ORIGINAL ARTICLE

J Turk Spinal Surg 2026;37(3):91-96

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DOI: 10.4274/jtss.galenos.2026.58561

THE EFFICACY OF THE SERIAL DEROTATIONAL CASTING IN EARLY ONSET SCOLIOSIS

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ABSTRACT

Objective: Serial derotational casting (SDC) is widely used in the management of early onset scoliosis (EOS) to control deformity and preserve thoracic growth; however, factors associated with curve progression remain incompletely defined. This study aimed to evaluate the clinical and radiographic outcomes of SDC and to explore factors associated with progression.

Materials and Methods: Thirty patients with EOS (20 girls, 10 boys) treated with SDC (≥2 casts) were retrospectively reviewed. Etiologies were congenital (n=18), syndromic (n=6), and idiopathic (n=6). Radiographs were evaluated at pre-cast, post-first-cast, and final follow-up. Progression was defined as a ≥5° increase in the main Cobb angle. Repeated-measures non-parametric tests assessed temporal changes, and univariate analyses explored associations with progression.

Results: At final follow-up, 23/30 patients (76.6%) were classified as stable/regressive, and 7/30 patients (23.4%) were classified as progressive. Mean age at first cast was 49.8±26.7 months, with a mean follow-up of 25.9±13.0 months. Heights at T1-T12 increased in both groups. In the stable/regressive group, the main Cobb angle improved after the first cast (from 59.4° to 48.6°) and remained relatively stable (58.5° at final follow-up), whereas, in the progressive group, it increased to 73.0°. Thoracic curve location was significantly associated with progression in univariate analysis (p=0.026), while other variables were not significant.

Conclusion: SDC effectively controlled deformity and preserved thoracic growth in most EOS patients. As the cohort was predominantly non-idiopathic (congenital), findings reflect surgical delay and growth preservation rather than curve regression. Thoracic curve location may be associated with a higher risk of progression; however, this finding should be interpreted cautiously due to the limited sample size. SDC appears to function primarily as a temporizing strategy, and close follow-up is essential. Further prospective studies are needed to clarify predictors of treatment response.

Keywords: Early onset scoliosis, serial derotational casting, elongation-derotation-flexion, thoracic curve, progression

INTRODUCTION

Early onset scoliosis (EOS) is defined as a spinal deformity with onset before 10 years of age, regardless of etiology[1,2]. Although this definition is straightforward, the underlying causes including idiopathic, neuromuscular, syndromic, and congenital demand individualized management strategies for each patient. Left untreated, progressive EOS can lead to severe spinal deformity, thoracic insufficiency syndrome, impaired lung development, and even life-threatening cardiopulmonary compromise[3,4].

The treatment philosophy for EOS has evolved from early definitive fusion to growth-friendly systems, such as growing rods, vertical expandable prosthetic titanium rib, and magnetically controlled growing rods. Despite their ability to maintain spinal growth, these approaches are associated with high complication rates, diminished correction with repeated lengthenings, and frequent unplanned reoperations[5,6]. Consequently, non-surgical strategies such as casting have regained importance to delay or avoid invasive procedures during early childhood.

Serial Derotational Casting (SDC), first described by Cotrel and Morel[7] and later popularized by Mehta[8], applies elongation-

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Received: 03.03.2026 **Accepted:** 26.04.2026 **Publication Date:** 06.07.2026
Cite this article as: Celilov R, Beydemir A, Kaymakoğlu M, Ayvaz M, Demirkıran HG, Yazıcı M. The efficacy of the serial derotational casting in early onset scoliosis. J Turk Spinal Surg. 2026;37(3):91-96

derotation-flexion (EDF) forces to correct deformity during rapid growth. SDC is widely accepted as a safe and effective non-surgical treatment, capable of controlling curve progression and maintaining thoracic growth. Idiopathic EOS patients, particularly those younger than two years and with moderate curves (<45°), show the most favorable outcomes with SDC, sometimes achieving complete resolution of deformity[9]. Several studies have also demonstrated its utility in congenital, syndromic or neuromuscular scoliosis, where although full correction is rarely achieved, SDC provides significant delay of surgical intervention (average 2-3 years) and allows continued thoracic growth[10,11].

