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Review Article (Pages: 15145-15164)

The Efficiency of Epiphysiodesis for Growth Modulation in Patients with Congenital Scoliosis: A Systematic Review

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Abstract

Background: Congenital scoliosis (CS) is a challenging entity in spinal surgery. Convex growth arrest (CGA) is a therapeutic method aiming at inhibiting growth on the curve convexity while remaining growth of concavity corrects the scoliotic curve over time. In the view of controversies in current clinical studies for efficiency of CGA in CS patients, we performed a systematic review of the literature to clarify the debate.

Methods: A comprehensive literature search was performed to identify studies assessing CGA outcome in CS patients, in following databases and search engines: Ovid MEDLINE, PubMed, Scopus, Cochrane Central Register of Controlled Trials (CCTR), EMBASE, Google Scholar, and Web of Science. Two authors screened the search results and selected the studies by the supervision of senior authors.

Results: In 19 studies, including 363 patients, age at surgery was 58.76 months ranging from 4 to 216 months. Anterior and posterior hemiepiphysiodesis was the most common approach. Eight studies added instrumentation to CGA. Follow-up mean was 64.57 months. Nine studies reported true epiphysiodesis effect (postoperative and final follow-up CCA difference): from among 162 patients, 69 improved, 59 stabilized, and 34 progressed. Other studies reported preoperative and final follow-up CCA difference: among 88 patients, 49 improved, 32 stabilized, and 7 progressed. Preoperative curve magnitude, sagittal plane deformities, age <5 years, and type of spinal anomalies did not affect CGA outcome. Instrumentation was preferred in complicated spinal anomalies and older ages.

Conclusion: CGA alone or with instrumentation is a feasible CS treatment, however the criteria for choosing suitable candidates need reconsideration.

Key Words: Epiphysiodesis, Congenital Scoliosis, Convex Growth Arrest, Coronal Balance.

<u>* Please cite this article as</u>: Rezaee H, Pourbagher-Shahri A, Tavallaii A, Abouei Mehrizi M, Khajereza Shahri V, Abdul Sater A, Keykhosravi E. The Efficiency of Epiphysiodesis for Growth Modulation in Patients with Congenital Scoliosis: A Systematic Review. Int J Pediatr 2022; 10 (1):15145-15164. DOI: **10.22038/IJP.2021.56414.4434**

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Received date: Mar.16,2021; Accepted date:Sep.12,2021

1- INTRODUCTION

Congenital spine deformities in children result from anomalous vertebrae and abnormal vertebral segmentation (hemivertebra, congenital bar malformation, more complex malformations) leading to deformities in the coronal and sagittal planes as a result of growth imbalances (7, 26). Growth imbalance is where convexity outweighs the growth at the level of the concavity. The compressive side of the deformity sustains supraphysiological loads that suppress the growth at the physis (11, 22, 23). These deformities in young children continue to be one of the challenging entities of spinal surgery.

In the past, the aim of surgical treatment of congenital curves was to stop the increase of the curve magnitude that accompanies the growth of the child; however, currently vertebral column resections and fusion are considered the preferred method for surgical correction of these deformities (20). However, early fusion becomes a problem when the anomaly involves a long segment, and the child is left with a short spine when he or she grows into adulthood. Modulation of vertebral growth on either the convex or concave side of the curve (growth arrest or growth enhancement, respectively), theoretically, can be an early and effective treatment alternative for the growing spine.

Convex anterior and posterior hemiepiphysiodesis, also known as convex growth arrest (CGA) is a growth modulating procedure that was regularly used to treat congenital progressive spine deformity in children (2, 4, 29). CGA relies on the Hueter-Volkmann principle (3, 26, 28, 29). This principle was primarily described for longitudinal long-bone growth and indicates that the compressive side of a deformity undergoes non-physiological loading that produces the suppression of growth at the physis (24). CGA aims at controlling the spine deformity by inhibiting growth, anteriorly, and posteriorly, on the convex side of the curve, allowing the concave side to grow and compensate for the deformity in the following years (3, 9).

Some special indications for CGA have been discussed, including a progressive pure scoliotic curve without major kyphosis or lordosis, patients aged less than 5 years, without unilateral segmental bar, with no cervical spine involvement (20, 27). Other studies recommended that CGA is a possible and safe procedure in patients aged younger than 5 years regardless of other curve specifications (26).

After being the treatment of choice of congenital spine deformity for many years, CGA progressively fell out of favor during the past years (4, 11). The major drawbacks of CGA include unpredictability of curve behavior, slow or inadequate correction, necessity of anterior surgery for completeness of the epiphysiodesis, poor control of the deformity in long sweeping curves greater than 50 degrees, and inability to control trunk balance immediately until some spontaneous correction occurs years after the index procedure (26). Keeping in mind that correction of deformity after hemiepiphysiodesis is a chronic and slowly progressive phenomenon, a long-term follow-up is needed before definitive outcome is fixed.

Three types of result for CGA are possible:

a) True epiphysiodesis effect, i.e., improvement of the curve after removal of the cast;

b) Fusion effect or stabilization of the curve, i.e., no improvement of ≥ 5 to the preoperative angle); c) Deterioration or progression of the curve (15).

Overall, the data and outcomes on CGA using epiphysiodesis in congenital scoliosis are sparsely dotted across the literature. In view of these controversies and the inadequacies of current clinical studies we performed a systematic review of the available literature to determine the efficiency of CGA using epiphysiodesis in patients with congenital scoliosis.

2- MATERIALS AND METHODS

2-1. Literature search and Study selection

The PICOTS (Population, Intervention, Comparator, Outcomes, Time, and Study type) components of the research question we tried to answer were: *P*, patients with progressive scoliosis (congenital, idiopathic); *I*, CGA using epiphysiodesis alone or in combination with any type of instrumentation; *C*, other surgical treatments of scoliosis; *O*, improvement (true epiphysiodesis effect) or stabilization (fusion effect) or progression of scoliosis based on the changes of coronal Cobb angle by 5 degrees or more between postoperative and last follow-up time points, were defined as follow: improvement was characterized by the decrease in coronal Cobb angle ≥ 5 degrees, steadiness of scoliosis as decrease or increase in coronal Cobb angle < 5 degrees, and progression as increase in coronal Cobb angle ≥ 5 degrees; *T*, last follow-up or skeletal maturity; *S*, any study design presenting individual patient data.

The postoperative time point was considered immediately after surgery until the removal of the cast. In studies that their criteria for improvement/stabilization/progression considering the changes of coronal Cobb angle were different from our criteria, if the individual data of patients was available in the paper, outcomes were calculated for those papers. If the data were not available, their outcomes are explained in detail in the text.

A comprehensive electronic search of the following databases was performed from inception to Jan 2021 using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 guidelines: Ovid MEDLINE, PubMed, Scopus, Cochrane Central Register of Controlled Trials (CCTR), EMBASE, Google Scholar, and Web of Science.

