significance set value).

Results

The average follow-up periods for Group 1, Group 2 and Group 3 was 3.04 (range: 2.3 to 4.8) years, 2.23 (range: 1 to 3.1) years and 2.18 (range: 1 to 3.2) years respectively (Table 1).

The average numbers of distractions for Group 1, Group 2 and Group 3 were 5.4 (range: 4 to 6), 4.1 (range: 2 to 7), and 4 (range: 2 to 5) respectively (Table 1). For Group 1, the average preoperative CHD was 14.3 (range: 2 to 38) mm, the average early postoperative CHD was 11.9 (range: 0 to 38) mm, and the average last follow-up period CHD was 9.6 (range: 0 to 35) mm (p>0.05). For Group 2, the average preoperative CHD was 15.9 (range: 2 to 35) mm, the average early postoperative CHD was 12.2 (range: 2 to 30) mm, and the average last follow-up period CHD was 15.1 (range: 0 to 35) mm (p>0.05). For Group 3, the average preoperative CHD was 16.2 (range: 2 to 37) mm, the average early postoperative CHD was 13.1 (range: 4 to 30) mm, and the average last follow-up period CHD was 16.7 (range: 2 to 50) mm (p>0.05) (Table 2).

For Group 1, the average preoperative CTAD was 12.4° (range: 0° to 24°), the average early postoperative CTAD was 7.5° (range, 0°-22°), and the average last follow-up period CTAD was 8.5° (range: 0° to 31°) (p>0.05). For Group 2, the average preoperative CTAD was 10.6° (range: 1° to 21°), the average early postoperative CTAD was 8.2° (range: 0° to 23°), and the average last follow-up period CTAD was a 6.9° (range: 1° to 20°) (p>0.05). For Group 3, the average preoperative CTAD was 11° (range: 3°-24°), the average early postoperative CTAD was 8° (range: 1°-25°), and the average last follow-up period was 13.5° (range: 2° to 40°) (p>0.05) (Table 2).

In Group 1, the average preoperative CRID was 10.9 (range: 3 to 25) mm, the average early postoperative CRID was 7.2 (range: 0 to 20) mm, and the average last follow-up period CRID was 8.7 (range: 1 to 22) mm (p>0.05). In Group 2, the average preoperative CRID was 10.3 (range: 1 to 30) mm, the average early postoperative was 7.4 (range: 0 to 30) mm, and the average last follow-up period was 11.3 (range: 1 to 21) mm (p>0.05). For Group 3, the average preoperative CRID was 11.4 (range: 1 to 36) mm, the average early postoperative was 9 (range: 1 to 20) mm, and the average last follow-up period was 14.4 (range: 2 to 36) mm (p>0.05) (Table 2).

In the inter-group comparison there was no significant difference among the 3 groups in terms of CHD, CTAD and CRID parameters
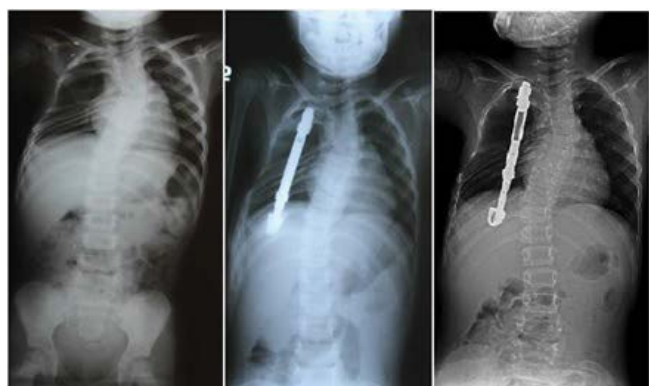
Figure 3: Posteroanterior X-ray images of a patient from Group 3 obtained in the preoperative, early postoperative periods and during the last follow-up.

		Group 2	Group 3
CHD (mm) (p>0.05)	Preoperative	15.9	16.2
	Early postoperative	12.2	8
	Last follow-up	15.1	13.5
CTAD (°) (p>0.05)	Preoperative	10.6	11
	Early postoperative	8.2	8
	Last follow-up	6.9	13.5
CRID (mm) (p>0.05)	Preoperative	10.3	11.4
	Early postoperative	7.4	9
	Last follow-up	11.3	14.4
Cobb Angle (°)	Preoperative	63.2	66.1
	Early postoperative	37(p<0.05)	52.1(p<0.05)
	Last follow-up	38.4(p<0.05)	58.2(p>0.05)
Coronal balance (cm)	Preoperative	2.7	2.18
	Early postoperative	1.65 (p<0.05)	2.95(p>0.05)
	Last follow-up	1.56 (p<0.05)	3.78(p>0.05)

Table 2: Comparison of the preoperative, postoperative and last follow-up coronal plane parameters of the three groups.