Predictors of successful outcomes with SDC include early initiation (<2 years of age), final in-cast Cobb angle ⩽10°, rib-vertebral angle difference (RVAD) <20°, and higher body mass index[12]. However, recurrence of deformity during adolescence remains a concern even after initial success, highlighting the need for long-term follow-up until skeletal maturity[13].

The aim of the present study was to evaluate the clinical and radiographic outcomes of SDC in EOS patients, to identify risk factors associated with curve progression, and to determine the contribution of casting as a temporizing measure before growth-friendly surgical procedures.

MATERIALS AND METHODS

Ethical approval for this study was obtained from the Hacettepe University Non-Interventional Clinical Research Ethics Committee (approval no: GO 15/805-26, date: 16.12.2015). The study was conducted in accordance with the principles of the Declaration of Helsinki. Due to the retrospective nature of the study, the requirement for informed consent was waived by the ethics committee. After approval of the institutional review board, we retrospectively reviewed patients diagnosed with EOS and treated with SDC between 2009 and 2016 at our institution. A total of 53 patients were identified, of whom 18 were excluded due to inadequate follow-up (less than 24 months), missing radiographs or fewer than two cast applications. The final study cohort included 30 patients treated by three independent spinal surgeons (M.A., H.G.D., M.Y.).

Patient demographics including sex, age at first casting, and comorbidities were recorded. Etiology was classified as idiopathic, neuromuscular, syndromic, or congenital. Curve extent was classified based on the number of vertebrae included in the major Cobb angle. Curves spanning ⩽5 vertebrae were defined as short-segment, and those spanning ⩾6 vertebrae as long-segment. Radiographic parameters measured were: T1-T12 spinal height, T2-T12 kyphosis, L1-L5 lordosis, Cobb angle of the main and compensatory curves, pelvic obliquity and coronal balance. Measurements were obtained from standard standing posteroanterior and lateral radiographs at three time points: prior to the first cast (pre-cast), on the day after the initial cast application (post-first-cast), and at final follow-up. Radiographs obtained during the casting period were taken in-cast to evaluate deformity control under corrective forces. All radiographic assessments were performed by one author under supervision of two experienced spine surgeons (M.A., H.G.D.).

Patients were categorized into two groups based on curve progression of the main deformity at final follow-up. Patients with ⩽5° change in the major Cobb angle were classified as stable group, whereas those with ⩾5° increase were classified as progressive.

Derotational Casting Technique

The EDF technique, initially described by Cotrel and Morel[7] and later refined by Mehta[8], was used for all patients. Casts were applied under general anesthesia with the patient positioned on a Risser or Cotrel casting table, allowing longitudinal traction through the head and pelvis. Corrective forces were applied by molding at the apex of deformity while maintaining elongation and lateral flexion. Casts were typically over-the-shoulder for thoracic curves and under-the-shoulder for lower apices. Anterior and posterior windows were routinely cut to preserve respiration, reduce thoracic compression, and allow abdominal motion (Figure 1). Casts were changed at 2-4 month intervals depending on patient age and growth. This protocol is consistent with international series reporting on EDF casting in idiopathic and non-idiopathic EOS[8,14]. Reported complications of casting, such as skin irritation, gastrointestinal discomfort, or transient pulmonary symptoms were monitored, though no major adverse events occurred in this cohort.

Statistical Analysis

All analyses were performed using SPSS version 18.0 (IBM, USA). Descriptive statistics were presented as means ± standard deviation for continuous variables and as frequencies and percentages for categorical variables. Comparisons between the stable/regressive and progressive groups were performed using the Mann-Whitney U test for continuous variables and Fisher's exact test for categorical variables. The Friedman test, a non-parametric repeated-measures analysis, was used to evaluate changes in radiographic parameters including major and compensatory Cobb angle, T2-T12 thoracic kyphosis, L1-L5 lordosis, T1-T12 spinal height, pelvic obliquity, and coronal balance. Changes were assessed across three time points: pre-cast, post-first-cast, and final follow-up. Pairwise comparisons were conducted using Wilcoxon signed-rank tests with Bonferroni correction.