The search was conducted with the following key words and strategies: "Epiphysiodesis," "Hemi Epiphysiodesis," and "Convex growth arrest" were combined using "OR" and they were combined with "scoliosis" using "AND" and were searched in "all field" modality. No language restrictions were applied.

After identifying the relevant studies and removing the duplicates, abstracts were screened and the articles to be considered as full-tests were selected according to the following inclusion criteria: studies 1) of scoliosis in humans, 2) treated with epiphysiodesis procedure alone or in combination with instrumentation 3) that described scoliotic curve outcome based on the changes of coronal Cobb angle measurements between postoperative and follow-up. Studies were excluded if not fulfilling the inclusion criteria or when we encountered the following conditions: 1) case reports, technical notes, editorials, comments, expert opinions; 2) if the number of subjects with scoliosis treated with epiphysiodesis were < 5; 3) Studies with incomplete or unavailable data; 4) Studies with animal experiments, and cadaveric experimental studies; 5) Gray literature and articles with poor quality evaluation or low credibility. After identifying relevant studies, the reference lists of included studies were hand searched to identify further appropriate studies.

2-2. Ethical considerations

All relevant aspects of ethics in the research were considered and followed throughout the study.

2-3. Data extraction

The following information was extracted: name of the first author, year of the study, study origin (country), study design, the study population inclusion and exclusion criteria, demographic characteristics (number, sex, and age), intervention details (anterior or posterior or combined, with or without instrumentation), follow-up period mean and range, coronal Cobb angle at pre-operation, post-operation, and final follow-up time points, outcome categorized in 3 sections: improvement, stabilization, and progression of scoliotic curve, and other uncategorized findings and outcomes. The extraction of continuous data (coronal Cobb angle) mainly included the mean and range (if reported).

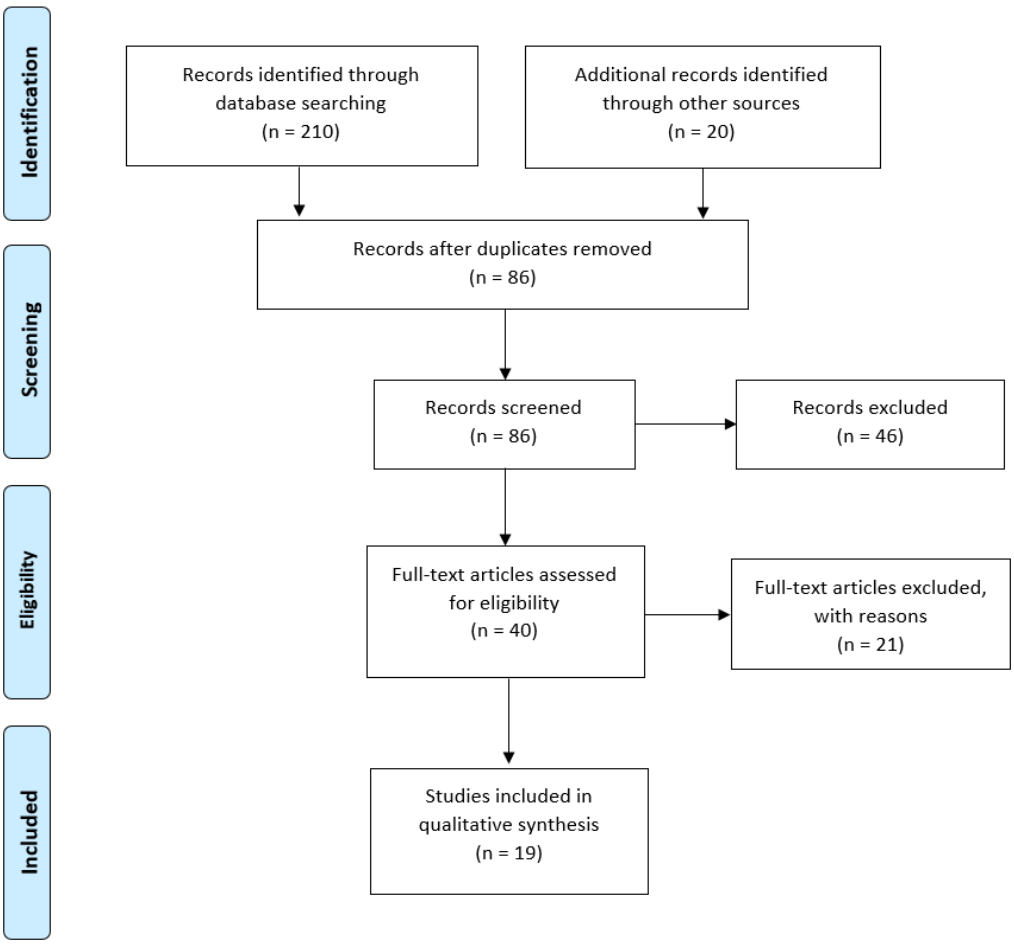
Two authors independently screened the articles concerning the inclusion and exclusion criteria. Any disagreements were solved with a senior author's opinion. The same two authors extracted information from eligible articles and disagreements were resolved by discussion between them; a third person was available when the consensus could not be reached.

3- RESULTS

3-1. Literature Search Results

The literature search identified 210 records in the databases, plus 20 additional relevant studies by hand search. After removing the duplications, 86 were screened, 40 full articles were assessed for eligibility, and 19 were included in the final pool, providing 363 individual patient data. The selection process is detailed in a flow diagram (**Fig. 1**).

Fig. 1: The flow diagram of searching databases based of PRISMA guideline



3-2. Study characteristics

The Included studies were published from 1981 to 2020. One study had only an abstract in English (18). Overall, 363 patients with congenital scoliosis were enrolled in 19 studies (1, 3, 8, 9, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 26, 27, 28, 29, 30). Among them, 13 studies were retrospective descriptive (8, 9, 12, 13, 14, 16, 19, 20, 21, 26, 27, 28, 30,) and 6 were case series (1, 3, 11, 15, 18, 29). Six studies were conducted in USA (13, 14, 16, 28, 29, 30), 4 studies in Turkey (1, 9, 11, 26), 3 studies in France (12, 15, 19), 2 studies in UK (3,20), 2 studies in China (8,18), 1 study in Netherland (27) and another 1 in Lebanon (21).

In 17 studies, the number of patients with scoliosis, kyphoscoliosis, and lordoscoliosis was reported (1, 3, 8, 9, 11, 12, 13, 14, 15, 16, 18, 20, 21, 26, 27, 28, 29). Kyphosis and lordosis were, respectively, found in 44 and 7 patients, from among the 285 patients with congenital scoliosis. Two studies reported kyphosis to be accompanied with scoliosis in their patients but did not clarify the exact number of affected patients (19, 30). Louis et al. (2010) reported that 24.3% of their population had kyphosis but it was not stated how many of them were among the 64 patients treated with hemiepiphysiodesis (19). In Yaszay et al.'s (2011) study, kyphosis was reported to be present in their 14 patients but the exact number of patients who had it was not reported (30).