(p>0.05) (Table 2).

The average preoperative Cobb's angle of the main curve in Group 1 was 58.5° (range: 35° to 80°), while the average early postoperative Cobb's angle was 37.7°(range: 20° to 66°), and the average Cobb's angle during the last follow-up period was 28.5° (range: 16° to 59°) (P<0.05). In Group 2, the average preoperative Cobb's angle of the main curve was 63.2° (range: 28° to 114°), the average early postoperative Cobb's angle was 37° (range: 7° to 62°), and the average Cobb's angle measured during the last follow-up period was 38.4° (range: 7° to 74°) (P<0.05). Finally, in Group 3, the average preoperative Cobb's angle was 66.1°(range: 48° to 88°), the average early postoperative Cobb's angle was 52.1° (range: 32° to 85°) (P<0.05), and the average Cobb's angle measured during the last follow-up period was 58.2° (range: 40.4° to 96°) (P>0.05) (Table 2).

The average preoperative coronal balance in Group 1 was identified as 1.47 (range: 0 to 4) cm, while the average early postoperative coronal balance was 1.44 (range: 0 to 3) cm, and the average coronal balance during the last follow-up period was 1.01 (range: 0 to 2.5) cm (p>0.05). In Group 2 the average preoperative coronal balance was 2.7 (range: 0.8 to 10) cm, the average early postoperative coronal balance was 1.65 (range: 0 to 6.2) cm, and the average coronal balance during the last follow-up period was 1.56 (range: 0 to 7) cm (p<0.05). In Group 3, the average preoperative coronal balance was 2.18 (range: 0.2 to 8) cm, the average early postoperative coronal balance was 2.95 (range: 0.6 to 8) cm, and the average coronal balance during the last follow-up period

was 3.78 (range: 0.2 to 12) cm (p>0.05) (Table 2).

In Group 1, in 9 of the 11 patients (81.8%) 27 complications (8.9/year) occurred (3.71/year/patient). The complications consisted of 9 hook dislocations, 8 rod fractures, loosening in 2 upper screw caps, 2 lamina fractures, 1 screw pullout, 1 superficial wound infection, 1 paraplegia, 1 proximal junctional kyphosis and hemothorax in 2 cases. Superficial wound infection healed with parenteral antibiotics. Lamina fracture and proximal junctional kyphosis were treated conservatively. Hook and screw dislodgements were managed using 1 level above/below the previous anchor sites by hooks/pedicle screws. Broken rods were exchanged in to new rods and after the revision lengthening continued using the same indications. Loosening screw caps were exchanged in to new screw caps after the revision lengthening.

In Group 2, in 8 of the 13 patients (61.5%) 14 complications (6.3/year) occurred (1.61/year/patient). These complications consisted of 4 hook displacements, 2 rod fractures, 2 screw pullouts, 2 skin infections, 1 lamina fracture, 1 deep wound infection and proximal junctional kyphosis in 2 cases. Skin infections healed with parenteral antibiotics. Deep wound infection healed with parenteral antibiotics and repeated debridement. Lamina fracture was treated conservatively. Hook and screw dislodgements were managed using 1 level above/below the previous anchor sites by hooks/pedicle screws. Broken rods were exchanged in to new rods and after the revision lenghthening continued using the same indication.

In Group 3, in 10 of the 12 patients (83.3%) 26 complications (11.9/year) occurred (3.62/year/patient). The complications consisted of 7 proximal cradle migrations, 5 distal laminar hook displacements, 5 deep wound infections, 3 distal cradle migrations, 2 screw pullouts, 1 lamina fracture, 1 crankshaft phenomenon, 1 skin infection, and the loosening of 1 distal McCarty rod. Skin infection healed with parenteral antibiotics. Deep wound infections healed with parenteral antibiotics and repeated debridement. Lamina fracture was treated conservatively. Hook and screw dislodgements were managed using 1 level above/below the previous anchor sites by hooks/pedicle screws. The loosening of distal McCarty rod was exchange with pedicle screw in L5. The crankshaft phenomenon devoloping VEPTR system was removed and then dual growing rod system was established instead of VEPTR. The proximal and distal cradle migrations were exchanged new 1 or 2 level above/below rib.