To explore factors associated with curve progression, defined as a ⩾5° increase in Cobb angle, univariate analyses were performed. Fisher's exact test was used for categorical variables and Mann-Whitney U test for continuous variables. In addition, univariate logistic regression analysis was performed to estimate odds ratios (ORs) with 95% confidence intervals (CIs). Due to the limited number of events in the progressive group, multivariate logistic regression analysis was not performed to avoid model overfitting. Therefore, the findings regarding potential predictors should be interpreted as exploratory.

All statistical tests were two-tailed, and a p-value ⩽0.05 was considered statistically significant.

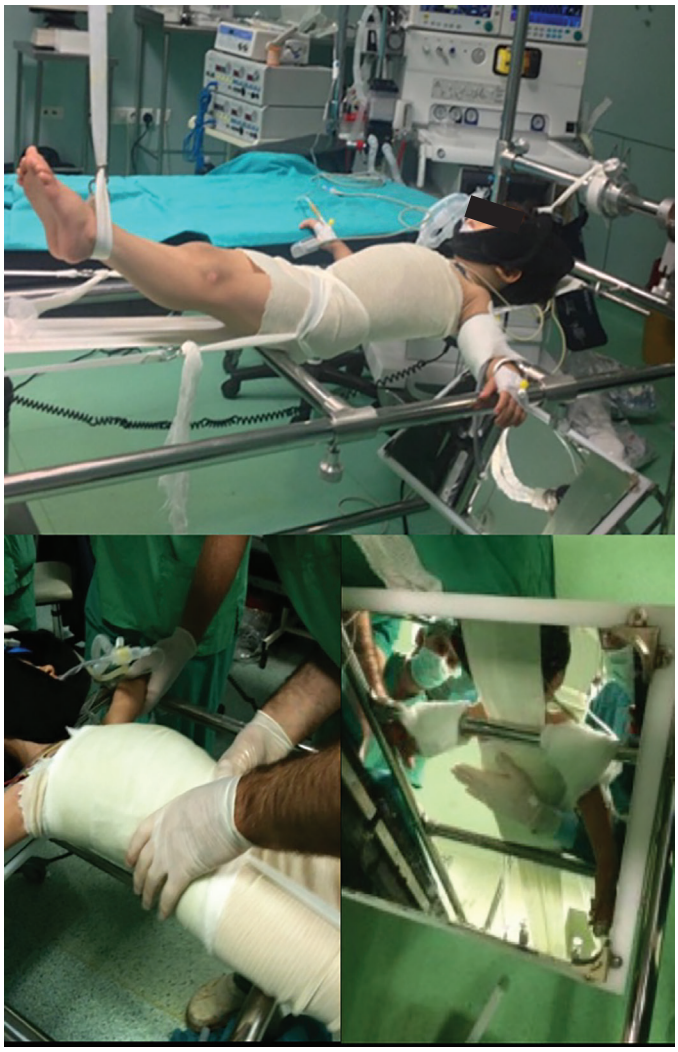

Figure 1. Preparation of the patient under traction for manipulation and casting. The wrapped cast is molded with the palm by applying pressure over the rib prominences at the apex of the thoracic curve, from posterior to anterior and from lateral to medial