The mean age of the patients at surgery reported in 18 studies was 58.76 months (1, 3, 8, 9, 11, 12, 13, 14, 15, 16, 19, 20, 21, 26, 27, 28, 29, 30), and the age range reported in 13 studies was from 4 month to 216 months (18 years) (1, 3, 8, 9, 11, 13, 14, 16, 20, 21, 26, 27, 28,). Li Ye-tian et al. (2020) reported neither the age's mean nor the range (18). Five other studies did not report age range, as well (12, 15, 19, 29, 30). Male to female ratio reported in 11 studies was on average 0.61 (1, 3, 8, 9, 11, 12, 15, 18, 26, 27, 28).

3-3. Types of interventions

Eleven studies reported their intervention to be anterior and posterior hemiepiphysiodesis (1, 8, 9, 12, 13, 15, 20, 26, 27, 28, 29); 2 studies were anterior hemiepiphysiodesis (14, 16); 1 study was posterior hemiepiphysiodesis (11); 3 studies reported epiphysiodesis without clarifying it to be anterior or posterior or both (3, 18, 21). Louis et al (2010) performed anterior and posterior hemiepiphysiodesis as well as posterior hemiepiphysiodesis alone, respectively, in 92.9% and 7.1% of their 64 patients (19). Yaszay et al. (2011) performed three surgical techniques in three groups of patients with congenital spinal deformities. One of the groups had hemiepiphysiodesis or in situ fusion, but it was not reported by the authors how many had hemiepiphysiodesis alone (30). Eleven studies did not use instrumentation in their surgeries (9, 12, 14, 15, 18, 21, 26, 27, 28, 29, 30), while 8 studies performed epiphysiodesis combined with instrumentation (1, 3, 8, 11, 13, 16, 19, 20) (for details see **Table 1**).

3-4. Outcome of studies

Mean of follow-up in 17 studies was 64.57 months (1, 3, 8, 9, 11, 12, 13, 14, 15, 16, 19, 20, 21, 26, 27, 28, 29, 30); one study did not report the follow-up duration (18). Follow-up range was reported in 12 studies with a minimum of 8 month to a maximum of 300 months (1, 3, 8, 9, 11, 14, 15, 16, 20, 21, 26, 27).

The preoperative coronal Cobb angle was reported in 18 studies and had a mean of 47.15 degrees; the study of Louis et al. (2010) did not report this data (19). The range of preoperative coronal Cobb angle reported in 5 studies was 20-105 degrees (8, 9, 11, 26, 27).

Table-1: Study characteristics of included studies

First author	Year	Country	Study Type	Spinal deformity types (number)	Number of Patients; Age Mean and Range (month); Male/Female Ratio	Intervention	Instrumentation (number, type)	Follow-ups Mean & Range (month)	Outcome							
									Coronal Cobb angle				Comparator	Improve	Stable	Progress
									Preop		Postop	Last follow-up				
Winter	1981	USA	Retrospective descriptive cohort	Scoliosis	10; 46 (13-89); 3/7	Anterior and posterior hemiepiphysiodesis	No	33	54		39.6	38.8	Post Op vs. last follow-up Cobb angle difference	2	7	1
Andrew & Piggot	1985	UK	Case series	Scoliosis (10); kyphoscoliosis (3)	13; 64 (30-164); 7/6	Epiphysiodesis	Posterior fusion both on the convex side; Dwyer cable instrumentation in 2 cases	52.2 (24-86)	49		42.2	34.84	Post Op vs. last follow-up Cobb angle difference	6	5	2
Winter	1988	USA	Case series	Scoliosis	13; 42; Not reported	Anterior and posterior hemiepiphysiodesis	No	78	46		Not reported	Not reported	Not reported	5	7	1
Dubousset	1992	France	Retrospective descriptive cohort	Scoliosis	13; 57; 4/9	Anterior & posterior hemiepiphysiodesis	No	68	45		37	39	Post Op vs. last follow-up Cobb angle difference	4	7	2
				Kyphoscoliosis	16; 44; 6/10			80	44		35	34		7	7	2
				lordoscoliosis	6; 39; 2/4			50	48		40	38.5		3	3	0
King	1992	USA	Retrospective descriptive cohort	Scoliosis	9; 109 (12-216); Not reported	Anterior hemiepiphysiodesis	Bilateral post spinal fusion + Harrington compressions rods in convexity	42 (26-60)	52		Not reported	Not reported	Preop vs. last follow-up Cobb angle difference	3**	6**	0**
Keller	1994	USA	Retrospective descriptive cohort	Scoliosis	16; 56 (11-156); Not reported	Anterior hemiepiphysiodesis	No	56 (24-114)	36		Not reported	38	Post Op vs. last follow-up Cobb angle difference	3*	10*	6*
Kieffer	1994	France	Case series	Kyphoscoliosis	6; 37; 3/3	Anterior and posterior hemiepiphysiodesis	No	54 (8-99)	42		26	34.33	Post Op vs. last follow-up Cobb angle difference	2	2	2
Marks	1995	UK	Retrospective descriptive cohort	Scoliosis	53; 76 (24-153); Not reported	Anterior and posterior epiphysiodesis	One case anteriorly and 2 cases posteriorly; Type not reported	104 (36-254)	Unilateral unsegmented bar (3 cases)	47.5 (40-55)	Not reported	74.5 (64-86)	Preop vs. last follow-up Cobb angle difference	Not reported	Not reported	Not reported
									Unilateral Unsegmented bars with HV (6 cases)	49 (36-62)	Not reported	52 (32-70)		Not reported	Not reported	Not reported
									HV (30 patients)	41 (20-64)	Not reported	35 (10-64)		Not reported	Not reported	Not reported
									Complex anomalies (12 cases)	74 (32-96)	Not reporter	90 (30-110)		Not reported	Not reported	Not reported
Cheung	2002	China	Retrospective descriptive cohort	Kyphoscoliosis	6; 40 (18-69); 5/1	Anterior and posterior fusion	Concave distraction	129 (96-168)	49		33	29	Post Op vs. last follow-up Cobb angle difference	2	3	1
Walhout	2002	Netherlands	Retrospective descriptive cohort	Scoliosis, Kyphoscoliosis (3)	10;30.8 (4-77); 4/6	Anterior and posterior hemiepiphysiodesis	No	59 (11-103)	54 (40-74)		50.3 (40-78)	58 (32-104)	Post Op vs. last follow-up Cobb angle difference	5	2	3