Discussion

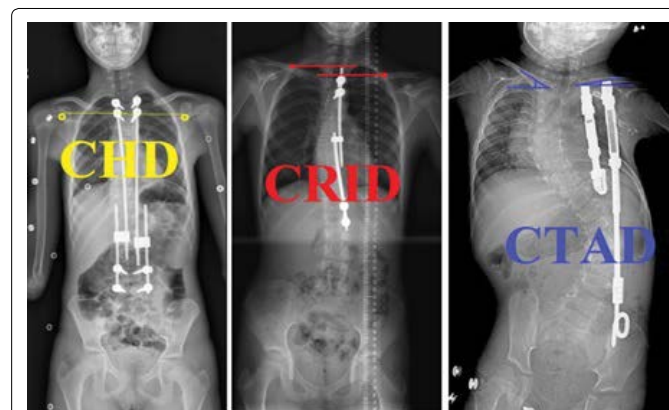In our study we used the radiological parameters to evaluate

Figure 4: Measurement of radiographic shoulder balance parameters. CHD indicates coracoid height difference; CRID indicates clavicle-rib intersection difference; and CTAD indicates clavicular tilt angle difference.

shoulder balance, because in the relevant literature the radiological parameters that are used to evaluate shoulder balance are reported to be correlated with the clinical evaluation of the shoulder [3,4,6]. In a study carried out by Bago et al. [3] CHD was determined to be significantly linked with the real shoulder balance. Akel et al. [4] evaluated shoulder balance of normal adolescent population evaluated both through a radiological and clinical perspective. They determined that CHD and CRID were highly correlated with the clinical evaluation parameters, while CTAD was correlated moderately. Uzumcugil et al. [7] , evaluated the shoulder balance in EOS scoliosis patients operated with a growing rod, due to various etiologies. They concluded that the CHD should be the primary parameter to be measured, as it proved to be the best method. We selected the above 3 parameters of radiology for our own evaluations of shoulder balance regarding the relevant literature. Our analysis showed that preoperative shoulder imbalance measurements were similar in all groups statistically. The single growing rod was found to be the best method by means of CHD and CRID measurements, and the dual growing rod was found to be the best method by mean of CTAD measurement to evaluate shoulder balance. However, in a comparison of all three implant groups, there was no statistically significant difference among them.

Samy et al. [8] reported that they have achieved improvement in Cobb's angle and modest intraoperative correction in shoulder balance in the patients with congenital scoliosis that were operated with VEPTR. They claimed that at the end of the follow-up period, CHD and CTAD parameters both improved significantly. In our series, 6 of the 12 patients who were treated with VEPTR had congenital scoliosis. At the end of the follow-up period, there was not a significant correction attained in Group 3. In the congenial cases, we noticed a regression in shoulder balance parameters postoperatively in Group 3. These parameters include CHD in two patients, CRID in 7 patients and CTAD in 4 patients. Uzumcugil et al. [7] published a report indicating that the single growing rod technique provided better improvement for shoulder imbalance. In our study, the single rod technique, when compared to the dual rod and VEPTR groups, provided greater improvement in shoulder imbalance, however we have found that in Group 3 there have been regression by means of shoulder imbalance.

Bess et al. [9] analyzed the complications of 140 patients treated with growing rods. The number of the complications was significantly higher in the patients treated with a single rod, than patients treated with dual rods. The correction of the curve was also found to be more significant in the dual rod group. In EOS patients treated with opening wedge thoracotomy by intercostal muscle lysis and VEPTR, Thompson et al reported 1.19 complications per patient [10]. Sankar et al. [11] pointed out that while the complication rate of patients with a dual growing rod was 2.3 per patient (average complications 0.52/year), the complication rate of VEPTR patients was 2.37 per patient (0.52/year) which is quite high in contrast to the other studies [12-14]. The study carried out by Thompson et al. reported that the single growing rod group experienced relatively fewer complications, compared with the dual growing rod group [10]. In our study, all three implants provided significant correction of the preoperative Cobb's angle, in the early postoperative period. However, during the last follow-up, the results were significantly bad in Group 3. Surprisingly, the follow-up period showed that the single growing rod offered the most significant correction. The dual growing rod led to the fewest number of complications, while the single growing rod and VEPTR had similarly high numbers of complications.

The lack of the data on the sagittal balance parameters, less number of patients in the groups, the existence of heterogeneities especially due to various etiologies and ages of the patients and the lack of the evaluation of the estimated growth in the length of the spine in conjunction with the age of the patients in the shoulder imbalance definition may be listed as the limitations of our study.

This study's major conclusions are as follows: the single growing rod technique provided the highest rate of correction, while the dual growing rod technique led to fewer complications, relatively more spinal growth and better coronal balance. The single growing rod technique provided better improvement in CHD and CRID. The dual growing rod technique offered more improvement in CTAD. However, based on the radiological parameters we used to evaluate shoulder balance, we claim that the single rod technique can provide better results for achieving shoulder balance. For a more accurate evaluation, a study including a larger number of patients with a greater amount of homogenity is essential for a meaningful comparison.

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