RESULTS

A total of 30 patients with EOS met the inclusion criteria (20 girls, 10 boys). Eighteen patients were excluded due to inadequate follow-up or missing data, and five patients with pure kyphosis were not analyzed. At final evaluation, 23/30 (76.6%) patients were classified as stable/regressive and 7/30 (24.4%) as progressive. Etiology distribution was congenital (n=18), syndromic (n=6), and idiopathic (n=6). The distribution of progression across etiological groups was as follows: 3/18 in congenital, 3/6 in syndromic, and 1/6 in idiopathic patients. The mean age at the start of casting was 51.3±28.8 months in the stable group and 45.1±19.5 months in the progressive group. Mean follow-up was 24.5±13.4 months in the stable group and 30.4±13.4 months in the progressive group. Patients underwent 5.3±3.4 casts (stable) and 6.1±1.7 casts (progressive). Sex, etiology, age at first cast, presence of a kyphotic component, curve extent, and most radiographic baselines did not differ significantly between groups; only curve location was associated with progression, with thoracic curves over-represented in the progressive group (p=0.026). During follow-up, surgical intervention was performed in 9 patients overall, including 6 patients (26%) in the stable/regressive group and 3 patients (42.8%) in the progressive group (Table 1).

T1-T12 spinal height increased from 13.9±2.5 cm to 15.6±2.5 cm in the stable group and from 13.7±2.8 cm to 14.4±2.2 cm in the progressive group (overall p=0.536). T2-T12 kyphosis, L1-L5 lordosis, main and compensatory Cobb angles, pelvic obliquity, and coronal balance showed within-group time effects but no significant between-group differences in final values (Table 2). Post-hoc comparisons indicated significant time-point changes inside groups (footnotes in Table 2).

In univariate analysis, thoracic curve location was significantly associated with progression. Thoracic curves were more frequently observed in the progressive group and demonstrated higher odds of progression compared with lumbar and thoracolumbar curves (OR: 9.00, 95% CI: 1.32-61.14; p=0.026). Other variables, including sex, etiology, curve extent, and the presence of a kyphotic component, were not significantly

Table 1. Demographic and clinical characteristics

Variable	Stable/regressive (n=23)	Progressive (n=7)	p-value
Sex (F/M)	14/9	6/1	0.228*
Etiology (congenital/syndromic/idiopathic)	15/3/5	3/3/1	0.357*
Age at first cast (months)	51.3±28.8	45.1±19.5	0.603^
Kyphosis status (normal/+)	15/8	4/3	0.515*
Curve extent (short-segment/long-segment)	1/22	1/6	0.418*
Curve location (thoracic/lumbar+thoracolumbar)	5/18	5/2	**0.026***
Follow-up (months)	24.5±13.4	30.4±13.4	-
Number of casts	5.3±3.4	6.1±1.7	-
Patients operated, n (%)	6 (26%)	3 (42.8%)	-

^: Mann-Whitney U test, *: Fisher's exact test

associated with progression. Although some variables showed trends toward higher odds, these did not reach statistical significance. Age at first cast was also not significantly associated with progression (OR: 1.51, 95% CI: 0.33-6.88; p=0.603) (Table 3).

DISCUSSION

In this EOS cohort managed with SDC, most patients achieved a stable/regressive course (76.6%) with measurable thoracic growth, confirming SDC's role in early deformity control and growth preservation; our progression rate is consistent with reports that casting can modulate curves during rapid growth while maintaining T1-T12 height[11,15]. The magnitude of early radiographic response we observed, particularly the initial improvement after the first cast, also mirrors prior series underscoring that the first application delivers the largest correction, with subsequent casts consolidating the effect[12].

Thoracic curve location was the only factor significantly associated with progression in univariate analysis, suggesting a potential thoracic-specific vulnerability under casting forces. This finding is biomechanically plausible, given chest-wall coupling and the relative rigidity of the rib-vertebra complex, which may limit EDF-driven derotation near thoracic apices[16]. Although the literature seldom isolates location as a sole risk factor, segment-level observations that lumbar components improve more readily under casting are congruent with our finding that thoracic localization signals a higher failure risk[12]. However, this finding should be interpreted with caution due to the limited sample size and the small number of progression events in our cohort. Given that only seven patients were classified in the progressive group, performing a reliable multivariate regression analysis was not feasible, as it would increase the risk of model overfitting. Therefore, only univariate associations were evaluated, and these findings should be considered exploratory and hypothesis-generating. Furthermore, while thoracic curve location reached statistical significance in the univariate analysis, the extremely wide 95% CI of the OR (OR: 9.00; 95% CI: 1.32-61.14) substantially limits the precision and reliability of this estimate, and the finding should therefore be interpreted as preliminary and hypothesis-generating rather than conclusive.