First author	Year	Country	Study Type	Spinal deformity types (number)	Number of Patients; Age Mean and Range (month); Male/Female Ratio	Intervention	Instrumentation (number, type)	Follow-ups Mean & Range (month)	Outcome						
									Coronal Cobb angle			Comparator	Improve	Stable	Progress
									Preop	Postop	Last follow-up				
Cil	2003	Turkey	Retrospective descriptive cohort	Kyphoscoliosis (All); Lordoscoliotic in 1	11; 35 (6-72); 3/8	Anterior and posterior hemiepiphysiodesis	No	40 (24-76)	58 (36-105)	Not reported	52 (13-107)	Preop vs. last follow-up Cobb angle difference	6	5	0
Uzumcugil	2004	Turkey	Retrospective descriptive cohort	Scoliosis, kyphoscoliosis in 2	32; 29 (6-72); 7/25	Anterior and posterior hemiepiphysiodesis	No	40 (24-120)	55 (31-105)	Not reported	50 (13-107)	Preop vs. last follow-up Cobb angle difference	13	15	4
Ginsburg	2007	USA	Retrospective descriptive cohort	Scoliosis	9; 125 (33-173); Not reported	Anterior and posterior hemiepiphysiodesis	Short segment instrumented posterior spinal fusion on the convex side	29	37.7	31.6	32.8	Post Op vs. last follow-up Cobb angle difference	3*	4*	3*
Louis	2010	France	Retrospective analytical cohort	Scoliosis, 24.3% had kyphosis ***	64; 64; Not reported	Posterior hemiepiphysiodesis : 7.1%; anterior and posterior hemiepiphysiodesis : 92.9%	16% of patients; Type was not reported	137	Not reported	Not reported	Not reported	Post Op vs. last follow-up Cobb angle difference	24	20	20
Yaszay	2011	USA	Retrospective analytical cohort	Scoliosis + kyphosis	14; 117.6 ± 74; Not reported	Hemiepiphysiodesis or in situ fusion	No	24	37 ± 14	Not reported	24 ±10	Preop vs. last follow-up Cobb angle difference	12	1	1
Alanay	2012	Turkey	Case series	Scoliosis	5; 40 (17-55); 0/5	Anterior and posterior Hemiepiphysiodesis	Convex side: unilateral pedicle screws on the anomalous vertebrae with a single rod connecting them; Concave side: growing rods with lengthening every 6 months	34 (26-40)	48	36	27	Post Op vs. last follow-up Cobb angle difference	5	0	0
Demirkiran	2013	Turkey	Case series	Scoliosis	13; 64.5 ± 30.1 (15-108); 6/7c	Posterior Hemiepiphysiodesis	Convex pedicle screws and compression	56.1 ± 10 (36-74)	49 ± 10.9 (34-68)	38.3 ± 9.7 (28-58)	33.5 ± 12.4 (16-52)	Post Op vs. last follow-up Cobb angle difference	9	3	1
Li Ye-tian	2020	China	Case series	Scoliosis	22; Not reported; 12/10	Epiphysiodesis	No	Not reported	40.5 ± 9.8	39.5 ± 11.1	46.8 ± 13.9	Post Op vs. last follow-up Cobb angle difference	Not reported	Not reported	20
Rizkallah	2020	Lebanon	Retrospective descriptive cohort	Scoliosis	22; 36 (6-96); Not reported	Hemiepiphysiodesis	No	128.5 (66-300)	40.6	Not reported	27.4	Preop vs. last follow-up Cobb angle difference	15	5	2

* These are based on the number of curves, not the patients; ** Improvement was considered if curve correction more than 10 degrees was obtained; *** The samples of studies were 251 patients and 64 of them are reported here.

The postoperative coronal Cobb angle was reported in 9 studies and had a mean of 37.44 degrees (1, 3, 8, 11, 12, 13, 15, 18, 28). Only Demirkiran et al. (2013) and Walhout et al. (2002) reported the range of postoperative coronal Cobb angle to be 28-78 degrees (11, 27).

The coronal Cobb angle at the final follow-up was reported in 15 studies and had a mean of 38.54 degrees (1, 3, 8, 9, 11, 12, 13, 14, 15, 18, 20, 21, 26, 27, 28, 30). The range of this item was reported in 5 studies and was between 10 to 110 degrees (9, 11, 20, 26, 27).

After the epiphysiodesis surgery, to ensure the safety of fusion occurrence as well as achieving some correction, a protecting cast is applied for 4 to 7 days until the radiography images show evidence for fusion. So, the true epiphysiodesis effects is assessed by measuring the difference between angle of scoliotic curve at the postoperative (i.e., removal of the cast), and at the last follow-up points. This is different from global correction in which the preoperative angle and the last follow-up angle are compared to each other (15). In this review 12 studies measured the difference between postoperative and last follow-up angle

(1, 3, 8, 11, 12, 13, 14, 15, 18, 19, 27, 28) while 6 studies measured the global correction of scoliotic curve (9, 16, 20, 21, 26, 30). Winter et al. (1988) did not reported their criteria for measuring the outcome of their patients (29). Among 12 studies which reported the true epiphysiodesis effect, in the studies by Keller et al. (1994) and Ginsburg et al. (2007), outcome of patients was reported based on the curves not the patients (13, 14). The study by Li Ye-tian et al. (2020) did not report the outcome of all patients (18). In the remaining 9 studies which reported the true epiphysiodesis effect, 42% of patients had improvements in their scoliosis, 36% showed stabilization, while 21% had worsened scoliosis in the last follow-up (28, 3, 12, 15, 8, 27, 19, 1, 11). Among the 6 studies that reported global correction of the scoliotic curve as the outcome, Marks et al. (1995) did not report the categorized outcome of patients per individual based on the difference between preoperative and final follow-up Cobb angle (20). In the 5 remained studies, among 88 patients, 49 (55.5%) showed improvement, 32 (36.5%) stabilization, and 7 (8%) deterioration in their last follow-up Cobb angle (9, 16, 21, 26, 30).

Regarding the outcomes of the studies, in 9 studies the changes of coronal Cobb angle between postoperative and final follow-up were compared to determine the outcome (1, 3, 8, 11, 12, 15, 19, 27, 28). These studies had 162 patients in total and reported that 69 patients had shown improvement, 59 had been stabilized, and 34 were worsened at the final follow-up.

Studies that compared the changes of coronal Cobb angle between preoperative and final follow-up time points, had 88 patients among whom 49 showed improvement, 32 showed stabilization of the scoliosis and 7 had progression at the final follow-up (9, 16, 21, 26, 30). Among these studies, King et al. (1992) considered the improvement of the scoliotic curve as a correction more than 10 degrees between preoperative coronal Cobb angle and follow-up (16). In Keller et al. (1994) and Ginsburg et al. (2007) studies, outcomes were reported based on the number of curves, not the patients, as former reported that from among 19 curves operated in 16 patients, 3 were improved, 10 had halted progression, and 6 worsened at the final follow-up (13, 14). In the study by Ginsburg et al. (2007), among 10 curves operated in 9 patients, 3 improved, 4 became stable, and 3 deteriorated at the final follow-up (13). Li Ye-tian (2020) did not report the outcome of all patients whereas in the sample size of 22 patients, 20 cases had progressed scoliosis at the final follow-up (18). Marks et al. (1995)

reported their patients' outcome in 4 subgroups of patients (Unilateral unsegmented bars, unilateral unsegmented bars with hemivertebra, hemivertebra and complex anomalies) as only coronal Cobb angle mean at preoperational and final follow-up time points. The detailed results of their study are represented in the following section.

3-5. Unclassified characteristics and results of included studies

In Winter et al. (1981) study, sites of curves in 10 patients were at thoracic in 6, thoracolumbar in 2, and lumbar in 2 (28). Anatomical malformations of these curves were unilateral unsegmented bars in 2, single hemivertebra in 7, and mixed anomalies in 1 patient. The only patient who had progression of the scoliotic curve in the last follow-up had unilateral unsegmented bar.

In the study by Andrew and Piggot (1985), cases 1 to 4 (all had hemivertebra) were operated in early childhood and showed progressive correction (3). Cases #5 to 8 had complex deformities. Cases #9 and 10 had lumbar hemivertebra and because they were too old for growth arrest alone, they had Dwyer compression apparatus as well, which did not change the outcome. Cases #11 to 13 had significant kyphosis along with their scoliosis which at final follow-up fusion effect was seen in 2 cases, and progression of scoliotic curve was seen in the other one.

Winter et al. (1988) did not report postoperative and final follow-up measures of Cobb angle but their criteria for improvement of scoliotic curve was a decrease ≥ 5 degrees (29). The only failed outcome was due to inadequate length of anterior surgery which was salvaged by the further surgery.

In Dubousset et al. (1993) study, later surgery resulted in more fusion and earlier fusions resulted in more Cobb angle improvement (12). Crankshaft phenomenon was the underlying reason for 4 patients whose curves progressed at final follow up.

In King et al. (1992) study, curves of the 9 included patients were sited in thoracic spine in 5, thoracolumbar in 1, and lumbar in 3 cases (15). The anatomic malformations consisted of 4 single hemivertebra, 3 multiple hemivertebra with contralateral bar and 2 mixed anomalies. Their 3 patients with improvement in their scoliosis all had single hemivertebra.

Keller et al. (1994) reported that anatomic malformations in 4 patients were single hemivertebra which in 3 cases, they were two ipsilateral hemivertebra; in 2 cases were two contralateral hemivertebra; in 2 they were unsegmented bar with contralateral hemivertebra which 1 had unsegmented bar with two contralateral hemivertebra and 1 had unsegmented bar with to ipsilateral hemivertebra; 1 case had unsegmented bar with ipsilateral and contralateral hemivertebra; and in 2 patients there were complex anomalies (14). Two patients had additional surgeries; 1 patient had posterior spinal fusion due to developing pseudoarthrosis; the other patient had thoracotomy and posterior spinal fusion. The latter was 13.5y at surgery and had an 80 degrees kyphosis. Keller et al. (1994) also reported that higher regression was seen in curves composed of unsegmented and hemivertebra; and the lowest regression was seen in curves related to single hemivertebra; however, these observations were not statistically significant (14).

Kieffer et al. (1994) reported that anatomical malformations in their patients were hemivertebra in 5 and unilateral unsegmented bar in 1 patient (15).

In the study by Marks et al. (1995), 53 patients with congenital scoliosis underwent anterior and posterior epiphysiodesis (15). Spinal deformities were as follows: 32 fully segmented non-incarcerated hemivertebrae in 30 patients, 4 unsegmented bars, 7 unsegmented bars with hemivertebrae, and 12 complex (unclassifiable) patterns. Regarding the sites of deformities, 31 were in the thoracic spine, 11 in the thoraco-lumbar, 10 in the lumbar and 1 in the lumbo-sacral. Co-existing congenital anomalies were present in 27 patients (51%). Anterior and posterior surgery was done in a single procedure in 35 patients and in 2 procedures for the remaining 18 patients with an interval of between 2 weeks and 3 months. Patients were divided into 4 subgroups based on their spinal anomalies: 1. Unilateral unsegmented bars, 2. Unilateral unsegmented bars with hemivertebra, 3. Hemivertebra and 4. Complex anomalies. Progression rate of coronal Cobb angle in groups 1 and 2 was +4.2 and +2.5 degrees preoperatively which were decreased to +3.6 and 0 degrees postoperatively but was not statistically significant. In group 3 (hemivertebra), progression rate decreased from +1.9 degrees preoperatively to -1.23 degrees postoperatively which was significant. Moreover, in group 3, progression rate of Cobb angle in 23 cases was reversed, arrested in 5, unchanged in 1, and progressed in 1. In group 4, the preoperatively progression rate of coronal Cobb angle was +4 degrees which decreased to +1.6 degrees postoperatively. Reported complications were three superficial wound infections, two chest infections and three neuropraxias. Authors declared that surgery at younger ages resulted in greater correction of coronal Cobb angle progression.

In the study by Cheung et al. (2002), all patients had kyphoscoliosis due to fully segmented hemivertebra at T11 or T12 levels (8). After the surgery, 4 cases had immediate improvement after the surgery, however only 2 had improved scoliosis at the final follow-up. The accompanied kyphosis deformities curves had a preoperative angle of 28 degrees, 26 at postoperative, and at the last follow-up they were 29 degrees. The Kyphosis improved in 3 patients, had no change in 1, and worsened in 2 patients. Complications were reported in 2 patients: case #3 had posterior deep wound infection and case #4 had pseudoarthrosis on the convexity.

Walhout et al. (2002), studying 10 patients with unclassified congenital scoliosis, reported that the preoperative curves were high thoracic in one, low thoracic in six and thoracolumbar in three patients (27). The number of vertebrae in the curves ranged from five to nine. Authors considered a minimum of 20 degrees change between preoperative and final follow-up Cobb angle of the curve as the comparator for determining the outcome. 5 Of the 10 curves progressed and 5 improved in the follow-up. Based on the authors' criteria, epiphysiodesis effect was achieved in 2 patients, stabilization of the curve was achieved in six patients, and progression of the curve occurred in two patients. The per annum progression rate of Cobb angle decreased from 2.9 degrees (-35 to +14) preoperatively to 2.4 degrees (-4 to 13) postoperatively; however, this change was not statistically significant. The average annual rate of Cobb angle change was 14° to –2° in one high thoracic curve, –2.5° to 3.5° in six low thoracic curves, and 9.9° to 1.6° in three thoracolumbar curves. Thoracic kyphosis averaged 32° preoperatively, ranging from 16° to 60° which at the follow-up changed to a mean of 44 degrees ranging from -10 to 76. Repeat surgery was necessitated by coexisting progressive kyphosis and pseudoarthrosis in one patient and involved extension of primary epiphysiodesis in two patients. Authors concluded that being under 5 years of age, having a thoracolumbar curve location, and the absence of coexisting kyphosis are associated with a more favorable outcome.