Etiology, sex, and age at initiation were not significantly associated with progression in our univariate analysis. Although these variables showed a trend toward higher odds of progression, the analysis likely lacked sufficient statistical power to detect statistical significance. This pattern is consistent with prior literature suggesting that idiopathic patients tend to respond more favorably, whereas non-idiopathic cases primarily benefit from surgical delay and growth preservation rather than substantial curve correction[10,17]. Accordingly, the

Table 2. Radiographic parameters

Parameters	Stable/regressive (n=23)			Progressive (n=7)			p-value
	Pre-cast	Post 1st cast	Final follow-up	Pre-cast	Post 1st cast	Final follow-up	
T1-T12 height (cm)	13.9±2.5	-	15.6±2.5	13.7±2.8	-	14.4±2.2	0.536[1]
T2-T12 kyphosis (°)	44.0±17.7	37.1±15.8	41.3±17.1	50.1±24.5	31.0±22.0	45.2±26.3	0.858[2]
L1-L5 lordosis (°)	40.2±14.9	28.9±9.6	39.2±12.0	42.5±13.0	32.5±16.0	33.0±15.4	0.980[3]
Main Cobb (°)	59.4±20.8	48.6±19.1	58.5±26.1	54.8±13.8	55.2±13.2	73.0±16.0	0.181[4]
Compensatory Cobb (°)	21.0±26.6	16.5±23.9	26.7±33.8	23.5±33.2	25.4±31.9	23.0±30.8	0.825[5]
Pelvic obliquity (°)	5.0±5.0	-	4.9±7.5	0.4±0.7	-	1.8±2.4	0.131[6]
Coronal balance (cm)	1.8±1.4	-	3.5±5.9	1.1±0.6	-	1.1±0.6	0.196[7]

Note: Statistical analysis across time points was performed using the Friedman test for repeated-measures, with post-hoc pairwise comparisons conducted using the Wilcoxon signed-rank test with Bonferroni correction. Superscript numbers indicate significant within-group pairwise comparisons across time points

Table 3. Univariate analysis of factors associated with curve progression

Variable		OR	95% CI	p-value
Sex	Female vs. male	3.86	0.40-37.58	0.228
Etiology	Syndromic vs. idiopathic	5.00	0.34-72.77	0.357
	Congenital vs. idiopathic	1.00	0.08-11.93	0.357
Age at first cast	Per 1-month increase in age	1.51	0.33-6.88	0.603
Curve location	Thoracic vs. other	9.00	1.32-61.14	**0.026***
Curve extent	Short-segment vs. long-segment	3.67	0.20-67.66	0.418
Kyphotic component	Present vs. absent	1.41	0.25-7.90	0.515

Odds ratios were calculated using univariate logistic regression analysis. For continuous variables, odds ratios (OR) represent the change in risk per one-unit increase. *: p<0.05, CI: Confidence interval

predominance of congenital cases in our cohort may have influenced the overall interpretation of treatment success.

In contrast to our finding of no significant association between age at initiation and progression, multiple studies, including longer-term follow-ups and a meta-analysis, have demonstrated clear advantages of earlier treatment initiation (e.g., <20 months or <1.8 years) for curve resolution and magnitude of correction. In our cohort, the relatively higher mean age at initiation is likely related to the predominance of congenital cases, in which the primary goal of casting is often to delay surgical intervention rather than to achieve curve regression. Therefore, the lack of a statistically significant association between etiology and progression in our study, as well as the observed age-related findings, may reflect both the limited sample size and the heterogeneity of the cohort rather than a true absence of effect. The results should therefore be interpreted with caution, particularly when applied to idiopathic EOS populations[9,18].

The heterogeneous composition of the cohort should also be considered when interpreting these findings. Congenital, syndromic, and idiopathic scoliosis differ substantially in their natural history and response to casting. Although subgroup comparisons would be valuable, the limited number of patients in each etiological group precluded meaningful statistical analysis. Therefore, the results reflect the overall cohort and should be interpreted with caution when applied to specific etiological subgroups.

The radiographic course observed in our cohort, characterized by early correction followed by curve stabilization and incremental thoracic height gain, aligns with prior evidence suggesting that SDC functions as a temporizing strategy while preserving thoracic growth in both idiopathic and non-idiopathic EOS[11,15]. In our cohort, 9 patients ultimately required surgical intervention, further supporting the interpretation of SDC as a growth-preserving and temporizing strategy rather than a definitive treatment. Accordingly, the observed rate of stable/regressive curves should be interpreted as reflecting short-term control of the deformity and delay of surgery rather than permanent stabilization. In addition, adolescent recurrence remains a recognized risk even after strong early responses, underscoring the need for long-term surveillance through skeletal maturity[9].

Clinical implications follow directly: prioritize early casting when feasible; apply meticulous thoracic molds (over-the-shoulder application, apex-focused derotation, judicious windows) and closer follow-up for thoracic curves; and set realistic goals in non-idiopathic EOS around growth preservation and surgical delay rather than complete correction. Strengths include the use of a standardized casting technique and repeated-measures radiographic assessment.

Study Limitations

This study has several limitations. The retrospective design limits the ability to establish causal relationships. The relatively small number of patients in the progressive subgroup may have reduced the statistical power of the analysis. In addition, the limited number of progression events precluded the use of multivariate analysis and restricted the ability to identify independent predictors.

Some well-established predictors reported in the literature, such as RVAD and the "final cast ⩽10°" threshold, were not available for all patients and therefore could not be included in the analysis. The absence of these parameters represents an important limitation and reduces the completeness of the predictive analysis. In addition, all radiographic measurements were performed by a single observer, which may introduce measurement bias, and intraobserver variability was not formally assessed. Future studies should incorporate independent double-reading with formal ICC analysis to enhance methodological reliability. The heterogeneous distribution of etiologies within the cohort, along with the small number of patients in each subgroup, further limited the ability to perform subgroup analyses.

Future prospective studies with larger cohorts are required to better clarify predictors of treatment success with SDC[19].

CONCLUSION

SDC effectively controlled deformity and preserved thoracic growth in the majority of patients with EOS. Thoracic curve location was associated with progression in univariate analysis; however, this finding should be interpreted cautiously due to the limited sample size. These findings emphasize the importance of meticulous thoracic molding, timely initiation of treatment when feasible, and close longitudinal surveillance, particularly for thoracic curves. Given the potential for progression over time, sustained follow-up through growth remains essential. Larger prospective studies are warranted to confirm these findings and to better define patient- and curve-specific factors influencing long-term outcomes.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the Hacettepe University Non-Interventional Clinical Research Ethics Committee (approval no: GO 15/805-26, date: 16.12.2015).

Informed Consent: Due to the retrospective nature of the study, the requirement for informed consent was waived by the ethics committee.

Footnotes

Authorship Contributions

Surgical and Medical Practises: M.A., H.G.D., M.Y., Concept: R.C., H.G.D., M.Y., Design: R.C., M.K., H.G.D., M.Y., Data Collection or Processing: R.C., A.B., M.K., Analysis or Interpretation: R.C., A.B., M.A., H.G.D., M.Y., Literature Search: R.C., A.B., M.K., Writing: R.C., A.B., H.G.D.

Conflict of Interest: No conflict of interest was declared by the authors. Two of the authors of this article (M.A. and M.Y.) is a member of the Scientific Board of this journal. They had no involvement in the peer-review process or editorial decision regarding this manuscript. The peer-review process and editorial decision were handled independently by another editor.

Financial Disclosure: The authors declared that this study received no financial support.

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