Cil et al. (2003) aimed to investigate the effect of sagittal plane abnormality and its course on the control of coronal plane deformity in patients with congenital scoliosis who were managed satisfactorily with convex growth arrest (9). Thus, authors excluded 2 kyphoscoliosis patients treated with anterior and posterior hemiepiphysiodesis from the study because of insufficient control of coronal plane deformity (increased from 54° and 66° to 65° and 77° at the end of the follow-up period, respectively). The anatomical malformations in the included patients were complex vertebral anomalies in 2, unilateral unsegmented bar and contralateral hemivertebra in 5 patients, and 4 patients had hemivertebra. Fusions of the ribs were seen in 5 patients, 1 patient had rib aplasia, and remaining patients did not have any associated rib anomaly. Regarding the curves segmentally, 9 patients (82%) were hyperkyphotic, 1 (9%) was hypokyphotic (case #9) and case #6 was lordotic before surgery. Indications for the surgery were documented as progression in 5 patients and magnitude of the curve >50 degrees at the admission in 6 patients. Patients' outcomes were reported based on the difference between preoperative and final follow-up coronal Cobb angle being more than 6 degrees. Outcome for sagittal plane deformities were as follow: mean global thoracic kyphosis was 34 degrees (range 10°–60°) before surgery, and 43 degrees (range 22°–74°) at the final follow-up; mean global lumbar lordosis was 44 degrees (range 12°–75°) before surgery and 56 degrees (range 26°–96°) at the final follow-up; in the end of follow-up period sagittal Cobb angles remained stable in 7 patients (64%) and deteriorated in 4 (36%). Results showed that presence of sagittal plane deformity does not have a negative effect on the control of scoliosis in 11 of 13 patients. Stabilization or improvement of coronal curve resulted in stabilization of the sagittal segmental abnormality in 7 of 11 patients.

In a study by Uzumcugil et al. (2004), from among 32 patients, 12 had complex vertebral anomalies, 9 patients had unilateral unsegmented bar and contralateral hemivertebra, 1 had unilateral unsegmented bar, and 10 had hemivertebra (26). They reported their outcome based on the difference between preoperative and final follow-up coronal Cobb angle being more than 6 degrees. Among 17 curves which had >50 degrees before surgery, 6 had improvement, 7 became stable, and the other 4 progressed. All curves that progressed were more than 50 degrees, however no significant difference between curves >50 degrees and <50 in outcome was observed. Preoperative curve magnitude had no significant relation with the result (improvement/stabilization/progression). Neither of age groups, more than 2 years or less than it at surgery, type of anomaly (complex or hemivertebra with or without unsegmented bar), having >5 or <5 segments fusion, location of curve, having or not having rib deformity and sagittal plane deformity, and presence of intraspinal anomalies did not affect the outcome at the final follow-up. In 4 patients who had progression in their scoliosis at the final follow-up, 3 patients aged less than 2 years, all had curves with initial degrees >50, all had complex anomaly or unsegmented bar with contralateral hemivertebra, 2 had sagittal plane abnormality, and 3 curves had lengths >5 segments. Overall, poorer prognosis was seen in larger complex curves involving longer segments in a younger child. Pulmonary complications were observed in six (19%) patients which were all related to anterior surgery to provide anterior hemiepiphysiodesis.

Ginsburg et al. (2007) studied 9 patients of progressive congenital scoliosis with 10 curves. One patient had bilateral hemivertebrae at T4 and T9 (13). The Risser sign was zero in all cases except one. The authors considered the patients' total main curve changes more than 6 degrees between the preoperative and the last follow-up points for determining the outcome (improvement, stabilization or progression) results reported as the following: 1 curve progressed, 6 curves improved, and 3 curves remained unchanged. Seven curves showed immediate improvement from the preoperative point as compared to the postoperative radiographs. However, when considering the defined criteria in this review, outcomes of patients were different as shown in **Table 1**. Three patients who had progression in their scoliotic curves aged more than 9 years and 10 months at the time of initial surgery.

Louis et al. (2010) determined the outcome of frontal plane deformities with several surgery managements in 251 patients, 64 of whom were managed by epiphysiodesis (19). Patients were at least 4 years old when evaluated at the end of the follow-up. Seventy-five percent of the 64 patients managed by epiphysiodesis showed less than 8◦ progress in malformation's curve angle between postoperative and final follow-up values. Epiphysiodesis provided identical long-term results as hemivertebra resection.

In a retrospective analytical cohort study by Yaszay et al. (2011), 3 surgical treatments (Hemivertebra resection, hemiepiphysiodesis/in situ fusion, and instrumented fusion without a resection) for congenital spinal deformity due to a hemivertebra in 76 patients were investigated (30). Our target group of patients in this review was group 1 which consisted of 14 patients and had hemiepiphysiodesis or in situ fusion; however, it was not clarified how many had epiphysiodesis alone. All patients in group 1 had scoliosis, and some of them also had kyphosis, but the exact numbers were not reported in the paper. Twelve had single and 2 had double hemivertebrae. One patient in this group developed a pseudoarthrosis that required revision surgery. Overall, hemivertebra resection produced better deformity correction than did either hemiepiphysiodesis/in situ fusion or instrumented fusion without a resection.

In the study by Alanay et al. (2012), the included patients were younger than 5 years and had congenital thoracic scoliosis with multiple anomalous vertebrae (1). Regarding the sagittal plane deformities preoperative global thoracic kyphosis curvatures were 28.2 degrees preoperatively, 28.8 degrees postoperatively, and 32.4 degrees at the last follow-up. Global lumbar lordosis curvature was 39 degrees preoperatively, 37.8 degrees postoperatively, and 44.4 degrees at the final follow-up. Reported complications were partial pullout of the proximal, distal, or both pedicle screws of the concave distraction in four of the five patients.

Demirkiran et al. (2014) reported that the patients had long sweeping curves which included >4 to 5 segments (11). All patients were Risser zero at the time of surgery. The average concave height was 94.2±20.2 mm in the early postoperative period and 104.7±21.7 mm at the last follow-up (P=0.003). The average T1-S1 height was 292.1±67.1 mm in the early postoperative period and 363.9±94.5 mm at the last follow-up (P=0.005). Coronal Cobb angle postoperatively was significantly different from that in the preoperative time point (38.3 ± 9.7 vs. 49 ± 10.9, respectively). However, this parameter was not significantly different between the last follow-up to the postoperative time (33.5 ± 12.4 vs. 38.3 ± 9.7, respectively). In 9 patients who had improvement in their Cobb angle measures, preoperative curve was 46.7±12 and 37.3±11.5 at early postop (P=0.007) and the main curve Cobb was 28.4±11.3 in the latest follow which was significantly different from early postoperative evaluation (P=0.007). Technical error caused the progression of scoliosis in 1 patient at the final follow-up. The sagittal plane remained stable and there was no deterioration (preoperative kyphosis=33.7±14.5 degrees; early postoperative kyphosis=35.6±12.5 degrees; follow-up kyphosis=33.9±9.5 degrees; P>0.05). A significant instrumented correction effect was obtained during the surgery in 1 patient; her curve deteriorated due to inappropriate instrumentation levels and malposition of most of the distal screws and she had to undergo revision surgery with vertebral column resection.

For the study of Li Ye-tian et al. (2020) only an English abstract was available (18). The Cobb angle of the main curve was significantly different between follow-up, preoperative and postoperative evaluations. Twenty patients had progression of main curve Cobb angle with a rate of 1.5 ± 1.4 degrees per annum and a total of 19.2 ± 17.9 %. Three patients underwent lateral convex orthopedic internal fixation due to postoperative scoliosis progression. The curve progression was significantly correlated with age at the time of surgery and number of hemivertebra. There was a significant correlation between the age of the operation and the main curve angle.

Rizkallah et al. (2020) studied patients with progressive congenital scoliosis with hemivertebra or congenital bar. Patients with associated syndromes and malformations (including medullary malformations) were excluded from their study (21). Among 22 patients, 18 had an isolated hemivertebra, and 4 patients had an associated congenital bar. Deformity was dorsal in 4 patients, dorsolumbar (D10-L2) in 9 patients, and lumbar in 9 patients. Cobb angles of the scoliotic curves were compared preoperatively and at the last follow-up. Limited fusion was performed on 16 patients (mean curve of 37.2 degrees) which resulted in 44.8% correction. Extensive fusion was performed on 6 patients where there was a congenital bar, a severe curve, and were older (mean curve of 50.3) and resulted in 11.3% correction. Patients who aged 3 years or younger had a correction of 43.1% which was not significantly different from the 21.5% correction in 7 cases older than 3 years of age. There were 18 isolated hemivertebrae which had a Cobb correction of 44.6% compared to 1.3% correction in hemivertebra with congenital bar (P=.004). Eight cases with curves <35 degrees had 58.2% Cobb correction compared to 23.7% correction in curves >35 degrees (P=.032). Four curves with >35 degrees of magnitude had congenital bar and hemivertebra; and were operated on after the age of 3 years. In these 4 patients, limited fusion performed in 1 case led to a progression of the curve, and extended fusion performed in 3 patients led to stabilization in 2 curves and to the reduction of Cobb angle in 1 curve at the last follow-up. Mean Cobb angle changes in 15 patients with improved scoliosis was -20.5 degrees, and in 2 patients with progressed scoliosis was +11.5 degrees.

3-6. Intra-study risk of bias assessment

The nine-star Newcastle-Ottawa Scale (NOS) (16) was used to evaluate the quality of clinical observational studies. The Newcastle–Ottawa Scale is a validated tool for the quality assessment of nonrandomized studies, including cohort and case-control studies, and contains the following categories: selection of cohorts (four items), comparability of cohorts (one item), and assessments of outcomes (three items). A study can be awarded a maximum of one star for each item within the selection of cohort and assessment of outcome categories and two stars for the items in the comparability of cohort category. The scores of the items identifying study quality varied from zero to nine. Any disagreement was settled by a group discussion with a third investigator. The results are represented in **Table 2**.

Table-2: Intra-study risk of bias assessment of Cohort studies

1st Author	Selection				Comparability	Outcome			Total Score
	Q1	Q2	Q3	Q4	Q1	Q1	Q2	Q3	
Winter	1	0	1	0	0	1	0	1	4
Dubousset	1	0	1	0	0	1	1	1	5
King	1	0	1	0	0	1	1	1	5
Keller	1	0	1	0	0	1	0	1	4
Marks	1	0	1	0	0	1	1	1	5
Cheung	1	0	1	0	0	1	1	1	5
Walhout	1	0	1	0	0	1	1	1	5
Cil	1	0	1	0	0	1	0	1	4
Uzumcugil	1	0	1	0	0	1	0	1	4
Ginsburg	1	0	1	0	0	1	0	1	4
Louis	1	0	1	0	0	1	1	1	5
Yaszay	1	0	1	0	0	1	1	1	5
Rizkallah	1	0	1	0	0	1	1	1	5

4- DISCUSSION

Congenital scoliosis represents spinal malformations in the coronal plane due to vertebral malformations. The underlying causes are failure of formation, segmentation, or a mix of them. Congenital scoliosis results in longitudinal and rotational imbalance. These deformities can progress further following longitudinal growth imbalances which subsequently causes simultaneous abnormal convexity and concavity in the spine.

The current treatment consists of observation, bracing, and surgery. Patients with balanced spine and vertebral malformations that have low progression rate or compensating defects of formation can be under observation and be evaluated periodically with serial plain radiographs every 4 to 6 months without requiring surgery. In the cases of long, non-rigid curves and compensatory curves located at distal or proximal of anomalous segments, bracing is a feasible option. Surgery approaches are based on inhibition, modulation, or preservation/stimulation of the growing spine. Using compression to arrest the growth of the convex side alone or associated with enhancing the growth on the concave side by distraction are the principles for modulation of growth. CGA surgery can be used in this matter. Scoliotic patients with developing skeleton and localized growth centers can be managed with growth arrest to achieve correction of deformities as well as growth control. CGA was popularized because of its safety and simplicity compared to other surgical alternatives.

Nineteen studies that met our eligibility criteria comprise the results of this review. Great heterogeneity was observed ranging from methodologies to the outcomes of the included studies. Several criteria for suitable patients for CGA have been defined in the literature, from which we can mention a strictly scoliotic curve of less than five segments with a magnitude of less than 70° for a patient not over 5 years of age. Suggested contraindications for CGA are Sagittal plane deformity, cervical involvement, intraspinal abnormalities, posterior arch defects (e.g., myelomeningocele), and unilateral bars. Compared to CGA, hemi-vertebrectomy surgery is a better option for deformities caused by a single hemivertebra (25, 27, 29).

Conflicting reports were found in included studies of this review regarding the criteria for suitable patients for CGA. The preoperative curve magnitude did not seem to affect the CGA outcome evidenced by Uzumcugil et al.'s (2004) study. They found no significant relation between preoperative curve magnitude and CGA outcome at the final follow-up (26).

Also, presence of sagittal plane deformities (kyphosis and lordosis) or other spinal deformities did not affect the outcome of congenital scoliotic patients with CGA. Subgroup analysis of studies, reporting true epiphysiodesis effect, showed that of 101 patients with associated sagittal plane deformities (kyphosis and lordosis), 40% had true epiphysiodesis effect, 34% had stabilization in their scoliotic curves, and 24% had worsened scoliosis in their last follow-up (3, 8, 12, 15, 19, 27). CGA outcomes were similar at the presence of sagittal plane deformities, as among 41 patients, 48% had true epiphysiodesis effect, 41% had stabilization and 9% had deteriorated at the final follow-up (1, 11, 12, 28). Also, stabilization or improvement of the coronal curve resulted in stabilization of the sagittal segmental abnormality in 7 of the 11 patients in one study (9). Furthermore, presence of other deformities such as rib deformity as well as intraspinal anomalies did not affect the CGA outcome (26). However, absence of coexisting kyphosis was associated with a more favorable outcome (27).

The limitation of an age less than 5 years at the time of surgery did not seem to be a determining factor for CGA outcome in identified studies as the reported mean age at surgery in 18 studies was 58.76 months. As reported by Dubousset et al. (1993), later surgery resulted in more fusion and earlier fusions resulted in more Cobb angle improvement (12). Marks et al. (1995) declared that surgery at a younger age resulted in greater correction of coronal Cobb angle progression (15). Walhout et al. (2002) indicated that being under 5 years of age is associated with more favorable outcomes (27). Interestingly, presence of large complex curves involving longer segments in younger ages, is associated with poor prognosis (26). On the other hand, Ginsburg et al. (2007) reported that out of 9 patients in their study, 3 who had progression in their scoliotic curve at the final follow-up aged more than 9 years and 10 months. However, the authors suggested that implementation of transpedicular hemiepiphysiodesis with short segment instrumented fusion was effective in the patients older than 5 years without signs of advanced skeletal maturity (13).

Regarding the type of spinal anomalies and their effects on the outcome, the identified studies in this review reported conflicting results. Some studies showed that the curves comprised of hemivertebrae, especially sing hemivertebrae, had better outcome in comparison to the curves comprised of unsegmented bars in terms of curve progression or deterioration (14, 15, 28).On the other hand, Uzumcugil et al. (2004) reported that the type of anomaly (complex or hemivertebra with or without unsegmented bar) did not affect the CGA outcome (26).

Some problems are associated with CGA. Among such problems are minor infections (wound or chest) and traction neuropraxias which are related to anterior surgery (3, 5, 12). The main problems of CGA are unpredictability of the curve behavior after the procedure and incapability to control the spinal balance.

To overcome these problems, adding instrumentation as concave distraction have been reported in the literature. The benefits of this modality are the ability to control the growth of the anomalous vertebral segments in both longitudinal (17) and transverse planes (10) and thereby elimination of the need for anterior fusion. Also, the growth of the concave side is stimulated as a result of distraction which further corrects the deformity (6). Furthermore, the addition of concave distraction produces immediate correction of coronal plane curvature and imbalance in comparison to CGA alone. Moreover, an acceptable cosmetic result can also be achieved. This article reviewed the studies which reported true epiphysiodesis effects, adding instrumentation to the main intervention resulted in higher rates of improvement compared to other studies that did not use instrumentation (59.5% vs 37.5%, respectively). Demirkirna et al. (2013) implemented instrumentation on the full length of convex curve posteriorly by pedicle screw and compression (11). There was a significant difference between preoperative and early postoperative coronal Cobb angle degrees as all 13 patients had some degrees of correction due to what the authors called “instrumentation effect”. However, at final follow-up 69% of patients showed true epiphysiodesis effect while 23% showed stabilization in their curve.

Alanay et al. (2012) performed instrumentation on the convex side only on the anomalous vertebrae forming the congenital curve, by unilateral pedicle screws and a single rod connecting them (11). On the concave side, instrumentation was performed using growing rods and lengthening was performed every 6 months. The convex curves that underwent instrumentation, coronal Cobb angle, were corrected for 25% at postoperative and had an overall correction of 44% at the final follow-up. For the concave curves instrumented with growing rods, the coronal Cobb angle had a 54% correction at the postoperative visit which increased further to a 77% correction at the final follow-up. The approach used by Alanay et al. (2012), obviated the need for anterior surgery and thus reduced the risk of pulmonary complications. The limitations of Alanay et al. 's (2012) study, such as small number of patients and short follow-up duration, are a drawback for the generalizability of their results.

On the contrary, in the study by Andrew and Piggot (1985), 2 older patients with hemivertebrae had instrumentation with Dwyer compression apparatus which did not produce any subsequent growth-mediated improvement in the curve (3). Cheung et al. (2002) implemented instrumentation on the concave side with subcutaneous Rochester and Harrington distraction rods and hook construct in all their 6 patients. The instrumentation spanned from the upper-end vertebra to the lower-end vertebra with longitudinal extension above and below the proposed fusion levels. Using instrumentation to enhance the concave growth of the scoliotic curve through distraction did not have substantial contribution to the curve correction in the outcomes. The authors concluded that distraction of the curve concavity without fusion does not enhance the spine growth. However, using anterior and posterior convex fusion combined with concave subcutaneous distraction produces an immediate improvement in deformity and balance of the coronal plane without the need to wait for uncertain growth-mediated improvements in the long-term. The authors recommended this procedure for children with severe deformities and decompensation (8). Ginsburg et al. (2007) used instrumentation to eliminate the need for immobilization by performing a short segmental fusion on the convex side of hemivertebrae. The instrumentation did not increase the complication rate and eliminated the need for postoperative bracing (13).

The main disadvantage of the instrumentation with distraction is that recurrent surgeries are required for distraction of the concave side. Also, some instrumentation procedures can fail upon complications. In Andrew and Piggot's study (1985), one patient with complex spinal deformity underwent instrumentation with insertion of a Harrington rod on the concave side; however, it was removed early because of meningeal ulceration and leakage of cerebrospinal fluid (3). King et al. (12) used Harrington compression rods in the curve convexity in 2 cases. In one case they were removed because of their causing prominence under the skin (16). Cheung et al. (2002) reported removal of subcutaneous Rochester and Harrington distraction rods and hook due to persistent deep wound infection in one patient (8). Alanay et al. (2012) reported partial pullout of the proximal, distal, or both pedicle screws of the concave distracted curves in 4 of 5 patients during the follow-up (11). In the study by Demirkirna et al. (2013), one patient despite having a significant correction at early postoperative, showed deterioration in her curve due to inappropriate instrumentation levels and malposition of most of the distal screws. Revision surgery with vertebral column resection was performed later.

The final fate of CGA depends on the remaining growth potential on the concave side which depends on the qualitative and quantitative properties of the apophyses. As evaluation of this potential before surgery is very difficult, thus predicting the outcome of CGA is impractical. Also, adding instrumentation to CGA, is an opportunity to achieve some immediate correction in every deformity with compression-derotation maneuvers after instrumentation. This cannot be achieved by CGA alone; thus, instrumented CGA should not be compared with CGA alone. Furthermore, the reason for failure of instrumentation in the included studies in this review might be the impaired growth potential on the concave side due to older age at the time of surgery or the inability of growth due to the type of malformation. So, criteria are needed to be defined to identify the suitable candidates and the appropriate types of instrumentation for instrumented CGA approach.

4-1. Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

5- CONCLUSION

This systematic review showed that the preoperative curve magnitude, presence of sagittal plane deformities, ages less than 5 years, and types of spinal anomalies do not affect the outcome of CGA. The growth-mediated correction of scoliotic curve or true epiphysiodesis effect, was seen in less than half of the patients (43%) while studies that reported the global correction of scoliotic curve or instrumentation-and/or postoperative casting-induced correction combined with growth-mediated correction showed a better improvement in scoliosis (55.5%), at the final follow-up. Adding instrumentation to CGA was preferred in cases of complicated spinal anomalies and older ages where the potential growth on the concave side was not much foreseeable.

Overall, considering the levels of evidence in the included studies, publication bias, presence of great heterogeneity in methodological aspects, variety in surgical techniques, and different styles for reporting the outcomes, make giving a robust answer to the question of this review a formidable task. Also, it is difficult to make direct comparisons between different CGA approaches due to the surgeon's experience. Therefore, results of this study should be interpreted with caution. More data from studies with low levels of evidence will not be useful in this matter. So, future research should consider designing studies with more focused aims and robust methodologies.

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